SUBSTITUTION BETWEEN TIMBER AND NON-TIMBER OUTPUTS ON PRIVATE FORESTLANDS IN OKLAHOMA

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Statement of the Problem

Timberlands not only serve as a source of timber outputs, but also as a source of non-timber outputs. Traditional non-timber outputs include recreation, wildlife habitat, watershed protection, and other environmental goods. There are many other values that consumers place on forestland for its non-timber attributes, such as the existence value of forests and timberland purchases for speculative purposes. Some non-timber outputs may coexist with timber production, while others may be competitive. Since non-timber outputs are an important part of the landscape, culture, and economy of most forest regions, they then play an important role in consumer choice.

When a consumer is considering the purchase of forestland, they will consider the ability of the land to produce timber and non-timber outputs in their purchase decision. The consumer's preferences for each of these outputs (products) from forestland, the consumer's income, and how society values (prices) these outputs will determine the consumer's optimal combination of timber and non-timber products; and thus the parcel of forestland that they purchase.

Because many non-timber products are not traded in the market, they do not have established market prices. Yet, they do have value. Non-timber outputs, like timber outputs, have value and great potential toward the development of forested regions. Since non-timber outputs do have an impact on consumer choice and thus economic activity, public policies that influence the quantity and value of such outputs are important to the economic growth of forested regions. The long-term effects of various environmental regulations, such as protection of the spotted owl in the Pacific Northwest, are not fully known. In such situations there is often a decrease in the timber outputs and an increase in the non-timber outputs in a region. Conversely, policies and programs that result in the conversion of forestlands toward monoculture timber plantations, increase timber outputs, but may also decrease some non-timber outputs such as biodiversity. Such changes impact the relative prices of timber and non-timber products. As the prices for the two products change the optimal bundle of timber and non-timber outputs purchased will also change. This will then influence what people are willing to pay for an acre of forestland, since the value of forestland is derived from its timber and non-timber output values.

This research determines the rate at which consumers substitute between timber and non-timber outputs in their purchase decisions of non-industrial private forestlands (NIPF). NIPF are forestlands owned by a private person or corporation, who or which does not possess timber processing facilities (Smith et al. 2001). Forestland is land at least 10 percent stocked by forest trees of any size, including land that formerly had such tree cover and that will be naturally or artificially regenerated. The minimum area for classification of forest is 1 acre (Smith et al. 2001).[1] Gaining knowledge about consumer behavior toward NIPF

[1] Forestland also includes transition zones, such as areas between heavily forested and non-forested lands that are at least 10 percent stocked with forest trees and forested areas adjacent to urban or built-up lands. Roadside, streamside, and shelterbelt strips of timber must have a

and how they substitute between timber and non-timber outputs will help in the analysis of the impacts of environmental regulations and other phenomena that influence the economies and development of forested regions. For example, if we want to implement a policy to increase non-timber outputs, we must analyze how that policy will influence the consumer's demand for that product.

Those consumer's that demand forestland can be characterized as deriving satisfaction (utility) from the production and/or consumption of various outputs (products) from their forestlands. We can classify these products into either timber or non-timber outputs. Furthermore, we assume that these two products are homogenous and that they combine to make an individual plot of forestland a differentiated composite good. We assume that the objective of forestland owners is to maximize utility. The forestland owner substitutes between timber and non-timber products based upon the price ratio of timber to non-timber outputs, as well as other factors. Since non-timber products have value to forestland owners, it should be possible to quantify this output and derive a price. This information, along with price and quantity information concerning timber products, is then used as a basis for estimating an elasticity of substitution between timber and non-timber outputs.

Purpose of the Study

The purpose of determining the elasticity of substitution between timber and non-timber outputs was to examine the effects of market structure and public policies on the development of forest regions. Market structure and public

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crown width of at least 120 feet to qualify as forestland. Unimproved roads and trails, streams, and clearings in forest areas are classified as forest if less than 120 feet wide. (Smith et al. 2001).

policies influence the price of timber, which influences relative outputs of timber and non-timber products. This in turn influences the demand for differentiated plots of forestlands and the allocation of resources and income, which influences the structure of the regional economy and its growth and development. Any public policy that influences the structure of the market can potentially influence the timber to non-timber price ratio and thus regional economic development. Such policies of interest include any public policy that affects the cost of holding forestlands, the management of forestlands, and the markets associated with the inputs to and outputs from forestlands. These policies include forestland taxation, timber harvest severance taxes, reforestation programs, environmental regulation, and incentives to forest product-processing firms. This study should be helpful to those who are interested in regional development, forestland consumers/owners, forestland use patterns, and any economic phenomena that influences the distribution of goods, resources, and income related to forestland.

Objectives of the Study

The overall objective of this research was to determine the rate at which consumers of NIPF substitute between timber and non-timber products in their purchase of NIPF timberlands. Timberlands are defined as forestlands that produce at minimum 20 cubic feet of industrial roundwood per acre per year (Smith et al. 2001).

The specific objectives of the study were to:

1. Predict the hedonic value of NIPF timberlands from a sample of sales.
2. Estimate the value and quantity of timber removals from the sample of NIPF timberlands.
3. Estimate a shadow price for non-timber output from the NIPF timberlands.
4. Estimate the elasticity of substitution between timber and non-timber outputs from the NIPF timberlands.

The area of study was limited to a two county area in southeast Oklahoma, which includes McCurtain and Pushmataha counties. The valuation of the timberlands was based upon sales data from 1999 for unimproved predominately-forested parcels in McCurtain and Pushmataha counties. The forestland parcels did not contain any significant structural improvements such as residential and vacation housing. The estimate of the quantity of timber removals was based upon an annualized quantity obtained from the U.S. Department of Agriculture, Forest Service, Southern-Forest Inventory Analysis for the area of study. The estimate of the value of timber removals utilized the quantity values obtained through the U.S.D.A. Forest Service, Southern-Forest Inventory Analysis and stumpage prices reported by Timber Mart South.

CHAPTER

II.

LITERATURE REVIEW

There is literature on timber and non-timber products from non-industrial private forest (NIPF). However, there is little literature on consumers' substitution between these two types of products from NIPF and how such substitution is affected by timber prices and how this substitution in turn influences regional economies and development.

Timber Products and Management of NIPF

The studies reviewed in this section provide a description of NIPF (particularly of the southern U.S.), the management of NIPF (mainly with respect to timber production), and the goals and priorities of NIPF owners.

Marion Clawson's early work (1979) provides a descriptive analysis of the value and quantity of timber products, uses, structure, and management of NIPF in the United States. Clawson's work is of a global nature in that it reviews many of the major factors that characterize NIPF in the U.S., including management issues related to timber and non-timber products.

Clawson notes that NIPF are an important source of timber products, providing approximately one-third of softwood timber and three-fourths of hardwood timber. His findings indicate that NIPF owners are a highly heterogeneous group holding parcels of various sizes for numerous objectives ranging from primarily a place for personal recreation to an investment for maximum economic return. With respect to timber output, Clawson concludes that in the long run nearly all truly merchantable timber from NIPF will be sold and harvested in regions where good markets exist, although the timing of such sales might be irregular and not what a forester would have recommended.

David Wear (1996) provides an analysis of forest management and timber production in the U.S. South. He concludes that the forest sector in the region is well organized and highly productive. He notes that the region is unique in that it is one of the few regions where much of the timberland (90%) is owned and managed by the private sector and that much of the private holding (78%) is managed by NIPF owners. As a region, he notes that the south is the most productive with an average potential of 80 cubic feet per acre per year.

Similar to Clawson, Wear notes that NIPF owners are atomistic and very diverse. Wear disputes the notion that NIPF owners in the south do not have access to information about the fair market value of their timber and notes that econometric studies indicate that, in their harvest decisions, private landowner's do respond to market signals.

The goals and attitudes of NIPF owners influence whether they produce timber or not, and thus the substitution between timber and non-timber outputs. Carpenter (1985) conducted a survey of NIPF owners in Michigan's Upper Peninsula region. His study examined how changes in ownership, their intents, and their actions might affect the region's timber output. His study was a third in a sequence of studies, following Quinney (1962) and Stone (1970) that examined

NIPF owner's actions and their potential affects on timber output. Carpenter found that Michigan's Upper Peninsula region NIPF owner's attitudes, objectives, and intentions were reasonably consistent over time and consistent with findings of studies in other areas. He notes that the NIPF owner's act in an economically rational manner in that they keep their investment in timber capital low to satisfy their high time preference for money and that they harvest timber as it becomes marketable.

Carpenter notes that even though landowners signified a desire to not harvest in an earlier study, many of them in fact did harvest at a later date. The most common reasons cited for not harvesting were related to timber being of immature size, poor quality, small volume or area, the proximity of timber to a home or cabin, and the esthetics and scenic degradation caused by timber harvesting. The most common reason cited for harvesting related to the fact that timber was mature and/or the NIPF owner needed money. Thinning, salvage, and own-use of the wood were also cited as being important reasons for harvesting.

The results of Carpenter's survey indicate that the most common primary reason for owning forestland was for recreation. Owning timberland to be part of residence and for investment rated second and third, respectively. Owning forestland for timber production was rated as the fourth most common primary reason. These results indicate that consumers of forestland might be willing to give up a relatively greater amount of timber production potential in order to obtain an additional unit of non-timber production potential. Thus, we might conclude that Carpenter's analysis indicates that consumers substitute non-timber products in place of timber products at a relatively high rate in their purchases of NIPF.

Carpenter also concludes that NIPF owners' attitudes in aggregate concerning harvesting have been consistent over time and that the quantity of timber available from NIPF does not significantly change from one point in time to the next due to ownership and attitudes toward harvesting.

Alig, Lee, and Moulton (1990) reviewed various research studies on NIPF management. Through their review process the authors conclude that NIPF owners are a heterogeneous group with diverse objectives and goals for holding forestlands. They note that NIPF are an important source of timber outputs, constituting from 47 to 52 percent of the total U.S. timber supply from 1950 through 1988 The main objective of their study was to isolate determinants of timber management behavior by NIPF owners. Their study attempts to simultaneously explore how markets, policies, and landowner characteristics affect timber management on NIPF. The authors note that gaining knowledge about the management practices of NIPF owners is not only essential in assessing future timber supplies, but it is also very important for analyzing policy options related to non-timber forestland services such as managing global climate change, wildlife habitat, and soil conservation.

Within Alig, Lee, and Moulton's study is an analysis of whether NIPF owners respond to timber-related market signals. Response to market signals is important because government programs are often designed in response to perceived market imperfections, which can also influence the substitution between timber and non-timber outputs. The authors broadly categorize management decisions into two parts, investment and disinvestment. An investment decision most often centers on regeneration, which relates to long-term timber supply. A disinvestment decision most often centers on harvesting, which relates to short-term timber supply.

An indication of the decision to pursue timber products may be reflected in the NIPF owner's attitudes toward and incentives for reforestation. Alig, Lee, and Moulton note that there is a positive relationship between available growing stock (inventory) and timber product harvested, which implies that planting may have an effect on short-term, as well as long-term supply of timber products. Most studies conclude that landowner income and stumpage prices are positively correlated with reforestation, yet research also suggests that they respond to reforestation costs. Alig, Lee, and Moulton note that government policies supporting tree planting have reduced the cost of reforestation and increased the number of acres planted by NIPF owners. These results suggest that public policies do influence the relative values of timber and non-timber products and thus the optimal bundle of timber and non-timber products demanded by the NIPF consumer.

Forestland owners who apply intermediate stand treatments, such as thinning, often do so to increase the quantity of timber products. The studies reviewed by Alig, Lee, and Moulton indicate that NIPF owner characteristics and attitudes were more significant than either stumpage price or income in predicting use of intermediate treatments. Tract size, education, use of technical assistance, previous harvest activity, and concerns over wildlife habitat and recreation values were also shown to be significant and positively related with the decision to apply intermediate treatments, whereas owner age was shown to have a negative correlation.

According to the studies reviewed by Alig, Lee, and Moulton, the effects of stumpage prices, tract size, and farmer owned NIPF are all generally significant and positively related to timber harvesting, and the main government program having a positive relationship with NIPF harvesting activity is the provision of public technical assistance. However, they note that an increase in the number of foresters providing assistance will not necessarily lead to an increase in harvesting, because joint demands for technical assistance and harvesting are derived from demands for wood products. Income and education are generally shown to be significant and negatively related to the decision to harvest.

In summary it is noted that NIPF owners are a diverse and heterogeneous group. The literature also indicates that timber production is not the primary objective of most NIPF owners. This result may indicate that consumers of NIPF are more willing to give up timber production attributes than non-timber production attributes when purchasing NIPF. The studies reviewed also indicate that NIPF owners respond to market signals and act in an economically rational manner. From this result, we may conclude that policies which influence the relative prices of timber and non-timber products will influence the optimal bundle of timber and non-timber products demanded by consumers of NIPF and thus the substitution between timber and non-timber products.

Non-timber Products and Management of NIPF

NIPF are an important source of numerous non-timber products, such as recreation, wildlife habitat, water, and esthetic values, as well as for the management of global climate change, biological diversity, and soil conservation. Clawson (1979) explains that it is widely believed that many NIPF owners value their forest more for these other outputs than for the income received from timber sales, yet firm evidence on this point is lacking. For example, Clawson estimates that the value of outdoor recreation from NIPF as a whole is one-third the value of their annual wood growth. The other values are more speculative in character and amount, and there is no firm evidence that they are relatively greater per acre on NIPF than on forests of any other ownership. In defense of non-timber outputs, he notes that NIPF owners face the problem that they are often unable to realize income from any forest outputs other than timber. Some of this may be due to the small size of NIPF parcels, which makes it difficult to gain income from other outputs such as recreation. Therefore, the NIPF owner is largely a consumer of his own outputs, particularly with respect to non-timber outputs.

Clawson notes that there is fairly good data on productivity classifications with respect to timber outputs, yet there is no system in place for obtaining data on site productivity for non-timber outputs. Clawson proposes a system of five cross-classifications of site productivity for pairs of timber and non-timber outputs. The proposed system would analyze the degree to which a forestland plot has the potential to produce timber and a particular non-timber output, such as wilderness. For example a plot may be classified high on timber and wilderness productivity, high on timber and low on wilderness, low on timber and high on wilderness, moderate on both, or low on both. He suggests that such information would be immensely helpful for national debates and decisions about wilderness reservation and wilderness use. Clawson notes that NIPF possess capabilities for these types of outputs and that the proposed productivity cross-classification is applicable to NIPF.

With regard to non-timber uses of forestland, David Wear (1996) notes that urban sprawl is one of the major reasons for reductions in the growth to removal ratio of softwood timber in the southern U.S. Although difficult to measure, he does note that many services provided by forestlands but not traded in markets, such as protection of wetlands and wildlife habitat may become increasingly scarce in the South. He notes that many of these services are the topic of policy and regulation, and that the collection of existing local, state, and federal regulations has not yet had discernable impacts on timber supplies in the south.

Researchers have begun to give more attention to the role that non-timber outputs play in the harvesting decisions and timber supply from NIPF in the U.S. One of the first to formalize this relationship was Clark Binkley (1981). He created a model of timber supply from NIPF in the United States. Binkley recognized the fact that NIPF owners' maximize utility and that utility comes from not only the consumption made possible by the income derived from timber outputs, but also from the consumption of non-timber outputs. The fact that landowners derive utility from non-timber outputs is now incorporated into timber supply models, such as in Prestemon and Wear (2000).

The decisions of whether and when to harvest have a direct impact on the supply of timber in any given period of time. Karen Lee (1997) examined the harvesting decisions of NIPF owners. She concluded that NIPF owners are not irrational if they hold timber beyond its financial maturity. She notes that there is an opportunity cost of doing so and that this opportunity cost is the value that the landowner places on non-timber outputs.

The literature reviewed in this section, although coming from a supply perspective, does illustrate that non-timber outputs are an important attribute to the consumer of NIPF. Clawson (1979) noted that the ability of a NIPF owner to gain income from traditional non-timber outputs and services may be limited due to the small parcel size of individual NIPF holdings and the lack of appropriate markets. Due to these aspects, he notes that NIPF owners are essentially consumers of their own outputs. Lee (1997) also notes that NIPF owners may hold timber beyond its financial maturity and that the opportunity cost of doing so can be defined as the value that the landowner places on non-timber products. Since NIPF owners obtain utility from both the consumption and production of products from their forestland, Binkley (1981) suggests that their behavior is more appropriately modeled in a utility, rather than a profit, maximization framework.

Theoretical Assumptions, Modeling Frameworks, and Data

Alig, Lee, and Moulton (1990) note that, limitations due to theoretical assumptions, modeling framework, and data must be considered when drawing conclusions about NIPF owner behavior. Standard methods in applied economics rely on consistent objectives and technologies across producers. In the modeling of NIPF owner behavior, these standard methods are often challenged due to the diversity of NIPF owners.

A major change in the underlying theoretical assumption for modeling the behavior of NIPF owners has been the use of a utility-maximizing framework, as compared with a profit-maximizing framework. The key difference in this approach is the significance of non-timber goods and services in a landowner's decision to implement certain land management practices. With the value of non-timber outputs relative to timber products growing as society becomes more affluent, this framework becomes even more important (Alig, Lee, and Moulton, 1990).

It is often assumed that NIPF owners have full information about prices, costs, and yields (Larson and Hardie, 1989). Alig, Lee, and Moulton (1990) note that there is uncertainty surrounding these variables, which is often caused by various forest hazards, volatile end-product markets, the diversity and changing composition of landowners, and changing policy environments; which can influence the management decisions of forestland owners.

According to Alig, Lee, and Moulton (1990), two other common theoretical assumptions are that interest rates are assumed to be certain and constant and that the market value of land for use in timber production reflects the present value of future harvests. They note that these assumptions may not necessarily be correct. Alig, Lee, and Moulton (1990) note that temporal changes in interest rates influence the attractiveness of long-term forestry investments, and that evidence suggests that the market value of immature timberland may not reflect the present value of the timber crop that will be produced due to the long time horizon involved, which typically exceeds the normal business planning time horizon.

According to Alig, Lee, and Moulton (1990) many modeling frameworks do not fully consider joint production possibilities and the simultaneous nature between timber and non-timber land use decisions. They note that modeling of regional NIPF timber investments are typically isolated from other aspects of land management. A common framework is to focus on even-aged management regimes (Alig, Lee, and Moulton, 1990). Experience suggests that landowners simultaneously produce and consume several forest products and that uneven-aged silvicultural systems can be important means of providing multiple outputs from the forest (Haight and Monserud, 1990).

Alig, Lee, and Moulton (1990) note that, in general there is a lack of good data for conducting research on NIPF owner behavior. This at times leads researchers to use proxy variables, which weakens hypothesis testing (Alig, Lee, and Moulton, 1990). Because of these problems the authors suggest that periodic and systematic surveys of landowners are essential to develop the data necessary to evaluate the effects of markets, policies, and owner characteristics on landowner decisions. An alternative source for micro-level data, which has other limitations such as a lack of data on landowner characteristics and forest resource conditions, are the timber deeds and tax rolls on file at county court houses.

Hedonic Price Estimation

In hedonic price estimation, the price of a good is defined by the attributes that make up the good. The good itself is considered heterogeneous, yet the attributes can be considered homogeneous. The price of the good is then a function of the homogenous attributes that make up the good. The price of forestland can then be considered a function of its many attributes, such as physical characteristics, location characteristics, and other attributes such as taxation and regulation policies.

The concept of estimating hedonic prices can be traced to Court (1939). However, estimation of hedonic prices did not become widely used until Sherwin Rosen (1974) published a theoretical model that could serve as a basis for empirical techniques. Rosen explains that hedonic prices are defined as the implicit prices of attributes and are revealed to economic agents from observed prices of differentiated products and the specific amounts of characteristics associated with them. Econometrically, implicit prices are estimated by the first-step regression analysis (product price regressed on characteristics) in the construction of hedonic price indexes.

The price of the commodity $P(Z)$ is described by n objectively measured attributes or characteristics, $Z = (z_1, z_2, \ldots, z_n)$, with each z_i measuring the i^{th}

characteristic contained in that good. The good Z is heterogeneous, yet each separate z_i can be considered homogeneous, and the demand for the good can be analyzed in terms of the demand for each of its homogeneous components. Each homogeneous characteristic is assumed to have a distinct market equilibrium price and thus the price of the heterogeneous good is a function of the prices of its homogeneous components. The resulting hedonic price function is defined as:

$$P(Z) = p(z_1, z_2, \ldots, z_n) \; . \tag{2.1}$$

This function relates prices and characteristics and is the buyer's (and seller's) equivalent of a hedonic price regression, obtained from shopping around and comparing prices of products with different characteristics. The function gives the minimum price of any package of characteristics. If two products offer the same bundle of characteristics, but sell for different prices, consumers only consider the less expensive one.

The implicit price for a characteristic can be written as the following partial derivative of equation (2.1):

$$P_{zi} = \frac{\partial P(Z)}{\partial z_i} \, . \tag{2.2}$$

Buyers and sellers can be thought of as facing a marginal implicit price schedule for each characteristic. A buyer maximizes utility by moving along these price schedules until the consumer's marginal willingness to pay is equal to the marginal implicit price of the characteristic.

Hedonic Price Estimation of Farmland and Residential Property

Most of the early applications using Rosen's model have dealt with differentiated consumer products. A seminal paper by Palmquist (1989) adapted Rosen's model to form a theoretical hedonic model for land as a factor of production. The purpose of Palmquist's (1989) paper was to estimate the derived demand for agricultural land as a differentiated factor of production and to develop welfare measurement techniques that could be applied to various land and agricultural policy questions. Following Palmquist's 1989 paper, there has been an expansion of the hedonic pricing method to land markets.

Although there have been numerous applications of the hedonic estimation to farmland and residential property prices, three recent papers are reported here: Nivens, *et al.* (2002), Perry and Robinson (2001), and Phillips (2000). Nivens, *et al.*, and Perry and Robinson estimated per acre sales price of farmland, and Phillips estimated per acre sales price of residential property adjacent to wilderness areas.

Nivens, et al. (2002) – Using Satellite Imagery in Predicting Kansas Farmland Values.

Nivens, *et al.* describe Kansas farmland values as being a function of geophysical characteristics, socioeconomic characteristics, and remotely sensed variables, where the remotely sensed variables include both geophysical variables (such as vegetation index as a proxy for plant production) and socioeconomic variables (such as an urban or recreational effect). The study was statewide, and included 8,178 observations for the period 1993 – 1999.

The remotely sensed data was obtained from the Kansas Applied Remote Sensing (KARS) program at the University of Kansas. This data provided a historical index of vegetation, as well as land cover data used to add urban and recreational effects to the hedonic model, which were matched with land sales data. Parcel specific land sales data were obtained from the Kansas Society of Farm Managers and Rural Appraisers (KSFMRA). The KSFMRA data included a subjective measure of land quality, road access, cropland area, size and location of the parcel, improvements, and other characteristics. Regional farm crop income was included as an explanatory variable for profitability. The income per region was obtained from the USDA/Kansas Department of Agriculture and converted to 1999 constant dollars using a personal consumption expenditure index reported by the Federal Reserve Bank of Kansas City. A time trend variable was also included to account for changes in technology that increase crop yields and decrease operating cost.

Their model included three remotely sensed variables: $Urban_i$, Rec_i, and $ENDVI_i$. These variables capture urban, recreational, and crop productivity effects, respectively, on the price of land. The variable $Urban_i$ is the urban effect, which is the percentage of the land classified as urban within a defined radius encircling parcel i. The variable Rec_i is the recreational effect, representing the percentage of land within a defined radius encircling parcel i which is classified as water bodies. The variable $ENDVI_i$ captures the effect of crop productivity on land prices and is a vegetation index of the land within a defined radius encircling parcel i.

The empirical equation was a Box-Cox functional form estimated in SAS using full information maximum likelihood. The authors reported a base model with 25 explanatory variables and an expanded model with 28 explanatory variables. In both models most of the variables were significant at the 5% level. Some of the variables having the largest positive influence on price were the distance to highway, improvements, land quality, and crop productivity. Aside from parcel size, seasonal dummy variables, and location dummy variables, most of the coefficients were positive. The expanded model had an R-square of 0.329 and the predicted price, using mean values, was $550/acre, slightly less than the mean observed value of $568/acre. A summary of the price effects of selected variables appears in Table 1.

Table 1: Summary of Farmland Price Influences

Study author(s)/dependent variable selected independent variables	Effect on price
Nivens, et. al. (2002) / Farmland price per acre (Land)	
Binary variable representing highway road access to parcel *i*, dirt road is default (Hwy)	+
Binary variable representing gravel road access to parcel i, dirt road is default (Gravel)	+
Binary variable = 1 if there were improvements made to parcel *i* (Imp)	+
Number of acres sold in parcel *i* (Acres)	-
Percentage of parcel *i* that is crop land (Crop)	+
Farm income/acre for the region and year in which parcel *i* was sold in 1999 constant $ (Income)	+
Year in which parcel *i* was sold - accounts for changes in technology (Year)	+
Binary variable = 1 if parcel *i* is high quality land, medium quality is default (HiQual)	+
Binary variable = 1 if parcel *i* is low quality land, medium quality is default (LoQual)	-
Binary variables to indicate regional location (relative to default region)	-
Percentage of land within a 10-mile radius of parcel *i* that is classified as urban (Urban)	+
Percentage of land within a 10-mile radius of parcel *i* that is classified as water bodies (Rec)	+
Expected vegetation index for parcel *i,* for a 10-mile radius (ENDVI)	+
Result for the "expanded model" containing remotely sensed variables	
The model was estimated using a Box-Cox functional form. R-squared = 0.329	

Perry and Robinson (2001) – Evaluating the Influence of Personal Relationships on Land Sale Prices: A Case Study in Oregon

The authors' paper was designed to determine how personal relationships influence the terms of trade for a property. They examined farmland transactions concluded in Linn County, Oregon, between July 1992 and December 1997. The county appraisal office provided data on the characteristics of land parcels sold including: total acreage by land class, value of improvements, number of home sites, and property location. To obtain further information, a single page survey was sent to the buyers of the farmland parcels. A total 364 surveys were mailed, 216 were returned, and 56 were dropped from the data set because: the property was less than 40 acres in size, there was significant commercial timber on the property, or because the respondent refused to complete the survey.

The authors reported results for both an expanded and a reduced model. The expanded model had 25 explanatory variables and the reduced model 23 explanatory variables. Due to heteroskedasticity the authors reported both standard OLS results and weighted least squares results for each model. The reduced form model contained the following variables: three irrigation classifications, seven land classifications, a monthly time trend, a summer seasonal dummy to indicate whether the land was sold in the summer, parcel size, distance to the nearest incorporated town, value of improvements, presence of a home site, and seven buyer-seller relationships. The expanded model contained two additional buyer-seller relationships.

The results of main interest to the authors were that transactions between relatives and neighbors more frequently involved special considerations than did those between strangers and acquaintances. Transactions between parent and child and between neighbors brought significantly less than sales between strangers. Transactions resulting from a realtor or advertisement sold at a significant premium.

The results of the reduced weighted least squares estimation had six parameter estimates significant at the 1% level, seven at the 5% level, and two at the 10% level. Eight of the parameter estimates were not significant. The coefficients for the parcel size and distance to city were insignificant but had the correct sign, indicating negative relationships with price. The time trend variable was significant and indicated that farmland values doubled in 5½ years. The presence of a home site and improvements were also significant and positive. A summary of the price effects of selected variables appears in Table 2.

Table 2: Summary of Farmland Price Influences

Study author(s)/dependent variable selected independent variables	Effect on price
Perry and Robison (2001) / Farmland price per acre (PRICE)	
monthly time trend (TMTH)	+
total acres (ACRES)	not significant
dummy variable to indicate whether land was sold during summer (SUMMER)	not significant
distance to nearest incorporated town (DIST)	not significant
sales between parent and child (PARENT)	-
sales between other family members (FAMILY)	-
sales between neighbors (NEIGH)	-
sales to a previous lessee (TENANT)	not significant
sales between acquaintances (ACQUAINT)	not significant
discovery of sale through advertisements (AD)	+
discovery of sale through interaction with realtor (REALTOR)	not significant
marketplace value of improvements (IMP)	+
seven non-irrigated land variables (land prices increase with increases in land quality)	+
three irrigated land variables (land prices increase with increases in land quality)	+
presence of a home site (SITE)	+
Reduced Weighted Least Squares model with PRICE as the weighting variable.	
R-squared = 0.8415	

Phillips (2000) – Windfalls for Wilderness: Land Protection and Land Value in the Green Mountains

Goals of the Phillips paper were to explain the price effects of wilderness areas on neighboring residential properties to illustrate the need for improved considerations of positive economic impact of land conservation and new mechanisms for financing land conservation. According to Philips, there is little known about the spatial relationship between land protection and land value in rural areas.

Phillips final data set included 6,148 transactions occurring between 1987 and 1997 for the State of Vermont. Parcel specific information, such as the sale price, parcel attributes, and parcel size came from Vermont's land transfer tax return database. The initial database contained more than 300,000 observations. Numerous observations were excluded for the following reasons: lack of key fields, such as acreage, price, and location; transfers that were less than full fee ownership; and those that do not represent market transactions, such as the division of parcels in cases of divorce or the dissolution of a business partnership, transfers to creditors to secure debt, and transfers to government agencies and to non-profit organizations. Further observations were excluded if the parcel was not used primarily for residential purpose after the transfer. Excluded primary purposes induced industrial, agricultural, timber management, and commercial activities. To further restrict the geographic area, the only observations retained were those that include parcels in towns that contain wilderness, towns adjacent to towns that contain wilderness, and towns adjacent to the second group of towns. After all of the preceding adjustments were made 195 outliers were dropped. These outliers were those with per acre prices in excess of $500,000 and one transaction involving more than 9,000 acres.

The data on the 6,148 observations obtained from the Vermont's land transfer tax return database was matched with data from Geographic Information System (GIS) layers and Census of population and housing data. The final model contained seventeen explanatory variables. Phillips used a transcendental functional form model. Due to heteroskedasticity, the model results were estimated using White's correction procedure. All but one of the explanatory variables was significant. Thirteen parameter estimates were significant at the 1% level and three at the 5% level. Population density had the greatest positive influence on price. Generally the presence of a home site or other building had a positive influence on the per acre sales price of land, excluding the presence of a mobile home which had a negative influence on price. Most of the algebraic signs conformed to expectations, except for population growth rate, which had a negative sign and was significant at the 1% level. The R-square on the model was 0.80. A summary of the price effects of selected variables appears in Table 3.

Table 3: Summary of Rural Residential Property Price Influences

Study author(s)/dependent variable selected independent variables	Effect on price
Phillips (2000) / Residential property price per acre	
log of parcel size, in acres	-
dummy variable for whether town contains wilderness	+
distance from town center to nearest wilderness area boundary (meters)	-
dummy for whether town contains an alpine ski area	+
median household income in 1990 (dollars)	+
population growth rate, 1980-1990	-
population density (persons per acre), 1990	+
dummy variable for whether parcel includes no buildings	-
dummy variable for whether parcel includes a house	+
dummy variable for whether parcel includes a vacation home	not significant
dummy variable for whether parcel includes a barn	+
dummy variable for whether parcel includes an apartment	+
dummy variable for whether parcel includes a mobile home	-
dummy variable for whether parcel includes a condominium	+
dummy variable for whether parcel includes a store	+
property tax rate ($ per $100 assessed value)	-
R-squared = 0.8026, F-statistic = 1466.1680	

Hedonic Price Estimation of Timberland

The majority of the land market applications have been in the analysis of farm and urban-fringe land where sale prices are regressed against a set of associated parcel characteristics. The application of HPM to the forestland market has been less common. A review of literature has revealed three papers applying HPM in the analysis of forestland, where the price per unit is regressed on associated parcel characteristics. These are Turner, Newton, and Dennis (1991); Roos (1995); and Roos (1996).

Turner, Newton, and Dennis (1991) – Economic Relationships between Parcel Characteristics and Price in the Market for Vermont Forestland

Turner, Newton, and Dennis (1991) used an implicit price model to analyze forestland in Vermont. The data consisted of 139 sales of unimproved, predominately forested, parcels that were 100 to 500 acres in size. The sales occurred between January 1986 and April 1988. The dependent variable was the real sales price per acre (total parcel price divided by size in acres and adjusted by the monthly consumer price index). The independent variables were grouped into physical characteristics, location characteristics, and other characteristics. The authors used a transcendental functional form converted to log-log form and performed the estimation using ordinary least squares (OLS) regression. The physical characteristics included: the number of acres in the parcel; percentage of non-forested area; a binary variable indicating frontage on a public road; a binary variable indicating whether frontage road is paved; and percentage of parcel area with a slope steeper than 15-percent. Because of a lack of data, the authors did not have any variables indicating the quality and quantity of timber on the land. The location characteristics included: population per square mile of the nearest town to where the parcel is located; rate of population growth for the nearest town to the parcel location; rate of population growth for the county where the parcel is located; road distance to highway; and road distance to nearest commercial ski area. The other explanatory variables are equalized town real estate tax rate and a trend variable indicating the month of sale. The results indicate the area of non-forested area, presence of a public road on the frontage of the parcel, and the percentage of land area with a slope greater than 15% were statistically significant. The size of parcel and whether the road is paved were not significant. Of the physical characteristics the percentage of non-forested land and the presence of a public road made a positive contribution to explaining price, whereas the others had a negative influence on price. All of the location characteristics were statistically significant, excluding population density. Population density and population growth rates had a positive impact on price and the distance to highway and commercial ski area had a negative influence on price. The property tax variable was significant and indicated that increases in property tax lead to decreases in forestland prices. The trend variable was positive, but not statistically significant. Table 4 summarizes the study by Turner, Newton, and Dennis (1991).

Table 4: Summary of Forestland Price Influences

Study author(s)/dependent variable selected independent variables	Effect on price
Turner, Newton, and Dennis (1991) / forestland price per acre	
parcel size	not significant
portion of the parcel that is not forested	+
parcel fronts on a road	+
portion of the parcel with a slope greater than 15%	-
population density	not significant
population growth rate for the nearest town to the parcel	+
distance to major roadway/highway	-
distance to commercial ski area	-
property tax	-
time trend variable	not significant
The model used was a translog functional form.	
R-squared = 0.46, F-statistic = 8.93	

Roos (1995) – The Price of Forest Land on Combined Forest Estates

In 1995, Roos published a paper that applied Palmquist's (1989) adaptation of Rosen's (1974) hedonic price model in an empirical study of combined forest estate land in Sweden. Combined forest estates contain forestland, agricultural land, and a residence. Combined forest estates can be viewed as inputs in forest and farm production as well as consumption goods.

The statistical analysis was based on 198 sales during 1992. The estates in the sample had to have a minimum productive forest[2] area of 20 hectares and contain agricultural land, outbuildings, and a house for permanent or seasonal living. The dependent variables were selected to describe the different uses of the estate: timber production, agricultural production, permanent or seasonal residence and use of outbuildings. There were 10 individual explanatory variables in the model. These included: inhabitants per square kilometer in the county (INH); area of forestland in the parcel (AFOR); percentage of productive forestland of total forestland in the parcel (PROD); average site index on productive forestland (SI); average standing volume per hectare of productive forestland (VOL); area of agricultural land in the parcel (AGR); points for farmland productivity (FER); value points for residence (VH); value points for outbuildings (VB); and a trend variable indicating the month of sale (TREND). A linear functional form with quadratic and interaction terms was chosen. This functional form allowed a straightforward interpretation of the coefficients. With this functional form, the implicit price of each land use on the combined estate is

[2] Roos defines a productive forest as one that can produce at minimum 1 cubic meter of industrial roundwood per hectare per year.

an easily determined linear function. The main results and interpretations of the study were: the implicit price for forestland on combined forest estates was a positive function of population density, the percentage of productive forestland compared with the total forest area, site index, and standing volume per hectare of productive forestland; forestland prices had negative relationships with the area of agricultural land, suggesting negative economies of scope between agricultural and forestland; and the estimations suggested economies of scale in agriculture but not in forestry. Table 5 summarizes Roos's 1995 study.

Table 5: Summary of Forestland Price Influences

Study author(s)/dependent variable selected independent variables	Effect on price
Roos (1995) / forest-estate price per hectare	
area of forestland in the parcel	-
area of agricultural land in the parcel	not significant
value of residence	+
value of outbuildings	not significant
area of forestland - population density interaction term	+
area of forestland - proportion of productive forestland interaction term	+
area of forestland - average site index of forestland interaction term	+
area of forestland - average standing timber volume interaction term	+
area of agricultural land - population density interaction term	not significant
area of agricultural land - farmland productivity interaction term	+
value points of residence - population density interaction term	not significant
value points of outbuildings - population density interaction term	not significant
area of forestland quadratic term	not significant
area of agricultural land quadratic term	+
value of residence quadratic term	+
value of outbuildings quadratic term	not significant
area of forestland - area of agricultural land interaction term	-
area of forestland - value of residence interaction term	not significant
area of forestland - value of outbuilding interaction term	not significant
area of agricultural land - value of residence interaction term	not significant
area of agricultural land - value of outbuilding interaction term	not significant
value of housing - value of outbuildings interaction term	not significant
time trend variable	not significant
Linear functional form with quadratic and interaction terms. Adjusted R-squared = 0.954	

Roos (1996) – A Hedonic Price Function for Forest Land in Sweden

Roos's 1996 paper focused on forestland principally used as production input for wood products. The parcels of land could not be more than 10% agricultural and grazing land; have at least 20 hectares of commercially productive forestland; and could not have any houses on the parcel. The data consisted of 143 observations from sales in Sweden during 1992. The estimates were performed using a linear Box-Cox functional form and likelihood ratio tests. The dependent variable was the price per hectare deflated with the monthly consumer price index. There were eight independent variables, which included; the number of hectares in the parcel; percentage of productive forestland of total area of forestland in the parcel; cubic meters per hectare of forestland; site productivity; population per square kilometer of forestland in the county; month of sale; a binary variable indicating the presence of agricultural land; and lastly a second binary variable indicating buyer restrictions. Excluding the two binary variables, all other independent variables were significant. The results indicated a positive relationship between the per-hectare price of forestland and the proportion of productive forestland in relation to the total forest area on the estate, the mean standing volume, the mean site productivity of the forestland, and the population density in relation to the area of forestland in the county. The parcel area has a negative effect on per hectare prices. The presence of agricultural land was insignificant and had a negative effect, and the presence of buyer restrictions was insignificant and positive. Table 6 provides summarizes Roos's 1996 study.

Table 6: Summary of Forestland Price Influences

Study author(s)/dependent variable selected independent variables	Effect on price
Roos (1996) / Forest (timber) land price per hectare	
area of forestland in the parcel	-
proportion of productive forestland in the parcel	+
timber volume per hectare of forestland	+
site productivity	+
population per square kilometer of forestland in the county	+
presence of agricultural land	not significant
buyer restrictions	not significant
time trend	-
The model used was a linear Box-Cox functional form.	
Adjusted R-squared = 0.59, F-statistic = 26.80	

Summary of Hedonic Estimation Applied to Timberland Markets

Turner, Newton, and Dennis (1991) included a total of 12 explanatory variables, which were classified into three categories: physical characteristics, location characteristics, and other characteristics. They used five explanatory variables in the physical characteristics category. The physical characteristic variable having the greatest influence on price was the variable indicating whether the parcel fronts on a road. It was positive, explained 48% of the price variation, and was significant at the 1% level. Among the location characteristics there were five explanatory variables. The location variable having the greatest influence was the population growth rate of the county. It had a positive effect on price, explained 7% of the price variation, and was significant at the 1% level. Among the other characteristics category there were two variables, one covering the real estate tax rate and the other a time trend. The time trend variable was insignificant. The equalized town real estate tax rate variable had a negative influence on price, the percentage effect on price was 21%, and it was significant at the 5% level.

Roos's 1995 study examined the price for forestland on combined estates that were predominately-forested. The model consisted of 23 explanatory variables. Of those that were statistically significant, the variable indicating the area of forestland in the parcel was negative, had the greatest influence on price, and significant at the 1% level. The coefficient for the value points for residence was positive, had the second largest absolute influence on price, and significant at the 5% level. The variable with the third greatest absolute influence on price was the interaction between the area of forestland in the parcel and the average site index of the forestland. The coefficient on the variable was positive and significant at the 1% level.

Roos's 1996 study examined the price of unimproved predominately-forested land. The model consisted of eight explanatory variables. The variable with the greatest influence on price was site productivity. The coefficient on the variable was positive and significant at the 1% level. The variables indicating the percentage of productive forestland of total area of forestland in the parcel and the cubic meters per hectare of forestland were of second greatest influence in explaining price. Both coefficients were positive and significant at the 1% level. Population density was also highly significant and positive.

In summary, each of these three studies is similar in that each examined the sales price of predominately-forested land. The variables that were highly significant and having large influence on price were related to population growth, population density, and non-timber development. Variables indicating high levels of timber productivity were also influential in explaining price.

Summary of Literature Reviewed

The review of literature addressed issues concerning non-industrial private forestry in the U.S. and in particular the southern U.S., the management of NIPF for both timber and non-timber outputs, the modeling of the behavior of NIPF owners, and the estimation of farmland, rural residential property, and forestland prices.

NIPF are forestlands owned by individuals and corporations that do not possess wood-processing facilities (*e.g.*, sawmills, pulp mills, chip mills). NIPF are a major contributor to the wood supply in the U.S. and are important sources of non-timber outputs (*e.g.*, watershed management, wildlife habitat, recreation). In the southern U.S. 90% of forestlands are owned by the private sector and 78% of these forestlands are managed by NIPF owners (Wear 1996).

Individuals and corporations have numerous objectives for owning forestland, and timber production is not always the most important reason (Carpenter 1985; Wear 1996; Alig, Lee, and Moulton 1990). Some of these studies indicate that recreation and investment opportunities rank higher than timber production as the major reason for purchasing non-industrial forestland. NIPF owners do manage their forestlands in an economically rational manner (Carpenter 1985, Wear 1996), and those that do choose to hold timber beyond its financial maturity may reflect the value that they place on the non-timber benefits of the forestland (Lee 1997).

Alig, Lee, and Moulton (1990) noted that the value of non-timber outputs relative to timber outputs is growing as society becomes more affluent, and thus it is important to address non-timber outputs in models of forestland owner behavior. Clark Binkley (1981) was one of the first researchers to publish a model that recognized the significance of non-timber goods and services in a landowner's decisions. Binkley's model recognizes the fact that NIPF owners maximize utility and that utility comes from not only the consumption made possible by the income derived from timber outputs, but also from the consumption of non-timber outputs. Binkley's model was a departure from the standard model focusing on profit maximization derived from timber outputs.

The decisions that forestland owners make, between producing timber or non-timber goods and services, can have a significant impact on timber output, environmental and natural resource amenities, employment, income, and growth for regions that are predominately forested. In order to estimate the rate of substitution between timber and non-timber outputs, we must have estimates of the prices and quantities of timber and non-timber outputs. The value of non-timber outputs can be viewed as a shadow price derived from the value of forestland and the value of the timber from the forestland. The hedonic pricing method can be used to estimate the price of forestland.

The final section of the literature review addressed the hedonic estimation method. Location attributes such as the distance to major roadways, urban areas, and recreational areas were shown to be significant in explaining the price of farm and forestland. Physical attributes of the land, such as its quality and productivity were also shown to be important in explaining price.

Chapter

III.

THEORETICAL MODEL

The purpose of this chapter is to explain the theoretical model used in the research. The chapter is divided into two main sections, one a review of how the behavior of non-industrial private forestland (NIPF) owners is modeled, and two a review of utility theory. In the first section it is explained that the appropriate framework for modeling the behavior of NIPF owners is through utility maximization and not profit maximization. In the second section it is explained why an indirect utility approach is more appropriate for this research than a direct utility approach. It is then explained how the own-price and cross-price elasticities for timber and non-timber products, and the elasticity of substitution between timber and non-timber products are calculated using expenditure shares from the NIPF owner's indirect utility function.

The Behavior of Non-industrial Private Forestland Owners

It is generally accepted that NIPF owners maximize utility, whereas industrial private forestland (IPF) owners, such as the large integrated timber products companies, maximize profits. According to Lee (1997), Binkley (1981) formalized the notion that NIPF owners maximize utility instead of profit. Binkley's analysis focuses on the production behavior of NIPF owners; whereas, my analysis focuses on the behavior of consumers in their NIPF purchasing decisions. In both cases, NIPF owners are assumed to obtain utility from timber and non-timber products.

Following Binkley (1981), it can be assumed that NIPF owners obtain utility from the production or consumption of timber products Q_T and non-timber products Q_{NT}. In symbols, we have

$$U = U(Q_T, Q_{NT}). \tag{3.1}$$

Binkley states that the productive aspects of the forestland provide the NIPF owner income, which can be used for the consumption of goods and services; and that the consumptive aspects of the forestland provide the NIPF owner direct utility through the various non-timber outputs, such as recreation, scenic beauty, and other amenity and economic values. Like any consumer faced with choices, the NIPF owner will decide how many resources should be devoted to the production or consumption of Q_T and Q_{NT} based upon the tradeoffs involved.

In Binkley's model the NIPF owner makes his decisions about how much timber and non-timber outputs to produce or consume as though he were maximizing a utility function subject to two constraints. The first constraint states that expenditures cannot exceed income. The NIPF owner's income equals an autonomous level of income plus income from timber sales less the cost of holding the land. Autonomous income is any income that is exogenous to the model. Secondly, the combination of Q_T and Q_{NT} are limited to what is technically feasible given the initial endowment of land.

The formal model of NIPF owner behavior, as described by Binkley (1981), is as follows.

$$\text{Max } U(Q_{NT}, Y) \tag{3.2}$$

subject to

$$Y = Y_0 + p_T Q_T - cL \tag{3.3}$$

$$Q_{NT} = g(Q_T, L) \tag{3.4}$$

where

$U(Q_{NT}, Y)$ = a utility function defined over Q_{NT} and Y,

Y = net income available for consumption of non-land goods,

Y_0 = autonomous income (income exogenous to the model),

p_T = price of timber (stumpage price),

Q_T = quantity of timber harvested,

c = per acre cost of holding land,

L = amount of land held,

Q_{NT} = non-timber outputs and consumption, and

$g(Q_T, L)$ = a function relating timber and non-timber outputs.

Binkley states that equation (3.4), which reflects the essential economic aspects of multiple-use NIPF, is difficult to estimate and the model simply postulates its existence.

Binkley's model of NIPF owners' behavior makes the following assumptions.

i. The only income-producing output from the forestland is timber. Other income generating operations (*e.g.*, grazing, syrup, and etcetera) are accounted for in autonomous income.

ii. Speculative gains associated with land ownership are not explicitly considered in the model. Speculative gains enter primarily through the costs of holding land, c.

iii. The land endowment is initially fixed and the only decision to be made is the amount of timber to be cut.

Binkley's model holds the usual assumptions concerning the shape of *U*:

$$\frac{\partial U(Q_{NT}, Y)}{\partial Q_{NT}} > 0 \tag{3.5}$$

$$\frac{\partial U(Q_{NT}, Y)}{\partial Y} > 0 \tag{3.6}$$

$$\frac{\partial^2 U(Q_{NT}, Y)}{\partial Q_{NT}^2} < 0 \tag{3.7}$$

$$\frac{\partial^2 U(Q_{NT}, Y)}{\partial Y^2} < 0 \tag{3.8}$$

$$\frac{\partial^2 U(Q_{NT}, Y)}{\partial Q_{NT} \partial Y} \geq 0 \tag{3.9}$$

Relations (3.5) and (3.6) state that utility increases with additions of either non-timber output or income. Relations (3.7) and (3.8) denote diminishing marginal utility from (3.5) and (3.6). Relation (3.9) states that at higher income levels NIPF owners will value increases in non-timber output more than at lower income levels.

Binkley states that the conditions on g are:

$$\frac{\partial g(Q_T, L)}{\partial Q_T} < 0 \tag{3.10}$$

$$\frac{\partial g(Q_T, L)}{\partial L} > 0 \tag{3.11}$$

$$\frac{\partial^2 g(Q_T, L)}{\partial Q_T^2} \leq 0 \tag{3.12}$$

$$\frac{\partial^2 g(Q_T, L)}{\partial L^2} \leq 0 \tag{3.13}$$

$$\frac{\partial^2 g(Q_T, L)}{\partial L \partial Q_T} \gtreqless 0 \tag{3.14}$$

Relation (3.10) states that some timber values must be foregone to obtain additional non-timber values. Relation (3.11) states that more land permits higher levels of both timber and non-timber outputs. Relations (3.12) and (3.13) denote diminishing marginal productivity. Relation (3.14) may be positive, negative, or neutral depending upon the effects of the changes in land acreage or timber output.

The solution to the problem is obtained by substituting equations (3.3) and (3.4) into (3.2) and then differentiating the result with respect to Q_T and L, setting the derivative equal to zero for a maximum, and solving the resulting equation, which yields

$$\frac{\partial U}{\partial Y} p_T = -\frac{\partial U}{\partial Q_{NT}} \frac{\partial g}{\partial Q_T}. \tag{3.15}$$

Equation (3.15) states that the marginal utility from an additional unit of timber output equals the marginal utility of the non-timber outputs that must be foregone. Equation (3.15) is also an indirect timber supply equation.

In Binkley's initial model, equations (3.2) – (3.4), he approaches the NIPF owner's behavior in a utility maximization framework. In a second model, a simple multiple-use forestland production function model, Binkley assumes the initial endowment of land is allocated between the production of timber and non-timber outputs and that the production of timber output is in direct proportion to the quantity of land allocated to that use. He further assumes that the production of non-timber output can be characterized by a Cobb-Douglas production function. Production possibilities are found by solving the following three equations:

$$Q_T = aL_T \tag{3.16}$$

$$Q_{NT} = b(L_{NT})^d \tag{3.17}$$

$$L = L_T + L_{NT} \tag{3.18}$$

where a, b, and d are parameters and the subscripts T and NT index the allocation of land L to timber and non-timber outputs. The parameters a and b are efficiency or shift parameters. The parameter d is the production function coefficient, which measures the proportional change in output resulting from a unit proportional change in all inputs (Beattie and Taylor 1993). The production function coefficient is a measure of the returns to scale exhibited by the function. If d < 1 then the function exhibits decreasing returns and output increases at a decreasing rate in response to a proportional increase in all inputs. If d = 1 then the production function exhibits constant returns and if d > 1 then the production function exhibits increasing returns. Solving these equations provides

$$Q_{NT} = b\left(L - \frac{Q_T}{a}\right)^d. \tag{3.19}$$

Figure 1 is the production possibilities frontier (PPF) that represents the production function, equation (3.19), in two-dimensional space. Depending upon the value of d, the PPF for timber and non-timber outputs will take different forms. If the parameter $d < 1$, the PPF is concave to the origin, which is the typical pattern. This pattern tells us that when a landowner takes resources away from one activity and applies them to the other activity, the opportunity cost of doing so increases; or that the opportunity cost increases for each additional unit produced. If $d = 1$ the opportunity cost of producing an additional unit would be constant and if $d > 1$ the opportunity cost would be decreasing.

The derivatives of equation (3.19) are

$$\frac{\partial Q_{NT}}{\partial Q_T} = -\frac{bd}{a}\left(L - \frac{Q_T}{a}\right)^{d-1} \qquad < 0 \text{ if } d > 0 \tag{3.20}$$

$$\frac{\partial^2 Q_{NT}}{\partial Q_T^2} = \frac{bd(d-1)}{a^2}\left(L - \frac{Q_T}{a}\right)^{d-1} \qquad < 0 \text{ if } d > 1 \tag{3.21}$$

$$\frac{\partial^2 Q_{NT}}{\partial Q_T \partial L} = -\frac{b}{a}d(d-1)\left(L - \frac{Q_T}{a}\right)^{d-2} \qquad > 0 \text{ if } d < 1 \tag{3.22}$$

$$\frac{\partial Q_{NT}}{\partial L} = bd\left(L - \frac{Q_T}{a}\right)^{d-1} \qquad > 0 \text{ if } d > 0 \tag{3.23}$$

$$\frac{\partial^2 Q_{NT}}{\partial L^2} = bd(d-1)\left(L - \frac{Q_T}{a}\right)^{d-2} \qquad < 0 \text{ if } d < 1. \tag{3.24}$$

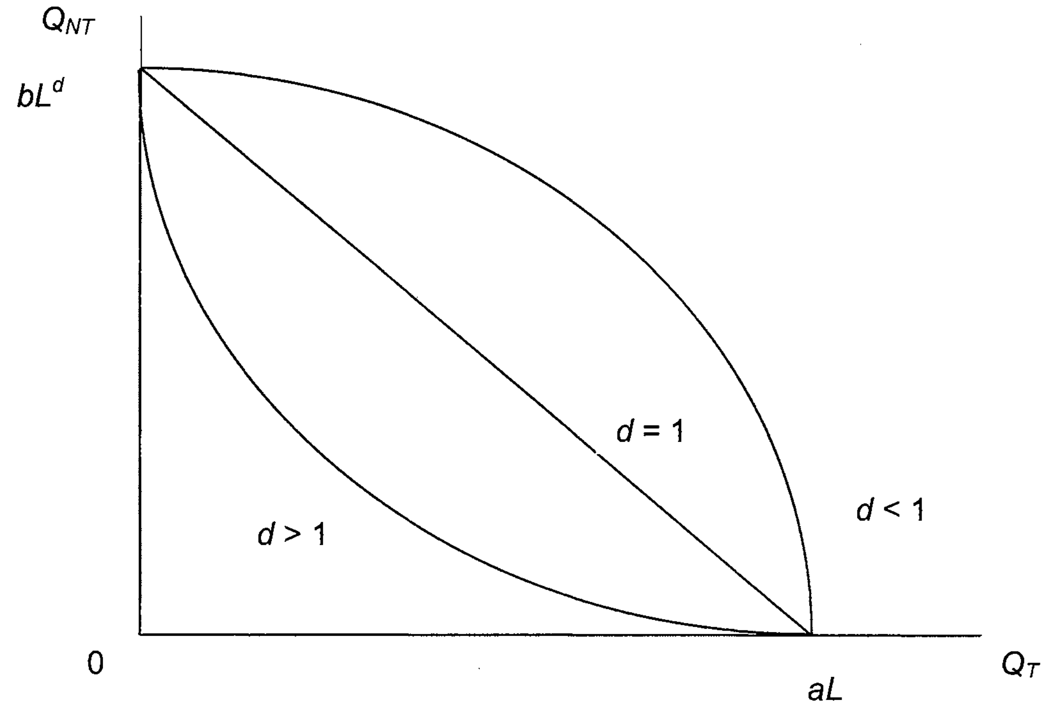

Figure 1: PPF for Timber and Non-timber Outputs from NIPF

Binkley provides some theoretical results of his model, which deal with the price of timber output, exogenous income and the cost of holding land, and the size of a land holding. These theoretical results are as follows:

1. Increases in timber prices will lead to increased timber output only if the income gained from the increased harvest more than offsets the utility losses associated with the reduction of non-timber production.
2. If increasing exogenous income decreases the amount of timber harvested, then increasing the cost of holding land will increase the timber harvest.
3. Increases in the size of a land holding will lead to declines in timber output.

The second theoretical result treats exogenous income and cost of holding land together because both enter the model by affecting the net income available for other consumption. Binkley explains that the theoretical result is contrary to the conventional argument that decreasing land holding costs, such as property taxes will lead, *ceteris paribus*, to greater timber supply. The theoretical argument regards land as fixed. As long as the amount of land held does not change, property tax reductions will lead to decreases in timber supply, for either small property tax changes or in the short run for large property tax changes. In the conventional argument, land can be bought and sold. So that in the long run, property tax decreases will increase the amount of land held by any individual and will therefore lead to increases in timber supply.

Binkley's third theoretical result is considered for a case in which land holding costs vary with the size of the holding. He states that a significant part of the costs of holding land is proportional to the market value of the land, such as *ad valorem* property taxes and the opportunity cost of the capital represented in the land. Binkley, assuming that the costs of holding land are proportional to land price, determined the optimal size of land holding where further increases in the size of holding could lead to decreases in timber supply. He noted that his results are extremely sensitive to fractional land holding costs, which include taxes and interest costs. Secondly he noted that where this negative relation between timber supply and size of land holding sets in may be quite large. Furthermore, as an empirical matter, he states that it is unlikely that the timber harvest from NIPF will, *ceteris paribus,* increase with decreases in the size of land holdings.

By modifying the net income constraint, equation (3.3), it is possible to enlarge the analysis to the problem of jointly determining the forestland owner's timber supply equation and land demand equation. For this purpose, Binkley modifies equation (3.3) as follows:

$$Y = Y_0 + p_T Q_T - (\alpha p_L + c)L \tag{3.25}$$

where

p_L = price of land, and

α = fractional land holding cost (taxes, interest, etc.).

The NIPF owner's nonlinear programming problem is then characterized by equations (3.2), (3.25), and (3.4) and the assumptions concerning U, equations (3.5) through (3.9), and the conditions on g, equations (3.10) through (3.14).

Solving the problem by substituting, differentiating with respect to Q_T and L, and solving, results in the following homogeneous equations:

$$\frac{\partial U}{\partial Y} p_T = -\frac{\partial U}{\partial Q_{NT}} \frac{\partial g}{\partial Q_T} \text{ and} \tag{3.26}$$

$$\frac{\partial U}{\partial Y}\left[p_T \frac{\partial Q_T}{\partial L} - (\alpha p_L + c)\right] = -\frac{\partial U}{\partial Q_{NT}}\left(\frac{\partial g}{\partial L} + \frac{\partial g}{\partial Q_T}\frac{\partial Q_T}{\partial L}\right). \tag{3.27}$$

Equation (3.26) states that the marginal utility from an additional unit of timber output equals the marginal utility of the non-timber outputs that must be foregone. Equation (3.27) states that the owner will buy land until the utility lost from the cost of the land just equals the utility from the non-timber values which that land affords. The cost of the land equals the purchase price less the timber income available from the land purchased. Binkley states that this model can be implemented empirically on a data set for which information on both the land and the timber markets are available.

Utility Theory

Binkley's analysis helps to organize one's thoughts about NIPF owners' behavior with regards to timber and non-timber production. My research helps us to organize our thoughts with regards to the behavior of consumers in their NIPF purchasing decisions. Both analyses utilize utility theory to model behavior.

The demand for forestland is a derived demand for the timber and non-timber products that the land affords. A consumer of forestland will then choose to purchase that parcel that maximizes his/her utility given his/her preferences for timber and non-timber products, his/her income, and the relative prices of timber and non-timber products.

Direct Utility

In this research, I am assuming that NIPF owners derive satisfaction from the consumption and/or production of two commodities produced by their forestlands, timber and non-timber commodities, and that they maximize utility subject to an income constraint. This problem can be expressed as

$$\text{Maximize} \quad U(Q_T, Q_{NT}) \tag{3.28a}$$

$$\text{subject to} \quad M = p_T Q_T + p_{NT} Q_{NT} \tag{3.28b}$$

where U denotes utility, Q_T timber outputs, Q_{NT} non-timber outputs, M income, and p_T and p_{NT} are the prices of timber and non-timber outputs, respectively. It must be noted that M is not the consumer's total income, but an amount of total income that is assumed to be fixed and available for the purchase of forestland.

Equation (3.28a) is a direct utility function. That is, utility is assumed to depend only on the quantities of the two commodities involved (Varian 1992). It is assumed that total utility increases with higher levels of consumption. The first-order partial derivatives of the utility function, taken with respect to the commodities, are assumed to be positive. They represent the marginal utilities for each commodity, which refers to the amount total utility rises when consumption increases by one unit. The second-order partial derivatives of the utility function, taken with respect to each of the commodities, are assumed to be negative. These represent the assumption of diminishing marginal utility. This assumption holds that as more of a given commodity is consumed, the marginal utility associated with the consumption of additional units tends to decline, other things equal.

The Lagrange function of (3.28a) and (3.28b) can be written as

$$L(Q_T, Q_{NT}, \lambda) = U(q_T, q_{NT}) + \lambda(M - p_T Q_T - p_{NT} Q_{NT}) \qquad (3.29)$$

where the Lagrange multiplier λ can be interpreted as the marginal utility of full income. The first order conditions are obtained by setting the first order partial derivatives of the Lagrange function (3.29) with respect to Q_T, Q_{NT}, and λ equal to zero:

$$\frac{\partial L}{\partial Q_T} = \frac{\partial U}{\partial Q_T} - \lambda p_T = 0 \;\Rightarrow\; \lambda = \frac{\partial U/\partial Q_T}{p_T} = \frac{U_T}{p_T} \;\Rightarrow\; p_T = \frac{U_T}{\lambda} \tag{3.30a}$$

$$\frac{\partial L}{\partial Q_{NT}} = \frac{\partial U}{\partial Q_{NT}} - \lambda p_{NT} = 0 \;\Rightarrow\; \lambda = \frac{\partial U/\partial Q_{NT}}{p_{NT}} = \frac{U_{NT}}{p_{NT}} \;\Rightarrow\; p_{NT} = \frac{U_{NT}}{\lambda} \tag{3.30b}$$

$$\frac{\partial L}{\partial \lambda} = M - p_T Q_T - p_{NT} Q_T = 0 \tag{3.30c}$$

$$\lambda = \frac{\partial U/\partial Q_T}{p_T} = \frac{\partial U/\partial Q_{NT}}{p_{NT}} \;\Rightarrow\; \frac{\partial U/\partial Q_T}{\partial U/\partial Q_{NT}} = \frac{p_T}{p_{NT}} \tag{3.31}$$

Equation (3.31) tells us that the ratio of the marginal utilities of timber and non-timber, $\frac{\partial U/\partial Q_T}{\partial U/\partial Q_{NT}}$, must equal the ratio of the prices of timber and non-timber outputs, $\frac{p_T}{p_{NT}}$, for a maximum. At this point the slope of the NIPF owner's indifference curve, $-\frac{U_T}{U_{NT}}$, is just equal to the slope of the NIPF owner's budget constraint, $-\frac{p_T}{p_{NT}}$, which tells us that the NIPF owner's marginal rate of substitution is equal to the price ratio of timber and non-timber outputs, or that the NIPF owner is willing to give up one unit of timber output for $\frac{p_T}{p_{NT}}$ units of non-timber output. To ensure that this optimal bundle is reached, not only must the first-order conditions be satisfied, but also the second-order sufficient condition.

Let us denote the second direct partial derivatives of the utility function by U_{11} and U_{22} and the second cross partial derivatives by U_{12} and U_{21}, where 1 denotes timber and 2 denotes non-timber output. The second-order sufficient condition for a constrained maximum requires that the relevant bordered Hessian determinant be positive.

$$\begin{vmatrix} U_{11} & U_{12} & -p_1 \\ U_{21} & U_{22} & -p_2 \\ -p_1 & -p_2 & 0 \end{vmatrix} > 0 \qquad (3.32)$$

The second-order sufficient condition requires that utility must decrease as the consumer moves away from the optimal choice along the budget line. This optimal choice is designated as (Q_T^*, Q_{NT}^*) in Figure 2.

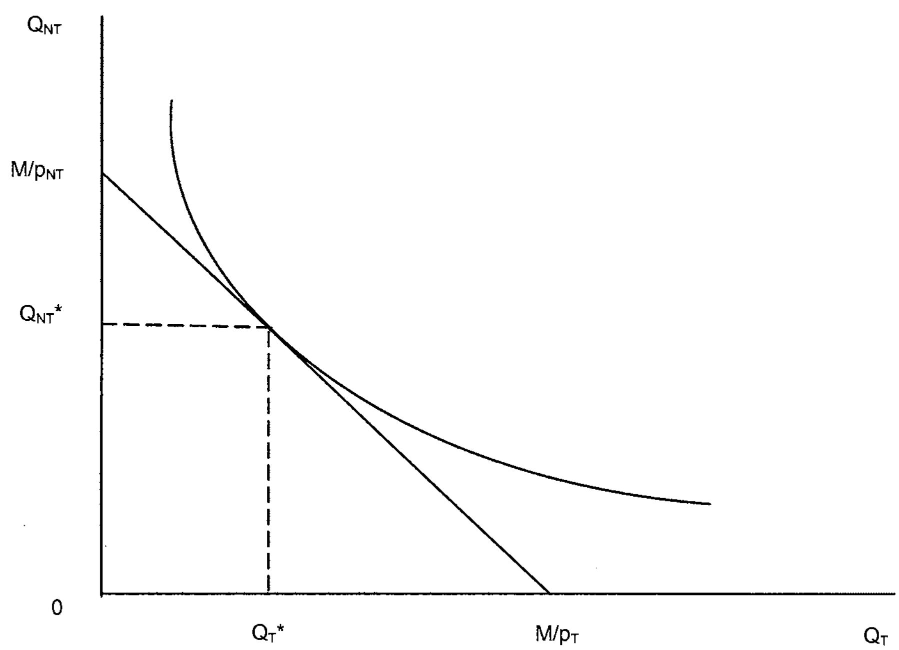

Figure 2: The NIPF owner's optimal choice (Q*T , Q*NT)

The demand function is the function that relates the optimal choice (Q_T^*, Q_{NT}^*) to the different values of prices (p_T, p_{NT}) and full income M (Varian 1999). The Marshallian demand functions for Q_T and Q_{NT} can be denoted as

$$Q_T = Q_T(p_T, p_{NT}, M) \text{ and } Q_{NT} = Q_{NT}(p_T, p_{NT}, M). \qquad (3.33)$$

Derivation of Marshallian Demand Functions from a Cobb-Douglas Direct Utility Function

In the direct utility function the NIPF owner is assumed to obtain utility from the consumption of Q_T and Q_{NT}. Utility is maximized subject to the full income constraint. Assuming a Cobb-Douglas functional form for the NIPF owner's utility function, the derivation of the NIPF owner's Marshallian demand functions for Q_T and Q_{NT} is as follows.

$$\text{Max} \qquad U(Q_T, Q_{NT}) = Q_T^c Q_{NT}^d \tag{3.34a}$$

$$\text{Subject to:} \quad M = p_T Q_T + p_{NT} Q_{NT} \tag{3.34b}$$

The Lagrange form of this optimization problem can be expressed as follows

$$\text{Max} \quad L = Q_T^c Q_{NT}^d + \lambda(M - p_T Q_T - p_{NT} Q_{NT}) \tag{3.35}$$

The first-order necessary conditions for a maximum are as follows

$$\frac{\partial L}{\partial Q_T} = cQ_T^{c-1} Q_{NT}^d - \lambda p_T = 0 \quad \Rightarrow \quad \lambda^* = \frac{cQ_T^{c-1} Q_{NT}^d}{p_T} \tag{3.36a}$$

$$\frac{\partial L}{\partial Q_{NT}} = dQ_T^c Q_{NT}^{d-1} - \lambda p_{NT} = 0 \quad \Rightarrow \quad \lambda^* = \frac{dQ_T^c Q_{NT}^{d-1}}{p_{NT}} \tag{3.36b}$$

$$\frac{\partial L}{\partial \lambda} = M - p_T Q_T - p_{NT} Q_{NT} = 0 \tag{3.36c}$$

$$\lambda^* = \frac{cQ_T^{c-1} Q_{NT}^d}{p_T} = \frac{dQ_T^c Q_{NT}^{d-1}}{p_{NT}} \quad \Rightarrow \quad Q_{NT} = \frac{p_T}{p_{NT}} \frac{d}{c} Q_T \tag{3.37}$$

By substitution of (3.37) into (3.36c) we obtain (3.38a), a hypothetical NIPF owner's Marshallian demand function for timber output.

$$M - p_T Q_T - p_{NT}\left(\frac{p_T d Q_T}{p_{NT} c}\right) = 0 \quad \Rightarrow Q_T\left(p_T + \frac{dp_T}{c}\right) = M \quad \Rightarrow Q_T^* = \frac{M}{p_T}\left(\frac{c}{c+d}\right) \tag{3.38a}$$

Then by substituting the result of (3.38a) into the result of (3.37) we obtain (3.38b), the Marshallian demand function for non-timber output.

$$Q_{NT}^{*} = \frac{p_T}{p_{NT}} \frac{d}{c}\left[\frac{M}{p_T}\left(\frac{c}{c+d}\right)\right] = \frac{M}{p_{NT}}\left(\frac{d}{c+d}\right) \tag{3.38b}$$

For this hypothetical case, the fraction of full income devoted to timber output is $(c/(c+d))$ and for non-timber output it is $(d/(c+d))$.

The Translog Direct Utility Function

Christiansen, Jorgenson, and Lau (1975) review both the direct and indirect transcendental logarithmic (translog) utility functions. They begin with the representation of the direct utility function U in the form

$$\ln U = \ln U(q_1, q_2, \dots, q_n) \tag{3.39}$$

where q_i is the quantity consumed of the i^{th} commodity. The consumer maximizes utility subject to the budget constraint

$$\sum_{i=1}^{n} p_i q_i = M \tag{3.40}$$

where p_i is the price of the i^{th} commodity and M is the value of total expenditures.

The first-order conditions for a maximum of utility can be written:

$$\frac{\partial \ln U}{\partial \ln q_j} = \mu \frac{p_j q_j}{U} \quad (j = 1, 2, \dots, n) \tag{3.41}$$

where μ is the marginal utility of income.

From the budget constraint they obtain:

$$\frac{\partial \ln U}{\partial \ln q_j} = \frac{p_j q_j}{M} \sum_{i=1}^{n} \frac{\partial \ln U}{\partial \ln q_i} \quad (j = 1, 2, \ldots, n) \tag{3.42}$$

where $\frac{p_j q_j}{M}$ is the budget share of the j^{th} commodity.

In order to preserve symmetry with their treatment of the indirect utility function, they approximate the negative of the logarithm of the direct utility function by a function quadratic in the logarithms of the quantities consumed:

$$-\ln U = \ln \alpha_0 + \sum_{i=1}^{n} \alpha_i \ln q_i + \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} \beta_{ij} \ln q_i \ln q_j \,. \tag{3.43}$$

Using (3.43), they obtain

$$\alpha_j + \sum_{i=1}^{n} \beta_{ij} \ln X_i = \frac{p_j X_j}{M} \sum_{i=1}^{n} \left(\alpha_k + \sum_{i=1}^{n} \beta_{ki} \ln X_i \right). \tag{3.44}$$

The budget constraint implies that the sum of the shares, $\sum \frac{p_i X_i}{M}$, equals one. So that the parameters of any $n-1$ equations for the budget shares, α_n and β_{nj}, can be determined from the definition of $\sum \alpha_k$ and $\sum \beta_{ki}$.

Since the equations for the budget shares are homogeneous of degree zero in the parameters, a normalization of the parameters is required for estimation. Christiansen, Jorgenson, and Lau use the convenient normalization that $\sum \alpha_k = \sum \alpha_i = -1$.

Indirect Utility

The indirect utility function gives the maximum utility achievable at given prices and income (Varian 1992). Given a direct utility function $U(Q_T, Q_{NT})$, where $Q_T = Q_T(p_T, p_{NT}, M)$ and $Q_{NT} = Q_{NT}(p_T, p_{NT}, M)$, we can write an indirect utility function:

$$V(p_T, p_{NT}, M) = U[Q_T(p_T, p_{NT}, M), Q_{NT}(p_T, p_{NT}, M)]. \tag{3.45}$$

In the case of the indirect utility function the NIPF owner maximizes utility attainable at prices (p_T, p_{NT}) and income M. Following the previous application with the Cobb-Douglas functional form, to write the indirect utility function we substitute the Marshallian demand functions into the utility function. Given $U(Q_T, Q_{NT}) = Q_T^c Q_{NT}^d$, $Q_T^* = \frac{M}{p_T}\left(\frac{c}{c+d}\right)$, and $Q_{NT}^* = \frac{M}{p_{NT}}\left(\frac{d}{c+d}\right)$, we can write the indirect utility function as

$$V(p_T, p_{NT}, M) = \left(\frac{M}{p_T}\left(\frac{c}{c+d}\right)\right)^c \left(\frac{M}{p_{NT}}\left(\frac{d}{c+d}\right)\right)^d = \frac{M^{(c+d)}}{p_T^c p_{NT}^d}\left(\frac{c^c d^d}{(c+d)^{(c+d)}}\right). \tag{3.46}$$

The indirect utility function V is quasiconvex in prices. If we let $V(p_T, p_{NT}, M) = k$ with M fixed, then when $V < k$ the consumer is worse off because prices are higher. Indirect utility increases as the function moves closer to the origin. The indirect utility function is decreasing in prices, $\frac{\partial V}{\partial p_i} < 0, i = 1, 2,$ (where we can let 1 denote timber and 2 denote non-timber outputs, respectively) and increasing in income $\lambda^* = \frac{\partial V}{\partial M} > 0$. This means that at higher prices and lower income the NIPF owner will be strictly worse off. The indirect utility function V is continuous in prices and income and thus V is usually differentiable. V is also homogenous of degree zero.

The Indirect Translog Utility Function

Christiansen, Jorgenson, and Lau (1975) begin their treatment of the indirect utility function with the following form

$$\ln V = \ln V(\mathbf{v}) \tag{3.47}$$

where $\mathbf{v} = \left(\frac{p_1}{M}, \frac{p_2}{M}, \ldots, \frac{p_n}{M}\right)$ is a vector of prices normalized by total expenditure M. Their approximation of the indirect utility translog model is given as

$$\ln V = \ln \alpha_0 + \sum_{i=1}^{n} \alpha_i \ln v_i + \tfrac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n} \beta_{ij} \ln v_i \ln v_j \,. \tag{3.48}$$

The model enforces equality, $\sum_{i=1}^{n} \beta_{ij} = \sum_{i=1}^{n} \beta_{ik},\ j, k, = 1, 2, \ldots, n$, symmetry, $\beta_{ij} = \beta_{ji}, \forall\ i, j \neq j$, and because the expenditure shares must add to one, they normalize $\sum_{i=1}^{n} \alpha_i = 1$.

The budget share of the j^{th} commodity is determined from Roy's Identity:

$$\frac{p_j q_j}{M} = -\frac{\partial \ln V / \partial \ln p_j}{\partial \ln V / \partial \ln M} \quad (j = 1, 2, \ldots, n) \tag{3.49}$$

where $\partial \ln V \big/ \partial \ln p_j = \alpha_j + \sum_{i=1}^{n} \beta_{ij} \ln v_i \quad (j = 1, 2, \ldots, n)$ and $-\partial \ln V / \partial \ln M = \sum_{k=1}^{n} \alpha_k + \sum_{k=1}^{n}\sum_{i=1}^{n} \beta_{ki} \ln v_i$. Noting the previously stated restrictions $-\partial \ln V / \partial \ln M = -1$, since $\sum_{k=1}^{n} \alpha_k = 1$ and $\sum_{k=1}^{n}\sum_{i=1}^{n} \beta_{ki} \ln v_i = 0$ and assuming the case of two commodities, the expenditure share equations reduce to:

$$s_1 = v_1 q_1 = \alpha_1 + \beta_{11} \ln\left(\frac{p_1}{p_2}\right), \tag{3.50}$$

and

$$s_2 = v_2 q_2 = \alpha_2 + \beta_{22} \ln\left(\frac{p_2}{p_1}\right). \tag{3.51}$$

Subscripts 1 and 2 denote timber and non-timber, respectively.

Derivation of Marshallian Demand Functions and Elasticities from the Indirect Utility Function

Using Roy's Identity the Marshallian demand function can be derived from the indirect utility function. Roy's Identity states that if $\mathbf{q}(\mathbf{p}, M)$ is the Marshallian demand function, then

$$q_i(\mathbf{p}, M) = -\frac{\dfrac{\partial V(\mathbf{p}, M)}{\partial p_i}}{\dfrac{\partial V(\mathbf{p}, M)}{\partial M}} \quad \forall\, i \tag{3.52}$$

provided that the right-hand side is well defined and that $p_i > 0$ and $M > 0$, where p_i is the price of commodity i and M is full-income.

<u>Elasticities</u>

From the use of the expenditure share equations, (3.50) and (3.51), and following the procedures of Chung (1994), we obtain the own price and cross price elasticities and the Morishima elasticity of substitution.

Own-price Elasticities

The own price elasticity of demand measures the percentage change in quantity demanded for a given percentage change in price along the ordinary, or own price market, demand function (Binger and Hoffman, 1998). The own-price elasticity of demand is given by equations (3.53a) and (3.53b).

$$\eta_{ii} = -1 + \frac{\partial s_i}{\partial p_i}\frac{p_i}{s_i} = -1 + \frac{\beta_i}{\alpha_i + \beta_i \ln\left(\frac{p_i}{p_i}\right) + \varepsilon_i} \tag{3.53a}$$

$$\eta_{jj} = -1 + \frac{\partial s_j}{\partial p_j}\frac{p_j}{s_j} = -1 + \frac{\beta_j}{\alpha_j + \beta_j \ln\left(\frac{p_j}{p_i}\right) + \varepsilon_j} \tag{3.53b}$$

Cross-price Elasticities

The cross-price elasticity is the percentage change in quantity demanded for a given percentage change in the price of the other good (Binger and Hoffman, 1998). For cross-price elasticity, substitute goods have positive cross-price elasticities and complement goods have negative cross-price elasticities. The cross price elasticity of demand is given by equations (3.54a) and (3.54b).

$$\eta_{ij} = \frac{\partial s_i}{\partial p_j}\frac{p_j}{s_i} = -\frac{\beta_i}{\alpha_i + \beta_i \ln\left(\frac{p_i}{p_j}\right) + \varepsilon_i} \tag{3.54a}$$

$$\eta_{ji} = \frac{\partial s_j}{\partial p_i}\frac{p_i}{s_j} = -\frac{\beta_j}{\alpha_j + \beta_j \ln\left(\frac{p_j}{p_i}\right) + \varepsilon_j} \tag{3.54b}$$

Elasticity of Substitution

The elasticity of substitution was originally introduced by John R. Hicks (1932) for the purpose of analyzing changes in the income shares of labor and capital in a growing economy (Blackorby and Russell 1989). Hicks's idea was generalized to more than two inputs by R. G. D. Allen and Hicks (1934), and later by Allen (1938), and Hirofumi Uzawa (1962). The Allen (or Allen/Uzawa) elasticity (AES) has been a standard statistic reported in empirical studies of production and consumption to classify input pairs and output pairs as substitutes or complements (Blackorby and Russell 1989).

Blackorby and Russell (1989) claimed that the AES is not a measure of the "ease" of substitution, or curvature of the isoquant; provides no information about relative factor shares (the purpose for which the elasticity of substitution was originally defined); and cannot be interpreted as a (logarithmic) derivative of a quantity ratio with respect to a price ratio (or marginal rate of substitution).

An alternative to the AES was formulated by M. Morishima (1967), later called the Morishima elasticity of substitution (MES) by Blackorby and Russell (1975). Blackorby and Russell (1989) noted that the MES, (i) *is* a measure of curvature, or ease of substitution, (ii) *is* a sufficient statistic for assessing – quantitatively as well as qualitatively – the effects of changes in price or quantity ratios on relative factor shares, and (iii) *is* a logarithmic derivative of a quantity ratio with respect to a marginal rate of substitution or a price ratio.

The MES was chosen for this research over the AES since it preserves the salient characteristics of the original Hicksian concept and is a sufficient statistic for assessing the effects of changes in price (or value) ratios on relative shares of timber and non-timber outputs.

For forestland consumers maximizing utility obtained from their forestland, the optimum (desired) ratio of timber to non-timber attributes they desire from a parcel of forestland is a function of the ratio of the relative values of timber to non-timber outputs. Following Chung (1994) and Blackorby and Russell (1989), the Morishima elasticity of substitution between timber and non-timber is given by

$$M_{ji} \equiv \frac{\partial \ln\left(s_j^*/s_i^*\right)}{\partial \ln\left(p_i/p_j\right)} \tag{3.55}$$

where $\left(s_j^*/s_i^*\right)$ is the utility maximizing ratio, and it is assumed that the percentage change in the price ratio, $\left(p_j/p_i\right)$, is induced solely by changing the i^{th} price. The Morishima elasticity of substitution can also be written as:

$$M_{ji} = \eta_{ji} - \eta_{ii} \tag{3.56}$$

where η_{jiT} is the constant output cross-price elasticity of demand and η_{ii} is the constant output own-price elasticity. If $M_{ji} > 0$, then outputs j and i are Morishima substitutes, and if $M_{ji} < 0$ then they are complements. A substitute relationship implies that an increase in p_i causes the ratio $\left(s_j^*/s_i^*\right)$ to rise; and a complementary relationship implies that an increase in p_i causes the ratio $\left(s_j^*/s_i^*\right)$ to fall (Chambers 1988).

Summary of Direct and Indirect Utility

In summary, the direct utility function assumes that the consumer maximizes utility $U(q_i)$ subject to his budget constraint $\mathbf{pq} \leq M$. The result of this problem is the Marshallian demand function $\mathbf{q}(\mathbf{p}, M)$. The indirect utility function $V(\mathbf{p}, M)$ gives the maximum utility achievable at given prices $\mathbf{p}$ and income M. The value of $\mathbf{q}$ that solves this problem is the consumer's demanded bundle, which expresses how much of each good the consumer desires at a given level of prices and income.

Direct utility relies on observable units of consumption, whereas indirect utility can be derived from expenditure or revenue shares. The fact that indirect utility can be derived from expenditure or revenue shares can be beneficial in a two good case where the total expenditures are known and expenditures on one good are known but not known for the other. For example, in this research, there are market prices and quantities for timber and timberland. However, there are no observable prices and quantities for non-timber outputs. Assuming that the full value of forestland is reflected in the sales price of forestland, the value of non-timber outputs per acre may be derived from the difference between the per acre value of the forestland and per acre value timber removals. Through this assumption, it is then possible to derive the per acre revenue shares for timber and non-timber outputs from NIPF.

Chapter

IV.

PROCEDURES

Direct Utility Approach

A direct procedure toward modeling consumers' behavior in their NIPF purchasing decisions would involve a direct utility function where the consumers' utility is derived from the consumption of observable units of timber products Q_T and non-timber products Q_{NT} each with respective observable market prices p_T and p_{NT}. In this regard the consumer of NIPF is assumed to maximize utility subject to income, where income M is defined as a fixed amount of the consumer's total income to be used to purchase forestland. The value of the forestland to the consumer is segmented into its hedonic attributes of timber $p_T Q_T$ and non-timber $p_{NT} Q_{NT}$. In this regard, the model can be expressed as

$$\text{Maximize} \quad U(Q_T, Q_{NT}) \tag{4.1a}$$

$$\text{subject to} \quad M = p_T Q_T + p_{NT} Q_{NT}. \tag{4.1b}$$

Using equation 4.1 and the appropriate data, it is possible to estimate the marginal utility of non-timber products. The elasticity of substitution between timber and non-timber products is then estimated by using the CES aggregation function of Sadoulet and de Janvry (1995), which is given as

$$\frac{Q_{NT}}{Q_T} = k_T \left(\frac{p_{NT}}{p_T} \right)^{-\sigma_T}. \tag{4.2}$$

Following the procedures of Bilgic *et al.* (2002) the elasticity of substitution is then econometrically estimated using the double-log form of equation (4.2), which is given as

$$\ln\left[\frac{Q_{NT}}{Q_T}\right] = \ln k_T + \sigma_T \ln\left[\frac{p_T}{p_{NT}}\right]. \qquad (4.3)$$

The left hand side of equation (4.3) is the natural log of the ratio of the demand for non-timber to timber products. The term $\ln k_T$ is an efficiency parameter, the term $\ln\left[\frac{p_T}{p_{NT}}\right]$ is the natural log of the price ratio of timber to non-timber products, and σ_T is the elasticity of substitution.

Indirect Utility Approach

Because many non-timber products are not traded in the market, do not have market prices, and are not quantifiable, using the direct utility approach is not possible. The value of timber products can be determined from market prices and quantities. The value of non-timber products, however, will be derived from a shadow price. If we assume that all value is captured in the sales price of the forestland, then the value of non-timber can be imputed from the market value of forestland less the value of the timber. Using this approach we then have value shares as the arguments for a utility function. Thus, an indirect translog utility function is a more appropriate framework for modeling the behavior of NIPF consumers. From this, the marginal utility of non-timber products and the elasticity of substitution between timber and non-timber outputs can be estimated.

Following the indirect utility approach, the steps toward achieving the objectives are as follows:

1. Predict the value of forestland.
2. Estimate the value of fixed timber output from the forestland.
3. Estimate the value of fixed non-timber output from the forestland.
4. Estimate the timber and non-timber shares.
5. Estimate the own-price, cross-price, and Morishima substitution elasticities.

Prediction of Forestland Values

The sales price of land per acre often varies inversely with the size of the parcel being sold. Due to this characteristic, various researchers (Chicoine 1981; Hushak and Sadr 1979; Phillips 2000; and Turner, Newton and Dennis 1991) have chosen a transcendental function to model the relationship between land price per acre and the relevant attributes that influence the price per acre. In transcendental form, we have:

$$PRICE = \beta_0 ACRES^{\beta_1} \mathrm{EXP}\left(\sum_{i=2\cdots n} \beta_i X_i\right) \tag{4.4}$$

where $PRICE$ is the purchase (sales) price per acre, $ACRES$ is the total acres of the parcel being sold, the X_i are other parcel attributes, and the β_i are the estimated coefficients. Converting this equation to logarithmic form allows estimation using ordinary least squares. Thus the statistical model is:

$$\ln(PRICE) = \ln \beta_0 + \beta_1 \ln(ACRES) + \left(\sum_{i=2\cdots n} \beta_i X_i\right) + \mu_i \tag{4.5}$$

where μ_i is the error term. For β_1, $\left(e^{\beta_1 / \overline{ACRES}} - 1\right)$ provides the percentage change in $PRICE$ for a unit change in $ACRES$. For $\beta_i, i > 1, \left(e^{\beta_i} - 1\right)$ provides the percentage change in $PRICE$ for a unit change in any single X_i.

The procedures of this research will also consider alternative functional forms to the transcendental model, such as models that allow for nonlinearity in explanatory variables beyond ACRES.

Expected Net Annual Value of Timber Output

The expected value of growing stock removals[3], for this research, was used as a proxy for the value of timber output. The USDA Forest Service (FS) Forest Inventory Analysis (FIA) database provides an annualized volume of growing stock removals per acre by county and ownership class. An expected annual removal per acre for each forestland parcel was estimated by utilizing the USDA-FS FIA data on growing stock removals from NIPF and the expected productivity index for each forestland parcel from the forestland sales transactions data set. Equation (4.6) was used to calculate the expected annual removals per acre for each forestland parcel in the forestland sales transactions dataset.

$$ExRem_{i_j} = \left(\frac{TmProd_{i_j}}{\sum_{i=1}^{n_j} TmProd_{i_j} / n_j} \right) \left(\frac{Removals_j}{Acres_j} \right), \quad j = 0, 1; i_0 = 1, \cdots, 36; i_1 = 1, \cdots, 45. \qquad (4.6)$$

[3] Removals are defined as the net volume of growing-stock or live trees removed from the inventory by harvesting, cultural operations, land clearing, or changes in land use. Growing stock are living trees of commercial species classified as saw-timber, pole-timber, saplings, and seedlings.

where:

$ExRem_{i_j}$ is the expected annual removals per acre for forestland parcel i in county j, (ft^3/acre),

$TmProd_{i_j}$ is the expected annual timber productivity per acre for forestland parcel i in county j, (ft^3/acre),

$Removals_j$ is the total annual growing stock removals on NIPF as reported by the Southern FIA for county j, (ft^3),

$Acres_j$ is the total NIPF acres in county j, and

n_j is the total number of forestland sales transactions parcels in county j.

The forestland sales transactions parcels in Pushmataha County ($j=0$) have an average productivity of 72.95 cubic feet per acre per year. The annualized growing stock removals for the county are 5.9 million cubic feet and the total number of NIPF acres is 375,800. Thus the expected average annualized removals are 15.7 cubic feet per acre. The forestland sales transactions parcels in McCurtain County ($j=1$) have an average productivity of 114.65 cubic feet per acre per year. The annualized growing stock removals for the county are 12.6 million cubic feet and the total number of NIPF acres is 178,000. Thus the expected average annualized removals are 70.79 cubic feet per acre.

To illustrate the calculation of an expected annualized removal let us consider a forestland sales transaction parcel in McCurtain County with an expected annual productivity of 102 ft^3/acre.

$$ExRem = \left(\frac{102}{114.65}\right)\left(\frac{12,600,000}{178,000}\right) = 63.$$

Thus, for this parcel the expected annualized removals are 63 ft^3/acre. Appendix-2 lists the estimated expected annual removals for each observation.

The expected annualized gross value of removals per acre for a forestland parcel was estimated as the product of the expected stumpage price per cubic foot and the expected annual removals per acre for that parcel. The average stumpage price for the region is based on a rolling five year average of prices for 1996 to 2000 reported by "Timber Mart-South" for western Arkansas (Zone 1) and north Texas (Zone 1) weighted by the mix of outputs reported for Oklahoma in "Oklahoma's Timber Industry – An Assessment of Timber Product Output and Use, 1996" (Howell and Johnson 1998).[4] Western Arkansas (Zone 1) and north Texas (Zone 1) stumpage prices are used since there is no known source of published stumpage price data for Oklahoma.

Stumpage price reports reflect an average of the stumpage prices from many different sales, each having unique conditions. Thus, the stumpage price for any one individual sale may be higher or lower than the average based upon various conditions such as: tree species and age, the quality and size of the trees, logging conditions, and proximity to wood processing facilities. According to Davis and Johnson (1987), land, logging, and market conditions are more uniform in the south relative to the other regions in the USA. One variable that we can account for is the distance to the nearest wood processing facility. The

[4] The average stumpage price for the region was calculated and obtained from a draft report on appraising Oklahoma forestland for ad valorem tax purposes by David K. Lewis and Darrel D. Kletke (July 2002).

average stumpage price was adjusted by the distance to the nearest community with two or more wood processing facilities. To obtain the adjusted stumpage price the following assumptions were made:

- An average stumpage price of $0.6942 per cubic foot.
- Transport cost per loaded mile equal to $2.25.[5]
- A load weight of 26 tons.
- A weighted output of 82.4% softwood and 17.6% hardwood[6].
- Weights per cubic foot for softwood and hardwood of 53 and 64 pounds, respectively[7].

Using these assumptions a cost of $0.0024 per cubic foot mile was calculated as follows:

$$p_{Tran} = \frac{p_{LM}}{\left(\frac{2000}{(W_s)(S)+(W_H)(H)}\right)(T_L)} = \frac{2.25}{\left(\frac{2000}{(0.824)(53)+(0.176)(64)}\right)(26)} = 0.0024 \qquad (4.7)$$

where:

p_{Tran} is the price per cubic foot mile to transport timber (U.S. dollars),

p_{LM} is the price per loaded mile (U.S. dollars),

W_s is the weighted mix of softwood removals,

W_H is the weighted mix of hardwood removals,

S is the weight per cubic foot for softwood (pounds),

H is the weight per cubic foot for hardwood (pounds), and

---

[5] Transportation costs and load capacity are based upon information obtained from industry professionals in the region.

[6] The weighted output of softwood and hardwood is based upon the mix of outputs reported in Howell and Johnson (1998).

[7] The weight of 53 pounds is for that of loblolly pine and 64 pounds for red oak; source, page 583 of Wenger, Karl F. 1984. *Forestry Handbook, Second Edition.* John Wiley & Sons, New York, NY.

T_L is the tons per load.

Equation (4.8) was then used to obtain the adjusted stumpage price for each observation:

$$p_{adj} = p_{Tran}\left(\overline{D} - D_i\right) + p_{avg} \tag{4.8}$$

where:

p_{adj} is the adjusted stumpage price ($/ft^3),

p_{Tran} is the price per cubic foot mile to transport timber (U.S. dollars),

p_{avg} is the average stumpage price ($/ft^3),

$\overline{D} = \frac{\sum_{i=1}^{81} D_i}{81}$ is the average distance in roadway miles to the nearest community with two or more wood processing facilities, and

D_i is the distance in roadway miles from parcel i to the nearest community with two or more wood processing facilities[8].

The divisor for $\overline{D}$ is 81 since there are a total of 81 observations throughout the region and in some cases the closest wood processing facility to the forestland parcel is outside of the county in which the forestland parcel resides. Appendix-2 lists the adjusted stumpage price for each observation.

The expected net annualized value of removals per acre was calculated as the expected gross revenue per acre minus the expected annualized production cost. Due to the fact that there is a significant difference in both the

[8] The average distance from parcel i to the nearest community with two or more wood processing mills was obtained from the spatial characteristics dataset prepared for this research by Jimmy Wood and Dr. Allen Finchum of the Department of Geography at Oklahoma State University.

expected timber productivity and the reported removals of growing stock between McCurtain County and Pushmataha County, different management levels were assumed for each county: a level of management involving silvicultural activities, and therefore production costs, in McCurtain County, and a level of management not involving prescribed silvicultural activities in Pushmataha County, and therefore no production costs.[9] The average annual potential timber productivity for the observations in McCurtain County is 114.65 cubic feet per acre, where as in Pushmataha County it is 72.95 cubic feet per acre. As reported by the Southern FIA, the average annual removals of growing stock per acre for NIPF in McCurtain County is 70.79 cubic feet per acre, where as in Pushmataha County it is 15.7 cubic feet per acre. Furthermore, all reported removals for NIPF in Pushmataha County came from natural stands. The average annual removals of growing stock may differ, not only from potential productivity, but also due to the fact that the timber products industry and culture of forestry may be more developed in McCurtain County than it is in Pushmataha County.

The expected annualized production costs for McCurtain County were estimated using the following assumptions:

- Site preparation with chemical treatment in year 0 at $85 per acre[10]
- Seedling plus planting in year 0 at $65 per acre
- Early release of herbaceous weeds with chemical treatment at $55 per acre

---

[9] In addition to the observation of data and other characteristics of the region, statistical tests were conducted to determine whether there was a significant difference in the removals and productivity between the two counties. These statistical tests are reported in Appendix-2.

[10] The selected silvicultural treatments, rotation age, and costs of silvicultural treatments are based upon discussions with William Ross, State Forestry Specialist, Oklahoma State University, Department of Forestry; and "Costs and Cost Trends for Forestry Practices in the South" by Dubois, McNabb, and Straka, *Forestland Owner*, March/April 1999.

- Mid-rotation release of herbaceous weed and woody plants with chemical treatment in year 15 at $70 per acre
- Timber marking for thinning in year 15 at $15 per acre
- Thinning in year 15 at $70 per acre
- Discount factor of 5% per year[11]
- Rotation age of 30 years

Under these assumptions the average annual discounted production costs per acre in McCurtain County is $9.32[12].

Under the preceding assumptions, the expected net annualized value of removals per acre for each observation was then calculated using equation (4.9):

$$P_{Rem} = (ExRem)(p_{adj}) - C_{Prod} \tag{4.9}$$

where:

P_{Rem} is the expected net annualized value of removals per acre for parcel i,

$ExRem$ is the expected annual removals per acre for forestland parcel i,

p_{adj} is the adjusted stumpage price ($/ft^3) for forestland parcel i, and

C_{Prod} is the discounted annualized production cost per acre.

The expected net annualized value of removals per acre for each observation is listed in Appendix-2.

[11] The discount factor is based upon a minimum acceptable real rate of return.
[12] Calculation of the average annual discounted production costs per acre for McCurtain County are in Appendix-2.

Expected Annualized Value of Non-timber Output

The expected annualized value of non-timber output per acre for each observation was estimated using equation (4.10):

$$\hat{p}_{NT} = \hat{p}_L - p_T \qquad (4.10)$$

where:

$\hat{p}_{NT}$ is the expected annualized value of non-timber output per acre,

$\hat{p}_L$ is the annualized price per acre for forestland[13], and

p_T is the expected net annualized value of removals per acre, where removals is being used as a proxy for timber harvest.

In this calculation, it is assumed that the per-acre sales price of forestland $\hat{p}_L$ incorporates the total value, or full-income M, of the forestland such that $\hat{p}_L = F(p_T, \hat{p}_{NT})$. The expected annualized values for non-timber outputs per acre for each observation are listed in Appendix-2.

Estimation of the Share Equations for Timber and Non-timber Outputs

The annualized forestland, timber output, and non-timber output values are used toward estimating the share equations. These value share equations are then used in the estimation of the own-price, cross-price, and Morishima elasticities. Theoretically an indirect translog utility model is used to derive the elasticity of substitution between timber and non-timber outputs. In this regard, we use the indirect utility function from which value shares are determined by Roy's Identity. This system is then fitted to value shares corresponding to

[13] $\hat{p}_L$ is the estimated timberland value for each observation discounted at 5% over a 30 years.

normalized prices to estimate the elasticity of substitution between timber and non-timber output.

The indirect utility model takes the following form:

$$V(p_T, p_{NT}, M) = \left(\frac{M}{p_T}, \frac{M}{p_{NT}} \right), \tag{4.11}$$

where p_T and p_{NT} are the corresponding annualized values of timber and non-timber outputs per acre and M is the forestland owner's expenditures necessary to achieve a utility level V. Christian, Jorgenson, and Lau's (1975) approximation of the indirect utility translog model is used for the empirical estimation,

$$\ln V(v;\theta, \varepsilon) = \ln \alpha_0 + \sum_{i=1}^{K} \alpha_i \ln v_i + \frac{1}{2} \sum_{i=1}^{K} \sum_{j=1}^{K} \beta_{ij} \ln v_i \ln v_j + \sum_{i=1}^{K} \varepsilon_i \ln v_i \tag{4.12}$$

where $v = \left(\frac{p_i}{M}, \cdots, \frac{p_k}{M} \right)' = (v_i, \cdots, v_k)'$ is a vector of prices normalized by total income, M, on timberland, error terms are $\varepsilon(\varepsilon_1, \cdots, \varepsilon_K) \sim N(0, \Sigma)$, and $\theta = (\alpha, \beta)$ are parameters of the model.

The value shares of timber and non-timber outputs are determined by Roy's Identity,

$$\begin{aligned} v_i q_i = \frac{\partial \ln V / \partial \ln p_i}{\partial \ln V / \partial \ln M} &= \frac{\alpha_i + \sum_{j=1}^{n} \beta_{ij} \ln v_j + \varepsilon_i}{\sum_{i=1}^{n} \alpha_i + \sum_{i=1}^{n} \sum_{j=1}^{n} \beta_{ij} \ln v_j} \,. \\ &= \alpha_i + \sum_{j=1}^{n} \beta_{ij} \ln v_j + \varepsilon_i \qquad (i = 1, \cdots, n) \end{aligned} \tag{4.13}$$

The value shares for timber and non-timber outputs are then given by equations (4.14a) and (4.14b):

$$s_T = v_T q_T = \alpha_T + \beta_T \ln\left(\frac{p_T}{p_{NT}}\right) + \varepsilon_T, \tag{4.14a}$$

and

$$s_{NT} = v_{NT} q_{NT} = \alpha_{NT} + \beta_{NT} \ln\left(\frac{p_{NT}}{p_T}\right) + \varepsilon_{NT}. \tag{4.14b}$$

A method of two-stage least squares (2SLS) was used to estimate equations (4.14a) and (4.14b). The basic idea behind 2SLS is to "purify" the stochastic explanatory variable p_{NT} of the influence of the stochastic disturbance term ε of the share equations. This goal is accomplished by performing the regression of $(\ln PRICE)$ in stage-1, from which estimates of p_{NT} are calculated. The estimates of p_{NT} are then used in stage-2 to estimate the share equations. The estimates obtained in stage-2 are consistent; that is they converge to their true values as the sample size increases indefinitely (Gujarati 1995).

In stage-1 the $\hat{p}_{L_i}$ were obtained through estimation of equation (4.5). The predicted values were then outputted and transformed: the $\hat{p}_{L_i}$ are equal to the exponential of the predicted values of $EXP(\ln PRICE)_i$. These were matched with the p_{T_i} to calculate the $\hat{p}_{NT_i}$ for stage-2, as follows:

$$\hat{p}_{NT_i} = p_{L_i} - p_{T_i} = \left(\hat{p}_{L_i} + \hat{u}_i\right) - p_{T_i}$$

The stochastic $\hat{p}_{NT_i}$ consists of three parts: $\hat{p}_{L_i}$, which is a linear combination of the non-stochastic $X's$, a random component $\hat{u}_i$, and a non-stochastic component p_{T_i}. Following OLS theory, $\hat{p}_{L_i}$ and the $\hat{u}_i$ are uncorrelated (Gurjarati 1995). Since the p_{T_i} are a non-stochastic component, the $\hat{u}_i$ will remain uncorrelated with the stochastic $\hat{p}_{NT_i}$.

In stage-2, the share equations were estimated using the $\hat{p}_{NT}$ and the "observed" values of p_{T_i}. The share equation for timber outputs was written as:

$$
\begin{aligned}
s_{T_i} = v_{T_i} q_{T_i} &= \alpha_T + \beta_T \ln\left(\frac{p_{T_i}}{\hat{p}_{L_i} + \hat{u}_i - p_{T_i}} \right) + \varepsilon_{T_i} \\
&= \alpha_T + \beta_T \ln\left(\frac{p_{T_i}}{\hat{p}_{NT_i}} \right) + \left(\varepsilon_{T_i} + \beta_T \hat{u}_i \right) \\
&= \alpha_T + \beta_T \ln\left(\frac{p_{T_i}}{\hat{p}_{NT_i}} \right) + \varepsilon^*_{T_i}
\end{aligned}
$$

where $\varepsilon^*_{T_i} = \varepsilon_{T_i} + \beta_T \hat{u}_i$. The $\varepsilon^*_{T_i}$ are *asymptotically* uncorrelated with the $\hat{p}_{NT_i}$. As a result, OLS can be applied to the above equation and it will give consistent estimates (Gujarati, 1995). Having the same properties and similarly written is the non-timber share equation:

$$
\begin{aligned}
s_{NT_i} = v_{NT_i} q_{NT_i} &= \alpha_{NT} + \beta_{NT} \ln\left(\frac{\hat{p}_{L_i} + \hat{u}_i - p_{T_i}}{p_{T_i}} \right) + \varepsilon_{NT_i} \\
&= \alpha_{NT} + \beta_{NT} \ln\left(\frac{\hat{p}_{NT_i}}{p_{T_i}} \right) + \left(\varepsilon_{NT_i} + \beta_{NT} \hat{u}_i \right) \\
&= \alpha_{NT} + \beta_{NT} \ln\left(\frac{\hat{p}_{NT_i}}{p_{T_i}} \right) + \varepsilon^*_{NT_i}
\end{aligned}
$$

The value share equations and their estimated coefficients were used to calculate the own price and cross price elasticities, and the elasticity of substitution between timber and non-timber outputs.

Estimation of the Own-price, Cross-price and Morishima Elasticities

In the following equations, p_{T_i} is the expected annualized value of timber output per acre for parcel i, $\hat{p}_{NT_i}$ is the expected annualized value of non-timber output per acre for parcel i, $\hat{s}_{T_i}$ is the share of timber value per acre for parcel i, and $\hat{s}_{NT_i}$ is the share of non-timber value per acre for parcel i.

Own-price elasticities:

Equations (4.15a) and (4.15b) are the own-price elasticity of demand for timber and non-timber outputs, respectively.

$$\hat{\eta}_{T,T} = -1 + \frac{\partial \hat{s}_T}{\partial p_T} \frac{p_T}{\hat{s}_T} = -1 + \frac{\hat{\beta}_T}{\hat{\alpha}_{T,T} + \hat{\beta}_T \ln\left(\frac{p_T}{\hat{p}_{NT}}\right) + \hat{\varepsilon}_T}, \tag{4.15a}$$

$$\hat{\eta}_{NT,NT} = -1 + \frac{\partial \hat{s}_{NT}}{\partial \hat{p}_{NT}} \frac{\hat{p}_{NT}}{\hat{s}_{NT}} = -1 + \frac{\hat{\beta}_{NT}}{\hat{\alpha}_{NT} + \hat{\beta}_{NT} \ln\left(\frac{\hat{p}_{NT}}{p_T}\right) + \varepsilon_{NT}}, \tag{4.15b}$$

Cross-price Elasticities

Equations (4.16a) and (4.16b) are the cross-price elasticity equations for timber and non-timber outputs, respectively.

$$\hat{\eta}_{T,NT} = \frac{\partial \hat{s}_T}{\partial \hat{p}_{NT}} \frac{\hat{p}_{NT}}{\hat{s}_T} = -\frac{\hat{\beta}_T}{\hat{\alpha}_T + \hat{\beta}_T \ln\left(\frac{p_T}{\hat{p}_{NT}}\right) + \hat{\varepsilon}_T}, \tag{4.16a}$$

$$\hat{\eta}_{NT,T} = \frac{\partial \hat{s}_{NT}}{\partial p_T} \frac{p_T}{\hat{s}_{NT}} = -\frac{\hat{\beta}_{NT}}{\hat{\alpha}_{NT} + \hat{\beta}_{NT} \ln\left(\frac{\hat{p}_{NT}}{p_T}\right) + \varepsilon_{NT}}, \tag{4.16b}$$

Morishima Elasticity of Substitution

The Morishima elasticity of substitution between timber and non-timber is given by

$$\hat{M}_{NT,T} \equiv \frac{\partial \ln\left(\hat{s}^*_{NT}/\hat{s}^*_T\right)}{\partial \ln\left(p_T/\hat{p}_{NT}\right)} \tag{4.17}$$

where $\left(\hat{s}^*_{NT}/\hat{s}^*_T\right)$ is the utility maximizing optimal output ratio of timber to non-timber outputs and $\left(p_T/\hat{p}_{NT}\right)$ is the price ratio of timber to non-timber. $\hat{M}_{NT,T}$ reflects the (proportional) effects on $\hat{s}^*_{NT}$ and $\hat{s}^*_T$ of varying $\left(p_T/\hat{p}_{NT}\right)$, induced solely by changing p_T. The Morishima elasticity of substitution between timber and non-timber outputs was calculated using the following equation:

$$\hat{M}_{NT,T} = \hat{\eta}_{NT,T} - \hat{\eta}_{T,T} \tag{4.18}$$

where $\hat{\eta}_{NT,T}$ is the constant output cross-price elasticity of demand and $\hat{\eta}_{T,T}$ is the constant output own-price elasticity. If $\hat{M}_{NT,T} > 0$, timber and non-timber products are Morishima substitutes, and if $\hat{M}_{NT,T} < 0$ then they are complements. A substitute relationship implies that an increase in p_T causes the ratio $\left(\hat{s}^*_{NT}/\hat{s}^*_T\right)$ to rise; and a complementary relationship implies that an increase in p_T causes the ratio $\left(\hat{s}^*_{NT}/\hat{s}^*_T\right)$ to fall (Chambers 1988).

Chapter

V.

DATA

To carry out the five procedures, the following are required:

1. Data for the hedonic forestland pricing model;
2. Data on the quantity and value of timber harvest;
3. From 2 and 3 we derive the shadow price for non-timber output;
4. The three preceding categories and the use of the indirect utility function and Roy's Identity provide the necessary data to estimate the share equation.
5. The results of the share equations are then used toward estimating the own-price, cross-price and Morishima elasticities.

Data for the Hedonic Estimation of Forestland Prices

There were two data sets developed for the hedonic price model, a forestland sales transactions dataset and spatial characteristics dataset. The forestland sales transactions data comes from a data set developed by Dr. Darrell Kletke and Dr. David Lewis of the Department of Agricultural Economics and Department of Forestry, respectively, at Oklahoma State University. The primary source of their data was the State of Oklahoma Tax Commission. This data set includes the following information: the sales price of forestland parcels, the size (acres) of each parcel sold, its location, the classification of land uses within each parcel, and the expected annual per acre timber production for each parcel. Jimmy Wood and Dr. Allen Finchum of the Department of Geography at

Oklahoma State University developed the spatial characteristics data set. The data set includes information on the distance to the nearest city having a population of 2,000 or more, the population growth of that city, the distance to the nearest community containing two or more wood-processing mills, the distance to the nearest natural resource attraction (*e.g.*, lakes, State Parks, the Ouachita National Forest), the distance to major roadways (*e.g.*, state and federal highways), and indication of whether the parcel fronts a road.

<u>Forestland Sales Transactions Data Set</u>

The data set was drawn from 109 sales of land parcels in a two county area of southeast Oklahoma in 1999. These consist of 40 transactions in Pushmataha County and 69 transactions in McCurtain County. The land area in the parcels was classified into cropland, improved pasture, native pasture, and timberland. In order to be included in the study, the parcel could not be industrial private forestland, could not contain any buildings, and had to include timber-producing soil[14]. Once this adjustment was made, the total land transactions involving timberland numbered 81, 36 in Pushmataha County and 45 in McCurtain County. Of the 81 transactions, none includes cropland, one includes improved pasture, and 12 include native pasture. The improved and native pasture uses were combined to form the variable $OPEN$, which denotes the

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[14] Timber producing soils are soils classified as having the potential for commercial timber production. Soils can determine which tree species yield the greatest timber volume, the time to harvest, and ultimately, the investment a landowner must make to yield an acceptable economic return (Hamilton, 1995). The procedure for classifying soils into productivity classes for McCurtain and Pushmataha counties is summarized in the draft report on appraising Oklahoma forestland for ad valorem tax purposes by Lewis and Kletke (July 2002).

percentage of the parcel that is classified as open land. The explanatory variable *ACRES* is the size of the parcel in acres, which is converted to logarithmic form $(\ln Acres)$. The variable *TmProd* denotes the expected annual per acre timber productivity.

Spatial Characteristics Data Set

The spatial data set describes relationships between the forestland parcels and the larger regional economy. The larger regional economy includes most of the counties in southeastern Oklahoma and bordering counties in Arkansas and Texas. The creation of the data set involved the use of the ArcView geographic information systems (GIS) software.

The spatial data set provides the following categories of information:

1. Distance to urban areas and population growth of those areas.
2. Distance to wood processing communities.
3. Distance to land areas classified as natural resource attractions.
4. Distance to major roadways.
5. A binary variable indicating whether the forestland parcel fronts a road of any type.

The distances were calculated using the network analyst extension of ArcView. The variable *DistCity* is the distance in roadway miles to the closest community having a population of at least 2,000. The variable *PopGro* is the population growth of that city measured as the change in population between the 1990 and 2000 census periods.

There are thirteen communities within close proximity of the forestland parcels that contain at least two wood-processing facilities. These communities were determined from use of the *Arkansas Wood Using Industries Directory, Oklahoma Wood Manufactures Directory,* and the Texas Forest Service *Directory of Forest Products Industries.* This data was combined with data on the expected annual per acre timber output from each parcel and the cost per cubic foot mile to transport timber to form the variable $TranCost$, which measures the annualized cost of transporting timber per acre from parcel i to the nearest community having two or more wood-processing mills.

Land classified as a natural resource attraction includes major lakes, State Parks, and the Ouachita National Forest. The variable $DistNat$ is a measure of the road mile distance to the nearest natural resource attraction for parcel i.

The variable $DistHwy$ is the linear distance in miles to the nearest major roadway, such as a State or U.S. Highway. $FRONT$ is a binary variable that indicates whether the parcel fronts (or is near) any type of road, this may include non-paved roadways such as section line roads. To determine whether the land fronts (near) a road a ¼ mile buffer was placed around each forestland parcel. If the buffer intersected a road of any type a number one was assigned (1 = yes, 0 = no).

Appendix-1 lists the data and provides additional information on the data for the hedonic price model. Table 7 provides a description of the variables of the hedonic price model, the explanatory variables' expected effect on price, and the source of data.

Table 7: Description of Data for the Hedonic Price Model

Variable	Description	Expected effect on price	Data source(s)
PRICE	Parcel sale price per acre	N/A	Kletke and Lewis (2002)
ACRES	Size of the parcel in acres	-	Kletke and Lewis (2002)
OPEN	Percentage of parcel not forested (open land)	-	Kletke and Lewis (2002)
TmProd	Expected annual per acre timber production on timber soils (ft^3)	+	Kletke and Lewis (2002)
FRONT	Dummy variable whether parcel fronts on a road	+	Wood and Finchum (2003)
DistHwy	The linear distance to the nearest major roadway or highway (miles)	-	Wood and Finchum (2003)
DistCity	Distance in road miles to the nearest city with a population > 2,000	-	Wood and Finchum (2003)
PopGro	Population growth of the nearest city with population > 2,000	+	US Census 1990 and 2000
TranCost	The annualized cost per acre to deliver timber to market	-	Multiple
DistNat	Distance in road miles to the nearest natural resource attraction	-	Wood and Finchum (2003)
ln*Price*	Log of *PRICE*	N/A	Kletke and Lewis (2002)
ln*Acres*	Log of *Acres*	-	Kletke and Lewis (2002)

Summary Statistics of the Data for the Hedonic Price Model

McCurtain County

The average per acre price of forestland sold was $1,083, with a minimum price of $66 and a maximum price of $9,330. The parcel size averaged 55 acres and ranged from 5 to 160 acres. On average the roadway distance to the nearest city having a population of 2,000 or greater was 18 miles and ranged from 2 to 44 miles. The linear distance to the nearest major roadway averaged 3.6 miles and ranged from 0.2 to 8.4 miles. The average annual expected timber productivity was 115 cubic feet per acre and ranged from 67 to 255 cubic feet per acre. On average 73% of parcels fronted on (or near) a road of any type, and 7% of the forestland parcel acreage sold was classified as open land. The average annual population growth rate of the nearest town to parcel i between the 1990 and 2000 census was 2.47%, the mean transport cost was $1.79 per cubic foot mile, and the average distance to the nearest natural resource attraction was 16.77 miles. Table 8 provides summary statistics of the data for McCurtain County.

Table 8: Summary Statistics of the Data for the Hedonic Price Model (McCurtain County)

Variable	Unit	Mean	Minimum	Maximum	Standard Deviation	Number of Observations
ln*Price*	$	6.34	4.18	9.14	1.0745	45
PRICE	$	1,082.59	65.58	9,329.65	1,708.80	45
ln*Acres*	acres	3.73	1.61	5.08	0.7962	45
ACRES	acres	55.11	5.00	160.00	40.0673	45
DistCity	miles	17.88	1.93	44.47	10.4819	45
DistHwy	miles	3.55	0.20	8.40	2.2390	45
TmProd	ft^3/acre	114.65	67.00	255.00	44.9682	45
FRONT	proportion	0.73	0.00	1.00	0.4472	45
OPEN	%	6.57	0.00	62.96	17.2647	45
PopGro	%	2.47	-4.92	6.79	3.4601	45
TranCost	\$/ft^3 mile	1.79	0.14	7.66	1.3112	45
DistNat	miles	16.77	3.33	37.99	8.2423	45

Pushmataha County

The average per acre price of forestland sold was $400, ranging from $86 to $1,250. Parcel size averaged 78 acres, ranging from 12 to 260 acres. The average roadway distance to the nearest city with a population of 2,000 or more was 23.2 miles, ranging from 3.2 to 43 miles. The linear distance to the nearest major roadway averaged 1.8 miles, ranging from 0.04 to 5.0 miles. The average annual productivity was 73 cubic feet per acre, ranging from 34 to 255 cubic feet per acre, 50% of parcels fronted on (or near) a road of any type, and 10% of the forestland parcel acreage sold was classified as open land. The average annual population growth rate of the nearest town to parcel i between the 1990 and 2000 census was -0.25%, the mean transport cost was $0.79 per cubic foot mile, and the average distance to the nearest natural resource attraction was 22.35 miles. Table 9 provides summary statistics of the data for Pushmataha County.

Table 9: Summary Statistics of the Data for the Hedonic Price Model (Pushmataha County)

Variable	Unit	Mean	Minimum	Maximum	Standard Deviation	Number of Observations
L*Price*	$	5.78	4.45	7.13	0.6552	36
PRICE	$	400.08	85.69	1,250.00	289.4684	36
ln*Acres*	acres	4.08	2.46	5.56	0.8076	36
ACRES	acres	78.42	11.67	260.00	56.6876	36
DistCity	miles	23.21	3.19	42.99	12.0636	36
DistHwy	miles	1.76	0.04	4.96	1.2990	36
TmProd	ft^3/acre	72.95	34.00	255.00	40.1575	36
FRONT	proportion	0.50	0.00	1.00	0.5071	36
OPEN	%	9.53	0.00	75.00	21.3410	36
PopGro	%	-0.25	-3.88	1.11	2.2669	36
TranCost	$/$ft^3$ mile	0.79	0.06	1.88	0.4452	36
DistNat	miles	22.35	2.79	41.51	7.4992	36

Annualized Timber and Non-timber Values Data for the Share Equations

Once the hedonic estimation of forestland values was obtained, then the annualized per acre values of the timber and non-timber outputs were calculated. This data was then used in the econometric estimation of the share equations.

The data on the annualized per acre values of timber and non-timber outputs used in the share equations are listed in Tables 52 and 53 on pages 214 – 219 for McCurtain and Pushmataha Counties, respectively. For McCurtain County, the mean and standard deviation of the expected annualized value of timber outputs per acre was $40.72 and $19.56, respectively; and for Pushmataha County, the mean and standard deviation were $10.70 and $6.24, respectively. For McCurtain County, the mean and standard deviation of the expected annualized value of non-timber outputs per acre was $137.79 and $134.35, respectively; and for Pushmataha County, the mean and standard deviation were $71.09 and $32.90, respectively.

The estimated coefficients from the share equations were then used toward estimating the own-price and cross-price elasticities and Morishima elasticities of substitution.

Chapter

VI.

RESULTS

Hedonic Estimation of Forestland Prices

The empirical model used to estimate forestland prices for McCurtain and Pushmataha Counties was a transcendental logarithmic function specified as follows:

$$\begin{aligned} \ln Price_i = \ln \beta_0 + \beta_1 \ln Acres_i + \beta_2 DistCity_i + \beta_3 DistHwy_i \\ + \beta_4 TmProd_i + \beta_5 Front_i + \beta_6 OPEN_i + \mu_i \end{aligned} \quad (6.1)$$

where $Price_i$ is the price per acre for observation (or forestland parcel) i, $Acres_i$ is the parcel size in acres for observation i, $DistCity_i$ is the distance in roadway miles to the nearest town having a population of 2,000 or more for observation i, $DistHwy_i$ is the linear distance to the nearest major roadway (*i.e.,* State or U.S. highway) for observation i, $TmProd_i$ is the expected annual timber productivity for observation i, $Front_i$ is a binary variable indicating whether the parcel fronts on (or near) a road of any type for observation i, and $OPEN_i$ is the percentage of the parcel that is open land for observation i. For McCurtain County $i = 45$, and for Pushmataha County $i = 36$. The variables $PopGro$, $TranCost$, and $DistNat$ were not included in the final model.

Regression Results for the Hedonic Forestland Pricing Models

McCurtain County

Due to heteroskedasticity the estimated generalized least squares procedure was used to estimate equation (6.1) for the McCurtain County data. Of the six explanatory variables in the model, four were significant. These were $\ln Acres$, *DistHwy*, *TmProd,* and *OPEN*. The variables *DistCity* and *FRONT* were not statistically significant.

The coefficient on $\ln Acres$ was significant at the 5% level and consistent with the expectation of a declining marginal relationship between parcel size and per acre sales price, as found in most studies. The results indicate that as parcel size increases by one acre that per acre sales price declines by $4.80.

The coefficient on *DistCity* was not significant. However, the coefficient does agree with the expectation that sales price per acre declines as distance to city increases.

The coefficient on *DistHwy* was significant at the 5% level and consistent with expectations. It indicates that for every additional linear mile the per acre sales price of forestland declines by $90. The coefficient on *FRONT* was not statistically significant and the sign does not agree with the expectation that road frontage has a positive influence on price.

The coefficient on *TmProd* was significant at the 5% level. However, it does not conform to the expectation that higher timber productivity increases per acre sales price. The results indicate that for each additional cubic foot of annual growth per acre, the sales price per acre declines by $1.70. The coefficient on

OPEN was significant at the 10% level and conforms to the expectation that sales price declines as the percent of open space increases. The results indicate that per acre sales price declines by $7.50 for each 1% increase in open space for the parcel being sold.

The overall F-statistic was 7.45 and significant with a p-value of less than 0.0001, the R-square was 0.54, and the adjusted R-square was 0.47. Table 10 provides a summary of the overall regression results for McCurtain County.

Table 10: Regression Results for the Hedonic Forestland Pricing Model (McCurtain County)

Independent Variable	Coefficient	Standard Deviation	T-value	Prob > |t|	Percentage Effect[1]	Marginal Implicit Price[2]
ln*Acres*	-0.4306	0.1894	-2.27	0.0287	-0.78	-4.79
DistCity	-0.0213	0.0142	-1.51	0.1403	-2.11	-12.98
DistHwy	-0.1574	0.0582	-2.70	0.0103	-14.57	-89.57
TmProd	-0.0027	0.0014	-2.02	0.0505	-0.27	-1.67
FRONT	-0.2687	0.3140	-0.86	0.3976	-23.56	-144.85
OPEN	-0.0122	0.0065	-1.88	0.0678	-1.21	-7.46
Intercept	9.5579	0.8567	11.16	0.0001		
R-squared	0.5403					
Adjusted R-squared	0.4678					
F-statistic	7.4500					
Number of observations:	45					
Predicted price ($) per acre:	614.85	(Based on Mean Values)				
Mean parcel size (acres):	55.11					

[1] For B_1, $(e^{B1/size}-1)*100$ provides the percentage change in PRICE for a unit change in ACRES.
For B_i, where $i>1$, $(e^{Bi} - 1)*100$ provides the percentage change in PRICE for a unit change in any single X_i.

[2] The marginal implicit price is the estimated percentage change times the predicted price per acre, and is equivalent to the partial derivative.

Pushmataha County

The ordinary least squares procedure was used to estimate equation (6.1) for the Pushmataha County data. Of the six explanatory variables in the model, three were significant. These were *DistHwy*, *TmProd,* and *FRONT*. The variables $\ln Acres$, *DistCity*, and *OPEN* were not statistically significant.

The coefficient on $\ln Acres$ was not significant and does not agree with the expectation of a declining marginal relationship between parcel size and per acre sales price, as found in most studies.

The coefficient on *DistCity* was not significant. However, it does agree with the expectation that sales price per acre declines as distance to city increases.

The coefficient on *DistHwy* was significant at the 5% level and conforms to the expectation that sales price per acre declines as the distance to a major roadway increases. The results indicate that for every additional linear mile of distance between a forestland parcel and a major roadway that the per acre sales price of forestland declines by $52. The coefficient on *FRONT* was also statistically significant at the 5% level and agrees with the expectation that road frontage increases sales price. The results indicate that per acre sales price of forestland increases by $210 if the parcel fronts on (or near) a road of any type.

The coefficient on *TmProd* was significant at the 10% level and conforms to the expectation that higher timber productivity increases per acre sales price. The results indicate that for each additional cubic foot of annual growth per acre, the sales price per acre increases by $1.42. The variable *OPEN* was not significant. However the coefficient conforms to the expectation that per acre sales price declines as the amount of open space increases.

The overall F-statistic was 3.67 and significant with a p-value of 0.0078, the R-square was 0.43, and the adjusted R-square was 0.31. A summary of the overall regression results for Pushmataha County appears in Table 11.

Table 11: Regression Results for the Hedonic Forestland Pricing Model (Pushmataha County)

Independent Variable	Coefficient	Standard Deviation	T-value	Prob > |t|	Percentage Effect[1]	Marginal Implicit Price[2]
ln*Acres*	0.1158	0.1239	0.93	0.3576	0.15	0.48
DistCity	-0.0053	0.0110	-0.48	0.6338	-0.53	-1.71
DistHwy	-0.1756	0.0787	-2.23	0.0334	-16.11	-52.07
TmProd	0.0044	0.0025	1.78	0.0856	0.44	1.42
FRONT	0.5006	0.1967	2.54	0.0165	64.96	210.01
OPEN	-0.0009	0.0059	-0.14	0.8874	-0.08	-0.27
Intercept	5.1759	0.7143	7.25	0.0001		
R-squared	0.4319					
Adjusted R-squared	0.3144					
F-statistic	3.6700					
Number of observations:	36					
Predicted price ($) per acre:	323.28	(Based on Mean Values)				
Mean parcel size (acres):	78.42					

[1] For B_1, $(e^{B1/size}-1)*100$ provides the percentage change in PRICE for a unit change in ACRES.
For B_i, where i>1, $(e^{Bi} - 1)*100$ provides the percentage change in PRICE for a unit change in any single X_i.

[2] The marginal implicit price is the estimated percentage change times the predicted price per acre, and is equivalent to the partial derivative.

Misspecification Tests

Tests were conducted for heteroskedastic and normally distributed residuals, as well as collinearity and influential observations.

Tests for Heteroskedastic Residuals

The Ramsey (1969), Koenker (1981), and Lagrange-Multiplier tests were used to detect heteroskedastic residuals. The results of these tests for McCurtain County indicated the presence of heteroskedasticity. Due to the presence of heteroskedastic residuals the estimated generalized least squares procedure was used for the McCurtain County data. For Pushmataha County, the results did not indicate the presence of heteroskedasticity. A full explanation of these tests and their results appears in Appendix-1.

Tests for Normally Distributed Residuals

To evaluate whether the residuals are normally distributed, tests for skewness and kurtosis in the residuals, the Bera-Jarque (1981), and Shapiro-Wilk (1965) tests were conducted. The results of these tests did not indicate the presence on non-normal residuals. A full explanation of these tests and their results appears in Appendix-1.

Detection of Multicollinearity

To detect multicollinearity the partial correlation coefficients and auxiliary regressions were calculated. In addition to these methods the condition index was calculated using the COLLIN option in SAS. The results indicated the presence of multicollinearity among some of the variables in the full data set.

Due to multicollinearity the variables *TranCost* and *PopGro* were dropped from the model. *DistCity* was maintained since it captures both timber marketing and urbanization influences on the price of forestland. *TranCost* not only captures the cost of transporting timber to market, but it also has perfect collinearity with distance to mill, and the correlation coefficients between distance to city (*DistCity*) and distance to mill (*DistMill*) are 0.68 and 0.98 for McCurtain and Pushmataha Counties, respectively.

For reasons other than collinearity, the variable *DistNat* was also dropped from the model. The variable *DistNat* measures the distance in miles from the forestland parcel to the center of the nearest natural resource attraction. This particular type of measurement is most likely not capturing the influence that neighboring natural resource and recreational areas may have on the price of forestland parcels in the region. Furthermore, individually the variable has little explanatory power on the price of forestland. A potentially better alternative measure would be a measure of the percentage of land area within a certain radius of the forestland parcel classified as a natural resource attraction, such as the Rec_i variable in Nivens *et al.* (2002).

A full explanation of the multicollinearity detection procedures and their results appears in Appendix-1.

Detection of Influential Observations

To detect influential observations, first an informal analysis was conducted by examining each of the data series and their summary statistics. Observations having extremely large and small values were noted, particularly among the price series data. Since per unit prices were calculated from total parcel sale price and parcel size, each of these observations was inspected to determine whether there were any mistakes made in their calculation. No mistakes were noted.

Formal testing for influential data points was conducted with the INFLUENCE option in SAS, which calculates DFBETAS, DFFITS, and studentized residuals. The formal methods did indicate the presence of influential observations. However, no observations were dropped since there is no known information that would justify their removal. A full explanation of the methods for detecting influential observations and their results appear in Appendix-1.

Summary of Forestland Price Estimation

The estimation of forestland prices in McCurtain and Pushmataha Counties was conducted on a series of explanatory variables describing the size of the forestland parcel, the distance to the nearest city having a population of 2000 or more, the distance to the nearest major roadway, the expected timber productivity of the forestland parcel, a binary variable indicating whether the parcel fronts on a road of any type, and the proportion of the parcel having open land.

The results for McCurtain County indicate that four of the six coefficients are significant in explaining the price of forestland. These were the parcel size, distance to a major roadway, the expected timber productivity, and the proportion of open space in the parcel. Of the statistically significant variables with the expected algebraic sign, the variable having the greatest influence on price was

DistHwy. It was significant at the 1% level and explained 15% of the price variation.

The results for Pushmataha County indicate that three of the six coefficients are significant in explaining the price of forestland. These were the distance to a major roadway, the expected timber productivity, and the binary variable indicating whether the parcel fronts on (or near) a road of any type. Of the statistically significant variables with the expected algebraic sign, the variables having the greatest influence on price were *FRONT* and *DistHwy*. *FRONT* was significant at the 2% level and explained 65% of the price variation, and *DistHwy* was significant at the 3% level and explained 16% of the price variation.

Estimation of the Own-price, Cross-Price, and Morishima Elasticities

To arrive at the elasticities, the following five steps were followed:

1. Prediction of the per acre forestland values
2. Estimation of the per acre timber output values
3. Estimation of the per acre non-timber output values
4. Estimation of the timber and non-timber shares
5. Estimation of own and cross-price elasticities

Forestland, Timber, and Non-timber Values

The predicted per acre values of forestland, timber, and non-timber products were discounted at a 5-percent discount rate for 30 years. The average of the discounted per acre forestland values for parcels sold in McCurtain County was \$179, of which \$41 is attributed to the parcels' timber products and \$138 is attributed to the parcels' non-timber products. For forestland parcels sold in Pushmataha County the average of the discounted per acre forestland values was \$82, with \$11 being attributed to timber products and \$71 to non-timber products.

The average discounted timber and non-timber product values were then used toward calculating the price ratios, which were used in the share equations. The average annualized per acre values for timber and non-timber products and the price ratios are listed in Table 12.

Table 12: Annualized Timber and Non-Timber Values and Price Ratios

County	PTim	PNTim	PTim/PNTim	PNTim/PTim
McCurtain	40.72	137.79	0.2955	3.3838
Pushmataha	10.70	71.09	0.1505	6.6439

<u>Estimated Shares for McCurtain County Using Mean Values</u>

The estimated timber and non-timber share equations for McCurtain County are:

$$\hat{s}_T = \hat{\alpha}_T + \hat{\beta}_T \ln\left(\frac{p_T}{\hat{p}_{NT}}\right) + \hat{\varepsilon}_T = 0.4248 + 0.1447 \ln\left(\frac{p_T}{\hat{p}_{NT}}\right)$$

$$\hat{s}_{NT} = \hat{\alpha}_{NT} + \hat{\beta}_{NT} \ln\left(\frac{\hat{p}_{NT}}{p_T}\right) + \hat{\varepsilon}_{NT} = 0.5790 + 0.1413\left(\frac{\hat{p}_{NT}}{p_T}\right)$$

Using the per acre mean discounted values for timber and non-timber outputs, the equations indicate that the average timber and non-timber shares for parcels sold in McCurtain County were 25% and 75%, respectively.

Table 13: Timber and Non-timber Shares (McCurtain County)

Commodity	Intercept	Beta	ln(Price Ratio)	Share
Timber	0.4248	0.1447	-1.2190	0.2484
Non-Timber	0.5790	0.1413	1.2190	0.7512

Estimated Shares for Pushmataha County Using Mean Values

The estimated timber and non-timber share equations for Pushmataha County are:

$$\hat{s}_T = \hat{\alpha}_T + \hat{\beta}_T \ln\left(\frac{p_T}{\hat{p}_{NT}}\right) + \hat{\varepsilon}_T = 0.3477 + 0.1090 \ln\left(\frac{p_T}{\hat{p}_{NT}}\right)$$

$$\hat{s}_{NT} = \hat{\alpha}_{NT} + \hat{\beta}_{NT} \ln\left(\frac{\hat{p}_{NT}}{p_T}\right) + \hat{\varepsilon}_{NT} = 0.6523 + 0.1090\left(\frac{\hat{p}_{NT}}{p_T}\right)$$

Using the per acre mean values for timber and non-timber outputs, the equation indicates that the average timber and non-timber shares for parcels sold in Pushmataha County were 14% and 86%, respectively.

Table 14: Timber and Non-timber Shares (Pushmataha County)

Commodity	Intercept	Beta	ln(Price Ratio)	Share
Timber	0.3477	0.1090	-1.8937	0.1413
Non-Timber	0.6523	0.1090	1.8937	0.8587

Estimated Elasticities for McCurtain County Using Mean Values

Own-price and cross-price elasticities of demand and the Morishima elasticity of substitution for McCurtain County are given in Table 15. Calculation of the elasticities appears in Appendix-4.

Table 15: Own-price, Cross-price, and Morishima Elasticities

(McCurtain County)

Commodity	Own and Cross Price Elasticities		Morishima Elasticity of Substitution	
	Timber	Non-timber	Timber	Non-Timber
Timber	-0.4175	-0.5825		0.2299
Non-Timber	-0.1876	-0.8124	0.2299	

Own-price Elasticities

The own price elasticities of demand for timber and non-timber products from NIPF in McCurtain County are both inelastic, indicating that the percent change in quantity demanded is less than the percent change in price. The own price elasticity of demand for timber products indicates that a 1% increase (decrease) in the price of timber products will result in a 0.42% decrease (increase) in the quantity demanded. The own price elasticity of demand for non-timber outputs indicates that a 1% increase (decrease) in the price of non-timber products will result in a 0.81% decrease (increase) in the quantity demanded.

Cross-price Elasticities

The algebraic signs of cross-price elasticities indicate that commodities are substitutes when the sign is positive or complements when the sign is negative. The results indicate that timber and non-timber products are complementary. The cross-price elasticity of demand between timber and non-timber products for parcels sold in McCurtain County is -0.5825, indicating that a 1% increase (decrease) in the price of timber products will result in a 0.58% decrease (increase) in the quantity of non-timber products demanded. The cross-price elasticity of demand between non-timber and timber products for parcels sold in McCurtain County is -0.1876, indicating that a 1% increase (decrease) in the price of non-timber products will result in a 19% decrease (increase) in the quantity of timber products demanded.

Morishima Elasticity of Substitution

The Morishima elasticity of substitution captures the difference between cross-price and own price elasticities resulting from a change in the own-price.

$$M_{T,NT} = \eta_{T,NT} - \eta_{NT,NT}$$

$$M_{NT,T} = \eta_{NT,T} - \eta_{T,T}$$

The estimated Morishima elasticity substitution for McCurtain County is 0.2299, which indicates that timber and non-timber outputs are Morishima substitutes. This result tells us, for example, in 1999 a 1% increase in the price of obtaining timber outputs causes the demand for non-timber outputs relative to timber outputs to increase by 0.23%.

Estimated Elasticities for Pushmataha County Using Mean Values

Own-price and cross-price elasticities of demand and the Morishima elasticity of substitution for forestland parcels sold Pushmataha County are given in Table 16. Calculation of the elasticities appears in Appendix-4.

Table 16: Own-price, Cross-price, and Morishima Elasticities (Pushmataha County)

Commodity	Own and Cross Price Elasticities		Morishima Elasticity of Substitution	
	Timber	Non-timber	Timber	Non-Timber
Timber	-0.2286	-0.7714		0.1017
Non-Timber	-0.1269	-0.8731	0.1017	

Own-price elasticities:

The own price elasticities of demand for timber and non-timber products are both inelastic. The own price elasticity of demand for timber outputs indicates that a 1% increase (decrease) in the price of timber products will result in a 0.23% decrease (increase) in the quantity demanded. The own price elasticity of demand for non-timber products indicates that a 1% increase (decrease) in the price of non-timber outputs will result in a 0.87% decrease (increase) in the quantity demanded.

Cross-price elasticities:

The results indicate that timber and non-timber products are complementary. The cross-price elasticity of demand between timber and non-timber products indicates that a 1% increase (decrease) in the price of timber products will result in a 0.77% decrease (increase) in the quantity of non-timber products demanded. The cross-price elasticity of demand between non-timber and timber products indicates that a 1% increase (decrease) in the price of non-timber products will result in a 0.13% decrease (increase) in the quantity of timber outputs demanded.

Morishima Elasticity of Substitution:

The estimated Morishima elasticity of substitution for Pushmataha County is 0.1017, which indicates that timber and non-timber products are Morishima substitutes. This result tells us that a 1% increase in the price of the timber attributes of a forestland parcel will cause the demand for non-timber attributes relative to timber attributes to increase by 0.1%.

<u>Summary of Elasticity Estimates</u>

The estimated elasticities describe the demand for forestland to produce timber and non-timber outputs. In particular, they explain consumer behavior for predominately-forested parcels of land sold in McCurtain and Pushmataha Counties in Oklahoma during 1999.

A consumer of forestland will choose to purchase that forestland parcel that provides them their utility maximizing combination (shares) of timber and non-timber products, given their preferences for timber and non-timber products, the prices of timber and non-timber, and their income. In this decision process, the consumer will compare parcels of land, each having different abilities to produce timber and non-timber outputs. For a given forestland parcel, at the time of purchase, the quantities of timber and non-timber products afforded by the forestland are fixed. Once the land is purchased, the consumer has revealed his/her preferences.

Since all of the own-price elasticities were inelastic, we may conclude that consumer's of forestland were relatively insensitive to price changes. In other words, if either timber or non-timber attributes afforded by forestland increased by 1% we would expect less than 1% decrease in the quantity demanded for these attributes from the forestland. For example, in Pushmataha County the own-price elasticity for non-timber indicates that if the price of obtaining non-timber attributes increased by 1% the consumer would decrease the quantity demanded for that attribute by 0.87%.

All of the cross-price elasticities were negative, which indicates that consumers of forestland in both counties during 1999 viewed the timber and non-timber attributes of forestland to be complementary. From this we can conclude that consumers of forestland prefer to consume/produce both timber and non-timber products from their forestland.

For both counties, the Morishima elasticities are positive indicating that timber and non-timber outputs are Morishima substitutes. Generically, this says that an increase in the price of j causes the ratio i/j to rise (Chambers 1988). Applying this to the results for McCurtain County, a 1% rise in the price of timber attributes causes the demand for non-timber attributes relative to timber outputs to increase by 0.23%. Whereas, in Pushmataha County if the price of timber attributes increases by 1% the demand for non-timber attributes relative to timber outputs increases by 0.1%. In both counties $\hat{M}_{T,NT} = \hat{M}_{NT,T}$. Thus, from the results of the Morishima elasticities of substitution we can conclude that consumers of forestland in McCurtain County during 1999 had a greater willingness to substitute between timber and non-timber in their purchases of forestland.

Chapter

VII.

SUMMARY AND CONCLUSIONS

The purpose of this study was to investigate the substitutability between timber and non-timber outputs for two southeastern Oklahoma Counties, McCurtain and Pushmataha. For this, the Morishima elasticity of substitution (MES) was chosen, since it preserves the salient characteristics of the original concept introduced by Hicks (1932), as explained by Blackorby and Russell (1989). Furthermore, the MES is a sufficient statistic for assessing the changes in relative prices of timber and non-timber outputs on relative "shares" of timber and non-timber outputs.

The estimated Morishima elasticities, with regards to this research, indicate how the utility maximizing ratio of timber and non-timber outputs from forestland will change due to a change in the relative price ratio. Furthermore, the Morishima elasticity of substitution captures the difference between cross-price and own-price elasticities resulting from a change in the own price. For both counties the Morishima elasticities are greater than zero, which indicates that timber and non-timber outputs are Morishima substitutes. These results suggest that if the price of one increases the relative share of the other increases. The results indicated that consumers of McCurtain County forestland, relative to Pushmataha County forestland, had a greater willingness to substitute between timber and non-timber attributes in their purchases of forestland.

These results are the first quantitative estimates of the elasticity of substitution between timber and non-timber outputs for buyers of non-industrial private forestlands. The procedures also provide us an instrument and methodology that can be applied to other regions. Both the procedures of this study and the results thus provide an additional tool that can be used to help anticipate how price and policy changes influence the purchases of timberland parcels and the relative demands for timber and non-timber outputs.

Furthermore, the results of this research improve our ability to model the impact of changes in timber and non-timber outputs on regional economic development under changing price regimes. In this regard, the elasticity of substitution can be applied to models, such as the Oklahoma Regional Computable General Equilibrium (CGE) Model (Vargas and Schreiner 1999). Vargas and Schreiner (1999) note that the raw material (timber) market in forestry is monopsonistic and thus there is a smaller quantity demanded and lower price paid for timber outputs. The monopsonistic Oklahoma CGE was used to simulate a pro-competitive shock. The results suggested increases in gross state product of $36.9 and $88.6 million in the short and long run, respectively. In this model the returns to land in the forestry sector are associated with only timber outputs. However, we know that returns to land in forestry are not only associated with timber, but also associated with non-timber outputs. Thus modifying the production function of the forestry sector to allow substitution between timber and non-timber outputs would allow returns to land to be associated with both timber and non-timber outputs. As a result a change in the price of timber would then not be completely reflected in timber output, but also non-timber output. And thus, the regional income effect of a change in the price of timber would be less than that as reported by Vargas and Schreiner.

The own-price and cross-price elasticities of demand are utilized in the calculation of the MES. The own-price elasticities of demand for timber and non-timber outputs in McCurtain County, were -0.4175 and -0.8124, respectively. For Pushmataha counties the own price elasticities for timber and non-timber outputs were -0.2286 and -0.8731, respectively. These results indicate that both timber and non-timber outputs are inelastic. This implies that consumers of forestlands in these two counties during 1999 were relatively insensitive to price changes in their purchase decisions.

The cross-price elasticities between timber and non-timber outputs and between non-timber and timber outputs were -0.5825 and -0.1876, respectively for McCurtain County. The cross price elasticities between timber and non-timber outputs and between non-timber and timber outputs were -0.7714 and -0.1269, respectively for Pushmataha County. These results indicate that timber and non-timber outputs are complementary. Thus, we can conclude that consumers of forestland in both counties during 1999 preferred forestland that had the potential to produce both timber and non-timber outputs.

We may also note that the absolute values of the own-price elasticities for timber are smaller than those for non-timber; and that the absolute values of the cross-price elasticities between timber and non-timber outputs are greater than those between non-timber and timber outputs. These results, may suggest that consumers of forestland are more sensitive to changes in the price of the timber outputs than they are for those of non-timber outputs. As a result, public policies that influence timber prices relative to non-timber values may be more effective in influencing the purchase decisions of consumers of forestland and thus the timber and non-timber uses and outputs.

Share equations were used to estimate these elasticities. Using mean values, the estimated share of timber and non-timber output were 25% and 75%, respectively in McCurtain County, and 14% and 86%, respectively, in Pushmataha County. To arrive at the share equations, forestland, timber, and non-timber values per acre were also estimated. These values were then discounted at 5-percent for 30-years to obtain annualized values. Using mean values, the estimated discounted value of forestland in McCurtain County was $179, with $41 being timber value and $138 being non-timber value. For Pushmataha County, using mean values, the estimated discounted per acre forestland value was $82, with $11 being timber value and $71 being non-timber value. These results suggest that non-timber values comprise a dominate share of the total value of the forestland.

No other known studies have estimated the elasticity of substitution between timber and non-timber outputs. Thus, a direct comparison to other studies is not possible. The study in closest comparison to this research might be the study by Karen Lee (1997) on the estimation of forest amenity values and harvesting decisions by non-industrial private forestland (NIPF) owners. Her model predicting the probability of harvest indicates that NIPF owners generally harvest at financial maturity and those variables representing amenity values were generally insignificant in harvest decisions. The amenity value variables included a 'scenic beauty estimator' index, and various indicators of wildlife habitat. She does note that NIPF owners are not irrational if they hold timber beyond its financial maturity. She notes that there is an opportunity cost of doing so and that this opportunity cost is the value that the landowner places on non-timber outputs. Another study by which some comparison can be drawn is that of Newman and Wear (1993) which compared the production economics of industrial and non-industrial forestland owners. In their study they calculated own-price elasticities of demand for sawtimber and pulpwood. Their study indicated that estimated own-price elasticities were highly inelastic. These results are similar to the results on own-price elasticities of demand for timber outputs found in this study. Newman and Wear (1993) also suggest that NIPF receive substantial non-market benefits from their forestlands, which is also similar to the findings of this study.

The major conclusions and implication of this study can be drawn from the estimated elasticities. Consumers of forestland in southeastern Oklahoma are relatively insensitive to price changes, prefer forestland parcels that have the potential to produce both timber and non-timber outputs, and an increase in the price of obtaining one output (timber or non-timber) will increase their demand for obtaining land with the other attribute. Furthermore, the elasticities indicate that consumers of McCurtain County forestland are more price sensitive and have a greater willingness to substitute between timber and non-timber outputs, relative to consumers of Pushmataha County forestland. Lastly, the study shows that non-timber outputs comprise a substantial amount of the value of forestland sold/purchased in southeastern Okalahoma; 86% in Pushmataha County and 75% in McCurtain County.

There are a multitude of policy and program issues that these results may be applicable to. These may include issues related to the demand for forestland, such land use and regional economic development. For example, private forestlands are becoming more important for our timber supply as timber production on large areas of public lands are being reduced in response to programs to preserve/increase the social and environmental uses of public forests. Such programs reduce the supply of timber, which, *ceteris paribus,* leads to an increase in timber stumpage prices. The results of this study could then be applied to help determine how such policies influence the demand for non-industrial private forestlands and thus the supply of timber outputs from NIPF.

Although this study covers just one period of time, one might expect that non-timber uses of forestland in southeastern Oklahoma have great potential for the development of the region. Since forestry is a major activity in the region, changes in market structure and public policies that influence the region, will most likely influence the price of timber, and thus the relative outputs of timber and non-timber outputs. These changes will in turn influence the demand for and use of forestlands and the allocation of resources and income, and thus the regional economy and its growth and development. Utilizing the elasticities from this research to improve the current Oklahoma general equilibrium model (Vargas and Schreiner 1999), may help to improve our analysis of how changes in the forestry sector influence the overall level of income and employment in the region.

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APPENDICES

The appendices are organized by the five procedures:

1. Estimation of the annualized per acre forestland values
2. Estimation of the annualized per acre values of timber outputs
3. Estimation of the annualized per acre values of non-timber outputs
4. Estimation of the share equations
5. Estimation of the own-price, cross-price, and Morishima elasticities

The appendices are as follows:

- APPENDIX-1: HEDONIC ESTIMATION OF FORESTLAND VALUES
- APPENDIX-2: ANNUALIZED VALUES OF TIMBER AND NON-TIMBER OUTPUTS
- APPENDIX-3: TIMBER AND NON-TIMBER SHARES
- APPENDIX-4: OWN-PRICE, CROSS-PRICE, AND MORISHIMA ELASTICITIES

APPENDIX-1

HEDONIC ESTIMATION OF FORESTLAND VALUES

To obtain the annualized forestland values, forestland values were first estimated with the hedonic forestland pricing model, equation (6.1). Two sets of data were used for this estimation: the forestland sales transactions data set and the spatial characteristics data set. The resulting estimated forestland values for each observation were then discounted at 5-percent over 30-years, to obtain the annualized forestland values.

Forestland Sales Transactions Data Set

The organization of the data is described in Table 17 and the forestland sales transactions data appear in Table 18 and Table 19 for McCurtain and Pushmataha Counties, respectively.

Table 17: Description of Forestland Sales Transactions Data Set

Column #	Column Title	Description
1	TRACTID	A parcel identification number
2	County	The county in which the parcel resides
3	QUARTER	The quarter section that the parcel resides
4	SECTION	The section that the parcel resides
5	TWP	The township that the parcel resides
6	NS	Indicates whether the parcel is in the northern (N) or southern (S) township
7	RNG	The range that the parcel resides
8	EW	Indicates whether the parcel is in the eastern (E) or western (W) range
9	PRICE	The price per acre for which the parcel was sold
10	ACRES	The size (in acres) of the parcel
11	OPEN	The percentage of non-forested land area in the parcel
12	TmProd	The expected timber productivity of forest soil, in cubic feet per acre per year

Table 18: Forestland Sales Transactions Data Set (McCurtain County)

TRACTID	County	QUARTER	SECTION	TWP	NS	RNG	EW	PRICE	ACRES	OPEN	TmProd
4507052124	McCurtain	SE/4	7	5	S	21	E	500.00	40.00	0.00	102.63
4512052114	McCurtain	SE/4	12	5	S	21	E	65.58	91.49	0.00	96.94
4531052125	McCurtain	SE/4	31	5	S	21	E	200.00	20.00	0.00	102.00
4531052122	McCurtain	SE/4	31	5	S	21	E	200.00	20.00	0.00	102.00
4534052143	McCurtain	SE/4	34	5	S	21	E	375.00	40.00	0.00	117.00
4520062136	McCurtain	SE/4	20	6	S	21	E	909.09	55.00	0.00	94.50
4522062111	McCurtain	SE/4	22	6	S	21	E	601.18	39.09	0.00	102.64
4521032221	McCurtain	SE/4	21	3	S	22	E	250.00	40.00	0.00	145.44
4528052232	McCurtain	SE/4	28	5	S	22	E	731.71	41.00	0.00	95.60
4512062222	McCurtain	SE/4	12	6	S	22	E	300.00	40.00	0.00	71.38
4501072215	McCurtain	SE/4	1	7	S	22	E	1,000.00	40.00	0.00	255.00
4501072241	McCurtain	SE/4	1	7	S	22	E	1,450.00	160.00	0.00	119.00
4524022321	McCurtain	SE/4	24	2	S	23	E	1,000.00	30.00	0.00	178.50
4501062312	McCurtain	SE/4	1	6	S	23	E	2,012.50	40.00	0.00	91.06
4509062333	McCurtain	SE/4	9	6	S	23	E	100.00	40.00	50.00	142.00
4525062311	McCurtain	SE/4	25	6	S	23	E	4,602.99	17.38	0.00	102.00
4525062312	McCurtain	SE/4	25	6	S	23	E	1,021.43	59.72	0.00	94.00
4525062313	McCurtain	SE/4	25	6	S	23	E	403.07	101.72	0.00	93.42
4519022412	McCurtain	SE/4	19	2	S	24	E	1,397.36	19.68	0.00	162.53
4526052427	McCurtain	SE/4	26	5	S	24	E	400.00	5.00	0.00	102.00
4501062416	McCurtain	SE/4	1	6	S	24	E	9,329.65	14.47	0.00	83.86
4534062421	McCurtain	SE/4	34	6	S	24	E	297.98	49.50	50.51	67.00
4507072432	McCurtain	SE/4	7	7	S	24	E	2,843.75	80.00	0.00	142.00
4508072423	McCurtain	SE/4	8	7	S	24	E	887.31	112.70	0.00	102.00

Table 18: Forestland Sales Transactions Data Set (McCurtain County)

TRACTID	County	QUARTER	SECTION	TWP	NS	RNG	EW	PRICE	ACRES	OPEN	TmProd
4518072413	McCurtain	SE/4	18	7	S	24	E	701.37	10.93	32.02	142.00
4509012512	McCurtain	SE/4	9	1	S	25	E	594.80	107.60	53.07	74.62
4505032512	McCurtain	SE/4	5	3	S	25	E	750.00	40.00	0.00	102.00
4522032522	McCurtain	SE/4	22	3	S	25	E	600.00	50.00	0.00	67.00
4522032531	McCurtain	SE/4	22	3	S	25	E	98.36	76.25	0.00	67.00
4536032532	McCurtain	SE/4	36	3	S	25	E	1,000.00	10.00	0.00	67.00
4521062521	McCurtain	SE/4	21	6	S	25	E	6,203.47	16.12	0.00	88.71
4513072532	McCurtain	SE/4	13	7	S	25	E	250.00	40.00	0.00	102.00
4521072533	McCurtain	SE/4	21	7	S	25	E	414.78	66.30	0.00	255.00
4517082535	McCurtain	SE/4	17	8	S	25	E	300.00	20.00	0.00	117.00
4517082541	McCurtain	SE/4	17	8	S	25	E	2,237.50	20.00	0.00	117.00
4522082521	McCurtain	SE/4	22	8	S	25	E	125.93	134.00	0.00	102.00
4515092511	McCurtain	SE/4	15	9	S	25	E	400.00	20.00	0.00	102.00
4510022632	McCurtain	SE/4	10	2	S	26	E	1,467.40	87.57	0.00	102.00
4505062636	McCurtain	SE/4	5	6	S	26	E	516.67	30.00	0.00	90.33
4526062631	McCurtain	SE/4	26	6	S	26	E	370.37	94.50	62.96	136.29
4509082432	McCurtain	SE/4	22	7	S	26	E	140.63	160.00	46.88	102.00
4509022721	McCurtain	SE/4	9	2	S	27	E	500.00	80.00	0.00	102.00
4509022712	McCurtain	SE/4	9	2	S	27	E	266.67	120.00	0.00	102.00
4531092723	McCurtain	SE/4	31	9	S	27	E	700.00	20.00	0.00	102.00
4521102711	McCurtain	SE/4	21	10	S	27	E	200.00	80.00	0.00	255.00
Average								1,082.59	55.11	6.57	114.65
Minimum								65.58	5.00	0.00	67.00
Maximum								9,329.65	160.00	62.96	255.00
Number of observations								45.00	45.00	45.00	45.00

Table 19: Forestland Sales Transactions Data Set (Pushmataha County)

TRACTID	County	QUARTER	SECTION	TWP	NS	RNG	EW	PRICE	ACRES	OPEN	TmProd
6436011521	Pushmataha	SE/4	36	1	S	15	E	375.00	40.00	0.00	67.00
6407021591	Pushmataha	SE/4	7	2	S	15	E	555.56	90.00	0.00	61.87
6428031571	Pushmataha	SE/4	28	3	S	15	E	282.05	39.00	0.00	88.05
6433041512	Pushmataha	SE/4	33	4	S	15	E	400.00	150.00	30.00	54.40
6413011651	Pushmataha	SE/4	13	1	S	16	E	400.00	80.00	0.00	67.00
6415011621	Pushmataha	SE/4	15	1	S	16	E	333.33	150.00	0.00	182.31
6428021661	Pushmataha	SE/4	28	2	S	16	E	250.00	30.00	33.33	35.65
6429021671	Pushmataha	SE/4	29	2	S	16	E	250.00	40.00	0.00	61.23
6429021641	Pushmataha	SE/4	29	2	S	16	E	1,100.00	80.00	0.00	75.16
6401041618	Pushmataha	SE/4	1	4	S	16	E	1,153.85	13.00	69.23	255.00
6417041641	Pushmataha	SE/4	17	4	S	16	E	600.00	80.00	62.50	34.00
6422041631	Pushmataha	SE/4	22	4	S	16	E	558.44	77.00	46.75	50.59
6401011721	Pushmataha	SE/4	1	1	S	17	E	200.00	150.00	0.00	55.34
6423011771	Pushmataha	NE/4	23	1	N	17	E	177.78	45.00	0.00	67.00
6423011701	Pushmataha	NE/4	23	1	N	17	E	155.56	90.00	0.00	67.00
6431011721	Pushmataha	NE/4	31	1	N	17	E	149.68	157.00	0.00	67.00
6425021771	Pushmataha	NE/4	25	2	N	17	E	175.62	68.33	0.00	67.00
6425021781	Pushmataha	NE/4	25	2	N	17	E	85.69	11.67	0.00	67.00
6410031711	Pushmataha	SE/4	10	3	S	17	E	300.00	260.00	0.00	40.97
6420031751	Pushmataha	SE/4	20	3	S	17	E	325.00	40.00	75.00	84.70
6421041791	Pushmataha	SE/4	21	4	S	17	E	500.00	80.00	0.00	79.90
6410011821	Pushmataha	NE/4	10	1	N	18	E	400.00	80.00	0.00	61.61
6410011822	Pushmataha	NE/4	10	1	N	18	E	550.00	80.00	0.00	56.80
6420011891	Pushmataha	NE/4	20	1	N	18	E	416.67	12.00	0.00	114.00
6426011861	Pushmataha	SE/4	26	1	S	18	E	325.00	40.00	0.00	50.50

Table 19: Forestland Sales Transactions Data Set (Pushmataha County)

TRACTID	County	QUARTER	SECTION	TWP	NS	RNG	EW	PRICE	ACRES	OPEN	TmProd
6429011831	Pushmataha	NE/4	29	1	N	18	E	918.75	160.00	0.00	67.00
6435041804	Pushmataha	SE/4	35	4	S	18	E	228.13	160.00	26.25	91.63
6403021921	Pushmataha	NE/4	3	2	N	19	E	368.75	80.00	0.00	67.00
6412021971	Pushmataha	NE/4	12	2	N	19	E	200.00	40.00	0.00	67.00
6412041921	Pushmataha	SE/4	12	4	S	19	E	150.00	120.00	0.00	47.75
6408022011	Pushmataha	NE/4	8	2	N	20	E	417.86	140.00	0.00	67.00
6414022014	Pushmataha	NE/4	14	2	N	20	E	1,250.00	40.00	0.00	67.00
6416022081	Pushmataha	NE/4	16	2	N	20	E	100.00	40.00	0.00	67.00
6436022061	Pushmataha	NE/4	36	2	N	20	E	300.00	20.00	0.00	67.00
6416022013	Pushmataha	NE/4	16	2	N	22	E	125.00	20.00	0.00	34.00
6419022241	Pushmataha	NE/4	19	2	N	22	E	325.00	20.00	0.00	72.60
Average								400.07	78.42	9.53	72.95
Minimum								85.69	11.67	0.00	34.00
Maximum								1,250.00	260.00	75.00	255.00
Number of observations								36	36	36	36

Spatial Characteristics Data Set

Description of the spatial characteristics data is provided in Table 20.

Table 20: Description of Spatial Characteristics Data

Variable	Description
FRONT	Dummy variable whether parcel fronts on a road
DistHwy	Distance to major roadway or highway (linear measure in miles)
DistCity	Distance in road miles to the nearest city with a population greater than 2000
PopGro	Population growth of the nearest city with population greater than 2,000 (1990-2000)
DistMill	Distance in road miles to the nearest community with two or more wood-processing mills
DistNat	Distance in road miles to the nearest natural resource attraction

Roadways within Close Proximity of the Forestland Parcels

There are two variables in the hedonic price model involving roads. One variable determines whether any type of road fronts (near) the forestland parcels. To determine this, a ¼ mile buffer was placed around each forestland parcel. If the buffer intersected a road, then a number one was assigned to indicate the presence of a road (1 = yes, 0 = no). The other variable involving roads is a linear measure in miles to the nearest major roadway (state or federal highway). Table 21 lists the major roadways near the forestland parcels and their locations.

Table 21: Major Roadways near the Forestland Parcels

Road/Highway	General Location
State Highway 2	N/S Antlers to Clayton in Pushmataha County
State Highway 3	E/W from Ada through Pushmataha and McCurtain Counties to Foreman, Arkansas
State Highway 4	E/W from US 259 at Smithville in northeast McCurtain County to US 59/71 at Cove, Arkansas
State Highway 43	E/W Northwest corner of Pushmataha County
State Highway 87	E/W in southeast McCurtain County from US 259 to Foreman, Arkansas
State Highway 93	N/S from Hugo to Rattan
US 70	E/W across southern Oklahoma through McCurtain County toward DeQueen, Arkansas
US 259	N/S through central McCurtain County toward De Kalb, Texas
US 271	N/S from Poteau through Pushmataha County via Albion and Antlers and toward Paris, Texas
Indian Nation Turnpike	N/S from Henryetta through western Pushmataha County toward Hugo.

Tables 22 and 23 provide data on whether the forestland parcel fronts a road $(FRONT)$, the distance to the nearest highway $(DistHwy)$, and the name of the nearest highway for McCurtain and Pushmataha Counties, respectively.

Table 22: Roadway Data for the Hedonic Forestland Pricing Models (McCurtain County)

TRACTID	County	QTR	SEC	TWP	NS	RNG	EW	PRICE	FRONT	DistHwy	Name of Highway
4507052124	McCurtain	SE/4	7	5	S	21	E	500.00	1	3.46	State Highway 3
4512052114	McCurtain	SE/4	12	5	S	21	E	65.58	0	2.12	State Highway 3
4531052125	McCurtain	SE/4	31	5	S	21	E	200.00	1	3.96	U.S. Highway 70
4531052122	McCurtain	SE/4	31	5	S	21	E	200.00	1	3.96	U.S. Highway 70
4534052143	McCurtain	SE/4	34	5	S	21	E	375.00	1	4.76	U.S. Highway 70
4520062136	McCurtain	SE/4	20	6	S	21	E	909.09	1	0.35	U.S. Highway 70
4522062111	McCurtain	SE/4	22	6	S	21	E	601.18	1	0.81	U.S. Highway 70
4521032221	McCurtain	SE/4	21	3	S	22	E	250.00	1	8.13	State Highway 3
4528052232	McCurtain	SE/4	28	5	S	22	E	731.71	1	2.86	State Highway 3
4512062222	McCurtain	SE/4	12	6	S	22	E	300.00	1	4.58	State Highway 3
4501072215	McCurtain	SE/4	1	7	S	22	E	1,000.00	0	0.81	U.S. Highway 70
4501072241	McCurtain	SE/4	1	7	S	22	E	1,450.00	0	0.81	U.S. Highway 70
4524022321	McCurtain	SE/4	24	2	S	23	E	1,000.00	1	1.61	U. S. Highway 259
4501062312	McCurtain	SE/4	1	6	S	23	E	2,012.50	1	1.02	State Highway 3
4509062333	McCurtain	SE/4	9	6	S	23	E	100.00	1	3.19	State Highway 3
4525062311	McCurtain	SE/4	25	6	S	23	E	4,602.99	1	4.37	State Highway 3
4525062312	McCurtain	SE/4	25	6	S	23	E	1,021.43	1	4.37	State Highway 3
4525062313	McCurtain	SE/4	25	6	S	23	E	403.07	1	4.37	State Highway 3
4519022412	McCurtain	SE/4	19	2	S	24	E	1,397.36	1	0.66	U. S. Highway 259
4526052427	McCurtain	SE/4	26	5	S	24	E	400.00	1	1.10	U. S. Highway 259
4501062416	McCurtain	SE/4	1	6	S	24	E	9,329.65	1	0.20	U. S. Highway 259
4534062421	McCurtain	SE/4	34	6	S	24	E	297.98	1	1.81	U.S. Highway 70
4507072432	McCurtain	SE/4	7	7	S	24	E	2,843.75	0	2.33	U.S. Highway 70
4508072423	McCurtain	SE/4	8	7	S	24	E	887.31	0	2.95	U.S. Highway 70

Table 22: Roadway Data for the Hedonic Forestland Pricing Models (McCurtain County)

TRACTID	County	QTR	SEC	TWP	NS	RNG	EW	PRICE	FRONT	DistHwy	Name of Highway
4518072413	McCurtain	SE/4	18	7	S	24	E	701.37	1	1.56	U.S. Highway 70
4509012512	McCurtain	SE/4	9	1	S	25	E	594.80	0	1.28	U. S. Highway 259
4505032512	McCurtain	SE/4	5	3	S	25	E	750.00	1	3.72	U. S. Highway 259
4522032522	McCurtain	SE/4	22	3	S	25	E	600.00	0	6.88	U. S. Highway 259
4522032531	McCurtain	SE/4	22	3	S	25	E	98.36	0	6.88	U. S. Highway 259
4536032532	McCurtain	SE/4	36	3	S	25	E	1,000.00	0	8.40	U. S. Highway 259
4521062521	McCurtain	SE/4	21	6	S	25	E	6,203.47	1	1.68	U.S. Highway 70
4513072532	McCurtain	SE/4	13	7	S	25	E	250.00	0	6.70	U.S. Highway 70
4521072533	McCurtain	SE/4	21	7	S	25	E	414.78	1	4.08	U.S. Highway 70
4517082535	McCurtain	SE/4	17	8	S	25	E	300.00	0	5.06	U.S. Highway 70
4517082541	McCurtain	SE/4	17	8	S	25	E	2,237.50	0	5.06	U.S. Highway 70
4522082521	McCurtain	SE/4	22	8	S	25	E	125.93	1	5.75	U. S. Highway 259
4515092511	McCurtain	SE/4	15	9	S	25	E	400.00	1	2.80	U. S. Highway 259
4510022632	McCurtain	SE/4	10	2	S	26	E	1,467.40	1	6.34	State Highway 4
4505062636	McCurtain	SE/4	5	6	S	26	E	516.67	1	1.07	U.S. Highway 70
4526062631	McCurtain	SE/4	26	6	S	26	E	370.37	1	3.59	U.S. Highway 70
4509082432	McCurtain	SE/4	22	7	S	26	E	140.63	1	5.71	U.S. Highway 70
4509022721	McCurtain	SE/4	9	2	S	27	E	500.00	1	2.76	State Highway 4
4509022712	McCurtain	SE/4	9	2	S	27	E	266.67	1	2.76	State Highway 4
4531092723	McCurtain	SE/4	31	9	S	27	E	700.00	1	7.62	State Highway 87
4521102711	McCurtain	SE/4	21	10	S	27	E	200.00	1	5.49	State Highway 87
Average								1,082.59	0.73	3.55	
Minimum								65.58	0.00	0.20	
Maximum								9,329.65	1.00	8.40	
Number of observations								45.00	45.00	45.00	

Table 23: Roadway Data for the Hedonic Forestland Pricing Models (Pushmataha County)

TRACTID	County	QTR	SEC	TWP	NS	RNG	EW	PRICE	FRONT	DistHwy	Name of Highway
6436011521	Pushmataha	SE/4	36	1	S	15	E	375.00	1	2.80	Indian Nation Turnpike
6407021591	Pushmataha	SE/4	7	2	S	15	E	555.56	1	2.43	Indian Nation Turnpike
6428031571	Pushmataha	SE/4	28	3	S	15	E	282.05	1	1.55	State Highway 3
6433041512	Pushmataha	SE/4	33	4	S	15	E	400.00	1	4.96	State Highway 3
6413011651	Pushmataha	SE/4	13	1	S	16	E	400.00	0	0.72	State Highway 2
6415011621	Pushmataha	SE/4	15	1	S	16	E	333.33	1	2.70	State Highway 2
6428021661	Pushmataha	SE/4	28	2	S	16	E	250.00	1	0.18	State Highway 2
6429021671	Pushmataha	SE/4	29	2	S	16	E	250.00	0	0.42	State Highway 2
6429021641	Pushmataha	SE/4	29	2	S	16	E	1,100.00	0	0.42	State Highway 2
6401041618	Pushmataha	SE/4	1	4	S	16	E	1,153.85	1	0.82	State Highway 3
6417041641	Pushmataha	SE/4	17	4	S	16	E	600.00	1	1.04	Indian Nation Turnpike
6422041631	Pushmataha	SE/4	22	4	S	16	E	558.44	1	0.04	Indian Nation Turnpike
6401011721	Pushmataha	SE/4	1	1	S	17	E	200.00	0	2.67	State Highway 2
6423011771	Pushmataha	NE/4	23	1	N	17	E	177.78	0	0.67	State Highway 2
6423011701	Pushmataha	NE/4	23	1	N	17	E	155.56	0	0.67	State Highway 2
6431011721	Pushmataha	NE/4	31	1	N	17	E	149.68	0	1.99	State Highway 2
6425021771	Pushmataha	NE/4	25	2	N	17	E	175.62	0	4.50	State Highway 2
6425021781	Pushmataha	NE/4	25	2	N	17	E	85.69	0	4.50	State Highway 43
6410031711	Pushmataha	SE/4	10	3	S	17	E	300.00	0	1.21	U.S. Highway 271
6420031751	Pushmataha	SE/4	20	3	S	17	E	325.00	1	1.85	U.S. Highway 271

Table 23: Roadway Data for the Hedonic Forestland Pricing Models (Pushmataha County)

TRACTID	County	QTR	SEC	TWP	NS	RNG	EW	PRICE	FRONT	DistHwy	Name of Highway
6421041791	Pushmataha	SE/4	21	4	S	17	E	500.00	0	0.89	State Highway 3
6410011821	Pushmataha	NE/4	10	1	N	18	E	400.00	1	0.55	State Highway 2
6410011822	Pushmataha	NE/4	10	1	N	18	E	550.00	1	0.55	State Highway 2
6420011891	Pushmataha	NE/4	20	1	N	18	E	416.67	0	0.58	State Highway 2
6426011861	Pushmataha	SE/4	26	1	S	18	E	325.00	1	0.73	U.S. Highway 271
6429011831	Pushmataha	NE/4	29	1	N	18	E	918.75	1	1.53	State Highway 2
6435041804	Pushmataha	SE/4	35	4	S	18	E	228.13	0	1.92	State Highway 93
6403021921	Pushmataha	NE/4	3	2	N	19	E	368.75	0	1.41	State Highway 2
6412021971	Pushmataha	NE/4	12	2	N	19	E	200.00	1	2.83	U.S. Highway 271
6412041921	Pushmataha	SE/4	12	4	S	19	E	150.00	0	2.16	State Highway 3
6408022011	Pushmataha	NE/4	8	2	N	20	E	417.86	1	2.55	U.S. Highway 271
6414022014	Pushmataha	NE/4	14	2	N	20	E	1,250.00	1	0.80	U.S. Highway 271
6416022081	Pushmataha	NE/4	16	2	N	20	E	100.00	0	1.22	U.S. Highway 271
6436022061	Pushmataha	NE/4	36	2	N	20	E	300.00	0	2.45	U.S. Highway 271
6416022013	Pushmataha	NE/4	16	2	N	22	E	125.00	1	3.74	U.S. Highway 271
6419022241	Pushmataha	NE/4	19	2	N	22	E	325.00	0	3.30	U.S. Highway 271
Average								400.07	0.50	1.76	
Minimum								85.69	0.00	0.04	
Maximum								1,250.00	1.00	4.96	
Number of observations								36	36	36	

Cities within Close Proximity of the Forestland Parcels

The spatial characteristics data set provided data on the cities closest to the forestland parcels having a population greater than 2000, the roadway mile distance to the city from the forestland parcel, and the population growth rate of that city between the 1990 and 2000 Census. To obtain this information the network analyst extension in ArcView was utilized along with a roadway network and population/city layer for Oklahoma, Arkansas and Texas, linked to the forestland parcel observations. For the 45 observations in McCurtain County: 21 observations are in closest proximity to Idabel, Oklahoma; 15 are closest to Broken Bow, Oklahoma; 7 are closest to Mena, Arkansas; and 2 are closest to New Boston, Texas. For the 36 observations in Pushmataha County: 26 observations are closest to Antlers, Oklahoma; and 10 are closest to Wilburton, Oklahoma. Table-24 lists the cities, their locations, and population information. Tables 25 and 26 list the city data associated with each forestland parcel in McCurtain and Pushmataha Counties, respectively.

Table 24: Cities within Close Proximity of the Forestland Parcels

Town/City	County	State	Population[1] (1990)	Population[2] (2000)	Population Growth
Antlers	Pushmataha	OK	2,524	2,552	1.11
Wilburton	Latimer	OK	3,092	2,972	-3.88
Broken Bow	McCurtain	OK	3,961	4,230	6.79
New Boston	Bowie	TX	5,057	4,808	-4.92
Mena	Polk	AR	5,475	5,637	2.96
Idabel	McCurtain	OK	6,957	6,952	-0.07

[1] U.S. Census 1990 http://homer.ssd.census.gov/cdrom/lookup

[2] U.S. Census 2000 http://quickfacts.census.gov/cgi-bin/state_QuickLinks?40000

Table 25: City Data for the Hedonic Forestland Pricing Model (McCurtain County)

TRACTID	County	QTR	SEC	TWP	NS	RNG	EW	PRICE	City	DistCity	PopGro
4507052124	McCurtain	SE/4	7	5	S	21	E	500.00	Idabel	28.69	-0.07
4512052114	McCurtain	SE/4	12	5	S	21	E	65.58	Broken Bow	22.87	6.79
4531052125	McCurtain	SE/4	31	5	S	21	E	200.00	Idabel	24.39	-0.07
4531052122	McCurtain	SE/4	31	5	S	21	E	200.00	Idabel	24.39	-0.07
4534052143	McCurtain	SE/4	34	5	S	21	E	375.00	Idabel	22.37	-0.07
4520062136	McCurtain	SE/4	20	6	S	21	E	909.09	Idabel	20.30	-0.07
4522062111	McCurtain	SE/4	22	6	S	21	E	601.18	Idabel	18.33	-0.07
4521032221	McCurtain	SE/4	21	3	S	22	E	250.00	Broken Bow	29.85	6.79
4528052232	McCurtain	SE/4	28	5	S	22	E	731.71	Broken Bow	18.52	6.79
4512062222	McCurtain	SE/4	12	6	S	22	E	300.00	Broken Bow	16.33	6.79
4501072215	McCurtain	SE/4	1	7	S	22	E	1,000.00	Idabel	11.92	-0.07
4501072241	McCurtain	SE/4	1	7	S	22	E	1,450.00	Idabel	11.92	-0.07
4524022321	McCurtain	SE/4	24	2	S	23	E	1,000.00	Broken Bow	24.95	6.79
4501062312	McCurtain	SE/4	1	6	S	23	E	2,012.50	Broken Bow	7.60	6.79
4509062333	McCurtain	SE/4	9	6	S	23	E	100.00	Broken Bow	10.40	6.79
4525062311	McCurtain	SE/4	25	6	S	23	E	4,602.99	Idabel	8.84	-0.07
4525062312	McCurtain	SE/4	25	6	S	23	E	1,021.43	Idabel	8.84	-0.07
4525062313	McCurtain	SE/4	25	6	S	23	E	403.07	Idabel	8.84	-0.07
4519022412	McCurtain	SE/4	19	2	S	24	E	1,397.36	Broken Bow	25.09	6.79
4526052427	McCurtain	SE/4	26	5	S	24	E	400.00	Broken Bow	4.73	6.79
4501062416	McCurtain	SE/4	1	6	S	24	E	9,329.65	Broken Bow	1.93	6.79
4534062421	McCurtain	SE/4	34	6	S	24	E	297.98	Broken Bow	7.98	6.79
4507072432	McCurtain	SE/4	7	7	S	24	E	2,843.75	Idabel	4.04	-0.07
4508072423	McCurtain	SE/4	8	7	S	24	E	887.31	Idabel	5.96	-0.07

Table 25: City Data for the Hedonic Forestland Pricing Model (McCurtain County)

TRACTID	County	QTR	SEC	TWP	NS	RNG	EW	PRICE	City	DistCity	PopGro
4518072413	McCurtain	SE/4	18	7	S	24	E	701.37	Idabel	3.00	-0.07
4509012512	McCurtain	SE/4	9	1	S	25	E	594.80	Mena	29.87	2.96
4505032512	McCurtain	SE/4	5	3	S	25	E	750.00	Broken Bow	26.21	6.79
4522032522	McCurtain	SE/4	22	3	S	25	E	600.00	Mena	40.67	2.96
4522032531	McCurtain	SE/4	22	3	S	25	E	98.36	Mena	40.67	2.96
4536032532	McCurtain	SE/4	36	3	S	25	E	1,000.00	Mena	44.47	2.96
4521062521	McCurtain	SE/4	21	6	S	25	E	6,203.47	Broken Bow	4.73	6.79
4513072532	McCurtain	SE/4	13	7	S	25	E	250.00	Idabel	14.04	-0.07
4521072533	McCurtain	SE/4	21	7	S	25	E	414.78	Idabel	10.86	-0.07
4517082535	McCurtain	SE/4	17	8	S	25	E	300.00	Idabel	9.79	-0.07
4517082541	McCurtain	SE/4	17	8	S	25	E	2,237.50	Idabel	9.79	-0.07
4522082521	McCurtain	SE/4	22	8	S	25	E	125.93	Idabel	13.44	-0.07
4515092511	McCurtain	SE/4	15	9	S	25	E	400.00	Idabel	18.05	-0.07
4510022632	McCurtain	SE/4	10	2	S	26	E	1,467.40	Mena	25.83	2.96
4505062636	McCurtain	SE/4	5	6	S	26	E	516.67	Broken Bow	9.58	6.79
4526062631	McCurtain	SE/4	26	6	S	26	E	370.37	Broken Bow	14.22	6.79
4509082432	McCurtain	SE/4	22	7	S	26	E	140.63	Idabel	17.53	-0.07
4509022721	McCurtain	SE/4	9	2	S	27	E	500.00	Mena	27.32	2.96
4509022712	McCurtain	SE/4	9	2	S	27	E	266.67	Mena	27.32	2.96
4531092723	McCurtain	SE/4	31	9	S	27	E	700.00	New Boston	27.78	-4.92
4521102711	McCurtain	SE/4	21	10	S	27	E	200.00	New Boston	20.51	-4.92
Average								1,082.59		17.88	2.47
Minimum								65.58		1.93	-4.92
Maximum								9,329.65		44.47	6.79
Number of observations								45.00		45.00	45.00

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Table 26: City Data for the Hedonic Forestland Pricing Model (Pushmataha County)

TRACTID	County	QTR	SEC	TWP	NS	RNG	EW	PRICE	City	DistCity	PopGro
6436011521	Pushmataha	SE/4	36	1	S	15	E	375.00	Antlers	21.97	1.11
6407021591	Pushmataha	SE/4	7	2	S	15	E	555.56	Antlers	16.33	1.11
6428031571	Pushmataha	SE/4	28	3	S	15	E	282.05	Antlers	7.67	1.11
6433041512	Pushmataha	SE/4	33	4	S	15	E	400.00	Antlers	10.75	1.11
6413011651	Pushmataha	SE/4	13	1	S	16	E	400.00	Antlers	19.01	1.11
6415011621	Pushmataha	SE/4	15	1	S	16	E	333.33	Antlers	19.86	1.11
6428021661	Pushmataha	SE/4	28	2	S	16	E	250.00	Antlers	9.77	1.11
6429021671	Pushmataha	SE/4	29	2	S	16	E	250.00	Antlers	8.98	1.11
6429021641	Pushmataha	SE/4	29	2	S	16	E	1,100.00	Antlers	8.98	1.11
6401041618	Pushmataha	SE/4	1	4	S	16	E	1,153.85	Antlers	3.19	1.11
6417041641	Pushmataha	SE/4	17	4	S	16	E	600.00	Antlers	3.46	1.11
6422041631	Pushmataha	SE/4	22	4	S	16	E	558.44	Antlers	3.47	1.11
6401011721	Pushmataha	SE/4	1	1	S	17	E	200.00	Antlers	31.88	1.11
6423011771	Pushmataha	NE/4	23	1	N	17	E	177.78	Antlers	26.34	1.11
6423011701	Pushmataha	NE/4	23	1	N	17	E	155.56	Antlers	26.34	1.11
6431011721	Pushmataha	NE/4	31	1	N	17	E	149.68	Antlers	30.47	1.11
6425021771	Pushmataha	NE/4	25	2	N	17	E	175.62	Wilburton	41.89	-3.88
6425021781	Pushmataha	NE/4	25	2	N	17	E	85.69	Wilburton	41.89	-3.88
6410031711	Pushmataha	SE/4	10	3	S	17	E	300.00	Antlers	16.51	1.11
6420031751	Pushmataha	SE/4	20	3	S	17	E	325.00	Antlers	11.30	1.11
6421041791	Pushmataha	SE/4	21	4	S	17	E	500.00	Antlers	6.99	1.11

Table 26: City Data for the Hedonic Forestland Pricing Model (Pushmataha County)

TRACTID	County	QTR	SEC	TWP	NS	RNG	EW	PRICE	City	DistCity	PopGro
6410011821	Pushmataha	NE/4	10	1	N	18	E	400.00	Antlers	32.37	1.11
6410011822	Pushmataha	NE/4	10	1	N	18	E	550.00	Antlers	32.37	1.11
6420011891	Pushmataha	NE/4	20	1	N	18	E	416.67	Antlers	32.46	1.11
6426011861	Pushmataha	SE/4	26	1	S	18	E	325.00	Antlers	21.97	1.11
6429011831	Pushmataha	NE/4	29	1	N	18	E	918.75	Antlers	31.45	1.11
6435041804	Pushmataha	SE/4	35	4	S	18	E	228.13	Antlers	18.73	1.11
6403021921	Pushmataha	NE/4	3	2	N	19	E	368.75	Wilburton	23.79	-3.88
6412021971	Pushmataha	NE/4	12	2	N	19	E	200.00	Wilburton	26.87	-3.88
6412041921	Pushmataha	SE/4	12	4	S	19	E	150.00	Antlers	26.37	1.11
6408022011	Pushmataha	NE/4	8	2	N	20	E	417.86	Wilburton	35.57	-3.88
6414022014	Pushmataha	NE/4	14	2	N	20	E	1,250.00	Wilburton	37.43	-3.88
6416022081	Pushmataha	NE/4	16	2	N	20	E	100.00	Wilburton	35.70	-3.88
6436022061	Pushmataha	NE/4	36	2	N	20	E	300.00	Wilburton	42.99	-3.88
6416022013	Pushmataha	NE/4	16	2	N	22	E	125.00	Wilburton	35.79	-3.88
6419022241	Pushmataha	NE/4	19	2	N	22	E	325.00	Wilburton	34.64	-3.88
Average								400.07		23.21	-0.28
Minimum								85.69		3.19	-3.88
Maximum								1,250.00		42.99	1.11
Number of observations								36		36	36

Wood Processing Mills and Timber Transport Costs

The spatial characteristics data set provided data on the nearest community with two or more wood-processing mills. This data includes the roadway mile distance to the mill town $(DistMill)$ and the name of that mill town. This data was combined with data on timber transport cost and expected removals to create the variable $TranCost$, which is the expected annualized cost to transport timber to mill. The $TranCost$ equation is defined as:

$$TranCost = ExRem \cdot p_{Tran} \cdot DistMill,$$

where:

$TranCost$ is the expected annualized cost to transport timber from forestland parcel i to the nearest community with two or more wood-processing mills,

$ExRem$ is the expected annualized removals (ft^3/acre) from forestland parcel i,

p_{Tran} is the expected cost per cubic foot mile to transport timber, which is equal to \$0.0024, and

$DistMill$ is the roadway miles from forestland parcel i to the nearest community with two or more wood-processing mills.

Table 27 lists the communities within close proximity of the forestland parcels that have two or more wood-processing mills. Tables 28 and 29 lists the data on expected annualized removals, roadway miles to the closest town having two or more mills, and the expected annualized timber transport costs for the forestland parcels in McCurtain and Pushmataha Counties, respectively.

Table 27: Wood-Processing/Mill Towns near the Forestland Parcels

City	County	State	Number of Mills
Broken Bow	McCurtain	OK	7
Idabel	McCurtain	OK	3
Valliant	McCurtain	OK	2
Wright City	McCurtain	OK	2
Battiest	McCurtain	OK	2
Antlers	Pushmataha	OK	4
Wilburton	Latimer	OK	2
Ashdown	Little River	AR	2
Cove	Polk	AR	3
New Boston	Bowie	TX	2

Arkansas Wood Using Industries Directory. (2002)
http://www.forestry.state.ar.us/manage/fidirectory.html
Oklahoma Wood Manufactures Directory. Oklahoma State University, Cooperative Extension Service, Department of Forestry, Stillwater, OK.
Directory of Forest Products Industries. (2003) Texas Forest Service, http://txforestservice.tamu.edu/landowner_assistance/index.html

Table 28: Data on Wood-Processing/Mill Towns and Timber Transport Costs (McCurtain County)

TRACTID	County	QTR	SEC	TWP	NS	RNG	EW	PRICE	Exp. Rem.	Dist Mill	Mill Town	Tran Cost
4507052124	McCurtain	SE/4	7	5	S	21	E	500.00	63.36	11.27	Valliant	1.71
4512052114	McCurtain	SE/4	12	5	S	21	E	65.58	59.85	7.15	Wright City	1.03
4531052125	McCurtain	SE/4	31	5	S	21	E	200.00	62.97	6.96	Valliant	1.05
4531052122	McCurtain	SE/4	31	5	S	21	E	200.00	62.97	6.96	Valliant	1.05
4534052143	McCurtain	SE/4	34	5	S	21	E	375.00	72.23	4.97	Valliant	0.86
4520062136	McCurtain	SE/4	20	6	S	21	E	909.09	58.34	2.88	Valliant	0.40
4522062111	McCurtain	SE/4	22	6	S	21	E	601.18	63.37	0.93	Valliant	0.14
4521032221	McCurtain	SE/4	21	3	S	22	E	250.00	89.79	13.30	Battiest	2.87
4528052232	McCurtain	SE/4	28	5	S	22	E	731.71	59.02	2.78	Wright City	0.39
4512062222	McCurtain	SE/4	12	6	S	22	E	300.00	44.07	5.31	Wright City	0.56
4501072215	McCurtain	SE/4	1	7	S	22	E	1,000.00	157.43	9.43	Valliant	3.56
4501072241	McCurtain	SE/4	1	7	S	22	E	1,450.00	73.47	9.43	Valliant	1.66
4524022321	McCurtain	SE/4	24	2	S	23	E	1,000.00	110.20	7.26	Battiest	1.92
4501062312	McCurtain	SE/4	1	6	S	23	E	2,012.50	56.22	7.44	Broken Bow	1.00
4509062333	McCurtain	SE/4	9	6	S	23	E	100.00	87.67	9.13	Wright City	1.92
4525062311	McCurtain	SE/4	25	6	S	23	E	4,602.99	62.97	8.05	Broken Bow	1.22
4525062312	McCurtain	SE/4	25	6	S	23	E	1,021.43	58.04	8.05	Broken Bow	1.12
4525062313	McCurtain	SE/4	25	6	S	23	E	403.07	57.68	8.05	Broken Bow	1.11
4519022412	McCurtain	SE/4	19	2	S	24	E	1,397.36	100.34	8.28	Battiest	1.99
4526052427	McCurtain	SE/4	26	5	S	24	E	400.00	62.97	5.03	Broken Bow	0.76
4501062416	McCurtain	SE/4	1	6	S	24	E	9,329.65	51.77	2.24	Broken Bow	0.28
4534062421	McCurtain	SE/4	34	6	S	24	E	297.98	41.37	7.18	Broken Bow	0.71
4507072432	McCurtain	SE/4	7	7	S	24	E	2,843.75	87.67	4.59	Idabel	0.97
4508072423	McCurtain	SE/4	8	7	S	24	E	887.31	62.97	6.51	Idabel	0.98
4518072413	McCurtain	SE/4	18	7	S	24	E	701.37	87.67	3.55	Idabel	0.75

Table 28: Data on Wood-Processing/Mill Towns and Timber Transport Costs (McCurtain County)

TRACTID	County	QTR	SEC	TWP	NS	RNG	EW	PRICE	Exp. Rem.	Dist Mill	Mill Town	Tran Cost
4509012512	McCurtain	SE/4	9	1	S	25	E	594.80	46.07	17.44	Cove	1.93
4505032512	McCurtain	SE/4	5	3	S	25	E	750.00	62.97	18.51	Battiest	2.80
4522032522	McCurtain	SE/4	22	3	S	25	E	600.00	41.37	25.58	Cove	2.54
4522032531	McCurtain	SE/4	22	3	S	25	E	98.36	41.37	25.58	Cove	2.54
4536032532	McCurtain	SE/4	36	3	S	25	E	1,000.00	41.37	29.38	Cove	2.92
4521062521	McCurtain	SE/4	21	6	S	25	E	6,203.47	54.77	4.64	Broken Bow	0.61
4513072532	McCurtain	SE/4	13	7	S	25	E	250.00	62.97	13.46	Idabel	2.03
4521072533	McCurtain	SE/4	21	7	S	25	E	414.78	157.43	10.28	Idabel	3.88
4517082535	McCurtain	SE/4	17	8	S	25	E	300.00	72.23	9.21	Idabel	1.60
4517082541	McCurtain	SE/4	17	8	S	25	E	2,237.50	72.23	9.21	Idabel	1.60
4522082521	McCurtain	SE/4	22	8	S	25	E	125.93	62.97	12.85	Idabel	1.94
4515092511	McCurtain	SE/4	15	9	S	25	E	400.00	62.97	17.46	Idabel	2.64
4510022632	McCurtain	SE/4	10	2	S	26	E	1,467.40	62.97	10.74	Cove	1.62
4505062636	McCurtain	SE/4	5	6	S	26	E	516.67	55.77	9.57	Broken Bow	1.28
4526062631	McCurtain	SE/4	26	6	S	26	E	370.37	84.14	14.22	Broken Bow	2.87
4509082432	McCurtain	SE/4	22	7	S	26	E	140.63	62.97	14.90	Idabel	2.25
4509022721	McCurtain	SE/4	9	2	S	27	E	500.00	62.97	12.31	Cove	1.86
4509022712	McCurtain	SE/4	9	2	S	27	E	266.67	62.97	12.31	Cove	1.86
4531092723	McCurtain	SE/4	31	9	S	27	E	700.00	62.97	27.60	Ashdown	4.17
4521102711	McCurtain	SE/4	21	10	S	27	E	200.00	157.43	20.26	New Boston	7.66
Average								1,082.59	70.79	10.72		1.79
Minimum								65.58	41.37	0.93		0.14
Maximum								9,329.65	157.43	29.38		7.66
Number of observations								45.00	45.00	45.00		45.00

Table 29: Data on Wood-Processing/Mill Towns and Timber Transport Costs (Pushmataha County)

TRACTID	County	QTR	SEC	TWP	NS	RNG	EW	PRICE	Exp. Rem.	Dist Mill	Mill Town	Tran Cost
6436011521	Pushmataha	SE/4	36	1	S	15	E	375.00	14.42	22.09	Antlers	0.05
6407021591	Pushmataha	SE/4	7	2	S	15	E	555.56	13.32	16.54	Antlers	0.04
6428031571	Pushmataha	SE/4	28	3	S	15	E	282.05	18.95	7.87	Antlers	0.02
6433041512	Pushmataha	SE/4	33	4	S	15	E	400.00	11.71	10.47	Antlers	0.03
6413011651	Pushmataha	SE/4	13	1	S	16	E	400.00	14.42	19.13	Antlers	0.05
6415011621	Pushmataha	SE/4	15	1	S	16	E	333.33	39.24	19.98	Antlers	0.05
6428021661	Pushmataha	SE/4	28	2	S	16	E	250.00	7.67	9.89	Antlers	0.02
6429021671	Pushmataha	SE/4	29	2	S	16	E	250.00	13.18	9.10	Antlers	0.02
6429021641	Pushmataha	SE/4	29	2	S	16	E	1,100.00	16.18	9.10	Antlers	0.02
6401041618	Pushmataha	SE/4	1	4	S	16	E	1,153.85	54.88	2.79	Antlers	0.01
6417041641	Pushmataha	SE/4	17	4	S	16	E	600.00	7.32	3.18	Antlers	0.01
6422041631	Pushmataha	SE/4	22	4	S	16	E	558.44	10.89	3.19	Antlers	0.01
6401011721	Pushmataha	SE/4	1	1	S	17	E	200.00	11.91	31.55	Antlers	0.08
6423011771	Pushmataha	NE/4	23	1	N	17	E	177.78	14.42	29.05	Antlers	0.07
6423011701	Pushmataha	NE/4	23	1	N	17	E	155.56	14.42	29.05	Antlers	0.07
6431011721	Pushmataha	NE/4	31	1	N	17	E	149.68	14.42	30.51	Antlers	0.07
6425021771	Pushmataha	NE/4	25	2	N	17	E	175.62	14.42	41.51	Wilburton	0.10
6425021781	Pushmataha	NE/4	25	2	N	17	E	85.69	14.42	41.51	Wilburton	0.10
6410031711	Pushmataha	SE/4	10	3	S	17	E	300.00	8.82	16.17	Antlers	0.04
6420031751	Pushmataha	SE/4	20	3	S	17	E	325.00	18.23	10.96	Antlers	0.03
6421041791	Pushmataha	SE/4	21	4	S	17	E	500.00	17.20	6.59	Antlers	0.02
6410011821	Pushmataha	NE/4	10	1	N	18	E	400.00	13.26	31.60	Antlers	0.08

Table 29: Data on Wood-Processing/Mill Towns and Timber Transport Costs (Pushmataha County)

TRACTID	County	QTR	SEC	TWP	NS	RNG	EW	PRICE	Exp. Rem.	Dist Mill	Mill Town	Tran Cost
6410011822	Pushmataha	NE/4	10	1	N	18	E	550.00	12.22	31.60	Antlers	0.08
6420011891	Pushmataha	NE/4	20	1	N	18	E	416.67	24.54	26.25	Antlers	0.06
6426011861	Pushmataha	SE/4	26	1	S	18	E	325.00	10.87	21.64	Antlers	0.05
6429011831	Pushmataha	NE/4	29	1	N	18	E	918.75	14.42	29.35	Antlers	0.07
6435041804	Pushmataha	SE/4	35	4	S	18	E	228.13	19.72	18.33	Antlers	0.04
6403021921	Pushmataha	NE/4	3	2	N	19	E	368.75	14.42	23.83	Wilburton	0.06
6412021971	Pushmataha	NE/4	12	2	N	19	E	200.00	14.42	26.52	Wilburton	0.06
6412041921	Pushmataha	SE/4	12	4	S	19	E	150.00	10.28	22.83	Valliant	0.05
6408022011	Pushmataha	NE/4	8	2	N	20	E	417.86	14.42	34.21	Wilburton	0.08
6414022014	Pushmataha	NE/4	14	2	N	20	E	1,250.00	14.42	36.24	Wilburton	0.09
6416022081	Pushmataha	NE/4	16	2	N	20	E	100.00	14.42	34.39	Wilburton	0.08
6436022061	Pushmataha	NE/4	36	2	N	20	E	300.00	14.42	33.02	Battiest	0.08
6416022013	Pushmataha	NE/4	16	2	N	22	E	125.00	7.32	34.45	Battiest	0.08
6419022241	Pushmataha	NE/4	19	2	N	22	E	325.00	15.63	30.18	Battiest	0.07
Average								400.07	15.70	22.35		0.05
Minimum								85.69	7.32	2.79		0.01
Maximum								1,250.00	54.88	41.51		0.10
Number of observations								36	36	36		36

Natural Resource Attractions within Close Proximity of the Forestland Parcels

The spatial characteristics data set provided data on the roadway mile distance to the center of nearest natural resource attraction and the name of that natural resource attraction. Table 30 lists the natural resource attractions within close proximity of the forestland parcels. Tables 31 and 32 list the distances to the closest natural resource attractions and the name of the attraction for each forestland parcel in McCurtain and Pushmataha Counties, respectively.

Table 30: Natural/Recreational Resource Attractions

Natural Resource Attraction	Location
Beavers Bend State Park	Central/East/North McCurtain County
Clayton Lake State Park	North Central Pushmataha County
DeQueen Lake	Northwest corner of Sevier County, Arkansas
Hugo Lake	Choctaw County near Pushmataha County Line
Lake Nanih Waiya	Pushmataha County 3 miles northeast of Clayton
Lake Raymond Gary	Eastern Choctaw County between Fort Towson and the Red River
Lake Wihelmina	Northwest corner of Polk County, Arkansas
McGee Creek Lake/State Park	Eastern Atoka County near Pushmataha County Line
Ouachita National Forest	Le Flore County, Polk County (AR), and Southeast McCurtain County
Pine Creek Lake	McCurtain County near the Pushmataha/Choctaw County Lines
Sardis Lake	Pushmataha/Latimer County Line
Ward Lake	Southeastern McCurtain County, North of State Highway 87

Table 31: Natural Resource Attractions Data for the Hedonic Forestland Pricing Models (McCurtain County)

TRACTID	County	QTR	SEC	TWP	NS	RNG	EW	PRICE	DistNat	Natural Resource Area
4507052124	McCurtain	SE/4	7	5	S	21	E	500.00	8.08	Pine Creek Lake
4512052114	McCurtain	SE/4	12	5	S	21	E	65.58	7.07	Pine Creek Lake
4531052125	McCurtain	SE/4	31	5	S	21	E	200.00	11.04	Lake Raymond Gary
4531052122	McCurtain	SE/4	31	5	S	21	E	200.00	11.04	Lake Raymond Gary
4534052143	McCurtain	SE/4	34	5	S	21	E	375.00	12.93	Pine Creek Lake
4520062136	McCurtain	SE/4	20	6	S	21	E	909.09	10.30	Lake Raymond Gary
4522062111	McCurtain	SE/4	22	6	S	21	E	601.18	11.60	Lake Raymond Gary
4521032221	McCurtain	SE/4	21	3	S	22	E	250.00	12.12	Pine Creek Lake
4528052232	McCurtain	SE/4	28	5	S	22	E	731.71	11.34	Pine Creek Lake
4512062222	McCurtain	SE/4	12	6	S	22	E	300.00	17.29	Pine Creek Lake
4501072215	McCurtain	SE/4	1	7	S	22	E	1,000.00	20.23	Lake Raymond Gary
4501072241	McCurtain	SE/4	1	7	S	22	E	1,450.00	20.23	Lake Raymond Gary
4524022321	McCurtain	SE/4	24	2	S	23	E	1,000.00	11.76	Beavers Bend State Park
4501062312	McCurtain	SE/4	1	6	S	23	E	2,012.50	18.74	Beavers Bend State Park
4509062333	McCurtain	SE/4	9	6	S	23	E	100.00	19.21	Pine Creek Lake
4525062311	McCurtain	SE/4	25	6	S	23	E	4,602.99	23.28	Beavers Bend State Park
4525062312	McCurtain	SE/4	25	6	S	23	E	1,021.43	23.28	Beavers Bend State Park
4525062313	McCurtain	SE/4	25	6	S	23	E	403.07	23.28	Beavers Bend State Park
4519022412	McCurtain	SE/4	19	2	S	24	E	1,397.36	11.90	Beavers Bend State Park
4526052427	McCurtain	SE/4	26	5	S	24	E	400.00	16.06	Beavers Bend State Park
4501062416	McCurtain	SE/4	1	6	S	24	E	9,329.65	17.31	Beavers Bend State Park
4534062421	McCurtain	SE/4	34	6	S	24	E	297.98	22.87	Ouachita National Forest
4507072432	McCurtain	SE/4	7	7	S	24	E	2,843.75	20.51	Ouachita National Forest
4508072423	McCurtain	SE/4	8	7	S	24	E	887.31	22.36	Ouachita National Forest
4518072413	McCurtain	SE/4	18	7	S	24	E	701.37	19.47	Ouachita National Forest

Table 31: Natural Resource Attractions Data for the Hedonic Forestland Pricing Models (McCurtain County)

TRACTID	County	QTR	SEC	TWP	NS	RNG	EW	PRICE	DistNat	Natural Resource Area
4509012512	McCurtain	SE/4	9	1	S	25	E	594.80	26.78	Beavers Bend State Park
4505032512	McCurtain	SE/4	5	3	S	25	E	750.00	12.24	Beavers Bend State Park
4522032522	McCurtain	SE/4	22	3	S	25	E	600.00	34.19	Beavers Bend State Park
4522032531	McCurtain	SE/4	22	3	S	25	E	98.36	34.19	Beavers Bend State Park
4536032532	McCurtain	SE/4	36	3	S	25	E	1,000.00	37.99	Beavers Bend State Park
4521062521	McCurtain	SE/4	21	6	S	25	E	6,203.47	20.68	Beavers Bend State Park
4513072532	McCurtain	SE/4	13	7	S	25	E	250.00	9.55	Ouachita National Forest
4521072533	McCurtain	SE/4	21	7	S	25	E	414.78	10.29	Ouachita National Forest
4517082535	McCurtain	SE/4	17	8	S	25	E	300.00	5.99	Ouachita National Forest
4517082541	McCurtain	SE/4	17	8	S	25	E	2,237.50	5.99	Ouachita National Forest
4522082521	McCurtain	SE/4	22	8	S	25	E	125.93	3.33	Ouachita National Forest
4515092511	McCurtain	SE/4	15	9	S	25	E	400.00	4.33	Ouachita National Forest
4510022632	McCurtain	SE/4	10	2	S	26	E	1,467.40	25.86	Lake Wihelmina
4505062636	McCurtain	SE/4	5	6	S	26	E	516.67	13.29	Beavers Bend State Park
4526062631	McCurtain	SE/4	26	6	S	26	E	370.37	17.70	De Queen Lake
4509082432	McCurtain	SE/4	22	7	S	26	E	140.63	16.95	Ouachita National Forest
4509022721	McCurtain	SE/4	9	2	S	27	E	500.00	27.35	Lake Wihelmina
4509022712	McCurtain	SE/4	9	2	S	27	E	266.67	27.35	Lake Wihelmina
4531092723	McCurtain	SE/4	31	9	S	27	E	700.00	6.00	Ward Lake
4521102711	McCurtain	SE/4	21	10	S	27	E	200.00	11.40	Ward Lake
Average								1,082.59	16.77	
Minimum								65.58	3.33	
Maximum								9,329.65	37.99	
Number of observations								45.00	45.00	

Table 32: Natural Resources Data for the Hedonic Forestland Pricing Models (Pushmataha County)

TRACTID	County	QTR	SEC	TWP	NS	RNG	EW	PRICE	DistNat	Natural Resource Area
6436011521	Pushmataha	SE/4	36	1	S	15	E	375.00	32.76	McGee Creek State Park
6407021591	Pushmataha	SE/4	7	2	S	15	E	555.56	19.30	McGee Creek State Park
6428031571	Pushmataha	SE/4	28	3	S	15	E	282.05	12.55	McGee Creek State Park
6433041512	Pushmataha	SE/4	33	4	S	15	E	400.00	17.10	McGee Creek State Park
6413011651	Pushmataha	SE/4	13	1	S	16	E	400.00	19.98	Clayton Lake State Park
6415011621	Pushmataha	SE/4	15	1	S	16	E	333.33	30.66	McGee Creek State Park
6428021661	Pushmataha	SE/4	28	2	S	16	E	250.00	20.56	McGee Creek State Park
6429021671	Pushmataha	SE/4	29	2	S	16	E	250.00	19.78	McGee Creek State Park
6429021641	Pushmataha	SE/4	29	2	S	16	E	1,100.00	19.78	McGee Creek State Park
6401041618	Pushmataha	SE/4	1	4	S	16	E	1,153.85	17.86	Hugo Lake
6417041641	Pushmataha	SE/4	17	4	S	16	E	600.00	17.55	Hugo Lake
6422041631	Pushmataha	SE/4	22	4	S	16	E	558.44	13.74	Hugo Lake
6401011721	Pushmataha	SE/4	1	1	S	17	E	200.00	12.83	Clayton Lake State Park
6423011771	Pushmataha	NE/4	23	1	N	17	E	177.78	12.15	Clayton Lake State Park
6423011701	Pushmataha	NE/4	23	1	N	17	E	155.56	12.15	Clayton Lake State Park
6431011721	Pushmataha	NE/4	31	1	N	17	E	149.68	22.74	Clayton Lake State Park
6425021771	Pushmataha	NE/4	25	2	N	17	E	175.62	2.89	Sardis Lake
6425021781	Pushmataha	NE/4	25	2	N	17	E	85.69	2.89	Sardis Lake
6410031711	Pushmataha	SE/4	10	3	S	17	E	300.00	25.22	Clayton Lake State Park
6420031751	Pushmataha	SE/4	20	3	S	17	E	325.00	27.43	Clayton Lake State Park
6421041791	Pushmataha	SE/4	21	4	S	17	E	500.00	12.73	Hugo Lake
6410011821	Pushmataha	NE/4	10	1	N	18	E	400.00	7.56	Clayton Lake State Park
6410011822	Pushmataha	NE/4	10	1	N	18	E	550.00	7.56	Clayton Lake State Park

Table 32: Natural Resources Data for the Hedonic Forestland Pricing Models (Pushmataha County)

TRACTID	County	QTR	SEC	TWP	NS	RNG	EW	PRICE	DistNat	Natural Resource Area
6420011891	Pushmataha	NE/4	20	1	N	18	E	416.67	12.11	Clayton Lake State Park
6426011861	Pushmataha	SE/4	26	1	S	18	E	325.00	12.87	Clayton Lake State Park
6429011831	Pushmataha	NE/4	29	1	N	18	E	918.75	11.10	Clayton Lake State Park
6435041804	Pushmataha	SE/4	35	4	S	18	E	228.13	6.71	Hugo Lake
6403021921	Pushmataha	NE/4	3	2	N	19	E	368.75	5.36	Sardis Lake
6412021971	Pushmataha	NE/4	12	2	N	19	E	200.00	3.89	Lake Nanih Waiya
6412041921	Pushmataha	SE/4	12	4	S	19	E	150.00	10.29	Pine Creek Lake
6408022011	Pushmataha	NE/4	8	2	N	20	E	417.86	7.63	Lake Nanih Waiya
6414022014	Pushmataha	NE/4	14	2	N	20	E	1,250.00	9.49	Lake Nanih Waiya
6416022081	Pushmataha	NE/4	16	2	N	20	E	100.00	7.76	Lake Nanih Waiya
6436022061	Pushmataha	NE/4	36	2	N	20	E	300.00	13.16	Clayton Lake State Park
6416022013	Pushmataha	NE/4	16	2	N	22	E	125.00	20.07	Lake Nanih Waiya
6419022241	Pushmataha	NE/4	19	2	N	22	E	325.00	18.92	Lake Nanih Waiya
Average								400.07	14.64	
Minimum								85.69	2.89	
Maximum								1,250.00	32.76	
Number of observations								36	36	

Hedonic Estimation of Forestland Prices

Initially the forestland price models were estimated using a translog functional form, ordinary least squares (OLS), and with the full data set for each county. Although various functional forms were investigated, based upon theory and a review of literature the translog functional form was the initial choice.

Misspecification tests were conducted to determine whether there were any deviations from the OLS assumptions. Deviations from the OLS assumptions will generally cause the estimates to be biased, inconsistent, and/or inefficient. The specification errors can be grouped into three categories:

1. problems with the error terms μ_i (autocorrelation, heteroskedasticity, non-normality);
2. problems with the explanatory variables X_i (influential observations, collinearity, omitted variables, functional form, non-nested models, correlation with the error terms); and
3. problems with the coefficients β_i (stability).

Autocorrelation is a violation that occurs with time series data. This is a situation in which the error term in any period is correlated with an error in any previous period. Since the data in this study are cross-sectional, no tests were conducted for autocorrelated errors. Tests were conducted for heteroskedastic and normally distributed residuals, as well as collinearity and influential observations.

Detecting Multicollinearity

It is often the case that economic variables may move together in a systematic manner. Multicollinearity is the case where several explanatory variables exhibit this behavior. Perfect multicollinearity exists when a k-variable regression involving explanatory variables $X_1, X_2, \ldots, X_k$ (where $X_1 = 1$ for all observations to allow for the intercept term), satisfies the following condition:

$$\lambda_1 X_1 + \lambda_2 X_2 + \cdots + \lambda_k X_k = 0 \qquad \text{(A1.1)}$$

where $\lambda_1, \lambda_2, \ldots, \lambda_k$ are constants such that not all of them are zero simultaneously (Gujarati, 1995).

The term multicollinearity is often used in a broader sense to include the case of perfect multicollinearity as well as the case where the X variables are intercorrelated but not perfectly so, as follows:

$$\lambda_1 X_1 + \lambda_2 X_2 + \cdots + \lambda_k X_k + v_i = 0 \qquad \text{(A1.2)}$$

where v_i is a stochastic error term (Gujarati, 1995).

The presence of multicollinearity does not imply any violation of the classical assumptions. The OLS estimators retain their properties. However, the coefficients will be imprecise and variances will be larger (Roche, 2001). When multicollinearity is present there is no guarantee that the data will be rich in information, or that it will be possible to isolate the economic relationship or parameters of interest (Hill, Griffiths, and Judge, 1997).

To detect multicollinearity the partial correlation coefficients and auxiliary regressions were calculated. The partial correlation coefficient is the correlation coefficient between any two regressors holding the remaining regressors constant. If the correlation is reasonably high (say greater than 0.8 in absolute terms) then there is a possibility that some serious collinearity exists (Roche, 2001). With the auxiliary regressions each independent variable was regressed on all the remaining independent variables. If any of the R^2 are substantially greater than the R^2 from the estimated equation then we should be concerned about multicollinearity (Roche, 2001).

SAS Models for Detecting Multicollinearity

The following code is an example of the SAS program for detecting the presence of multicollinearity.

```
/************Tests for Multicollinearity for McCurtain Forestland************/
filename HPMmc dde 'excel| HPMmc_Data! R2C2:R46C11';
data HPMmc; infile HPMmc;
INPUT PRICE ACRES OPEN TmProd FRONT DistHwy DistCity PopGro
TranCost DistNat;
LPrice = LOG(PRICE);
LAcres = LOG(ACRES);
LTmProd = LOG(TmProd);
LDistHwy = LOG(DistHwy);
LDistCit = LOG(DistCity);
LTranCos = LOG(TranCost);
LDistNat = LOG(DistNat);
proc print;

/*Descriptive Statistics*/
proc means data = HPMmc;
run;

/*Correlation Coefficients to detect Collinearity*/
proc corr data = HPMmc;
var PRICE ACRES OPEN TmProd FRONT DistHwy DistCity PopGro TranCost
DistNat;
run;

/*Auxiliary Regressions to detect multicollinearity*/
```

```
/*R-square on auxiliary regressions should be low*/

proc reg data = HPMmc;
model LAcres = OPEN TmProd FRONT DistHwy DistCity PopGro TranCost
DistNat;
run;

proc reg data = HPMmc;
model OPEN = LAcres TmProd FRONT DistHwy DistCity PopGro TranCost
DistNat;
run;

proc reg data = HPMmc;
model TmProd = LAcres OPEN FRONT DistHwy DistCity PopGro TranCost
DistNat;
run;

proc reg data = HPMmc;
model FRONT = LAcres OPEN TmProd DistHwy DistCity PopGro TranCost
DistNat;
run;

proc reg data = HPMmc;
model DistHwy = LAcres OPEN TmProd FRONT DistCity PopGro TranCost
DistNat;
run;

proc reg data = HPMmc;
model DistCity = LAcres OPEN TmProd FRONT DistHwy PopGro TranCost
DistNat;
run;

proc reg data = HPMmc;
model PopGro = LAcres OPEN TmProd FRONT DistCity DistHwy TranCost
DistNat;
run;

proc reg data = HPMmc;
model TranCost = LAcres OPEN TmProd FRONT DistCity DistHwy PopGro
DistNat;
run;

proc reg data = HPMmc;
model DistNat = LAcres OPEN TmProd FRONT DistCity DistHwy PopGro
TranCost;
run;
```

```
/*Estimated Full Model with Transcendental Functional Form*/
proc reg data = HPMmc;
model LPrice = LAcres OPEN TmProd FRONT DistHwy PopGro DistCity
TranCost DistNat / COLLIN;
run;
```

Results of Multicollinearity Detection (Full Model)

The results indicate that there is serious collinearity between *TranCost* and *DistCity* in both McCurtain and Pushmataha Counties. In McCurtain County there is moderate correlation between *TranCost* and *DistHwy*. In Pushmataha County there is moderate correlation between *TranCost* and *OPEN*, *TranCost* and *PopGro*, and *DistCity* and *PopGro*. The correlation coefficient matrices for McCurtain and Pushmataha Counties are in Tables 33 and 34, respectively.

Table 33: Correlation Coefficients Matrix (McCurtain County)

	PRICE	ACRES	OPEN	TmProd	FRONT	DistHwy	DistCity	PopGro	TranCost	DistNat
PRICE	1.00	-0.26	-0.17	-0.11	0.05	-0.29	-0.39	0.19	-0.29	0.12
ACRES		1.00	0.25	0.005	-0.19	0.04	0.04	-0.18	0.12	0.20
OPEN			1.00	-0.04	0.08	-0.11	-0.12	0.20	0.06	0.18
TmProd				1.00	0.06	-0.10	-0.17	-0.25	-0.06	-0.28
FRONT					1.00	-0.15	-0.15	0.17	-0.29	-0.27
DistHwy						1.00	0.49	-0.31	0.66	0.11
DistCity							1.00	-0.01	0.68	0.27
PopGro								1.00	-0.21	0.17
TranCost									1.00	0.30
DistNat										1.00

Table 34: Correlation Coefficients Matrix (Pushmataha County)

	PRICE	ACRES	OPEN	TmProd	FRONT	DistHwy	DistCity	PopGro	TranCost	DistNat
PRICE	1.00	-0.03	0.26	0.36	0.35	-0.36	-0.28	0.14	-0.31	0.08
ACRES		1.00	-0.11	-0.13	-0.10	0.08	-0.09	0.34	-0.06	0.14
OPEN			1.00	0.29	0.38	-0.14	0.60	0.28	-0.61	0.25
TmProd				1.00	0.10	-0.06	-0.21	0.14	-0.22	0.17
FRONT					1.00	-0.001	-0.26	0.12	-0.25	0.20
DistHwy						1.00	0.41	-0.47	0.40	-0.05
DistCity							1.00	-0.65	0.98	-0.45
PopGro								1.00	-0.62	0.46
TranCost									1.00	-0.46
DistNat										1.00

The R-square for each of the auxiliary regressions for the full models appears in Table 35. The auxiliary regressions regressed each independent variable on all of the remaining independent variables. The estimated equation is the full model in transcendental form. The results indicate $TranCost$, $DistCity$, $PopGro$, and $DistHwy$ are the most significant variables contributing to multicollinearity.

Table 35: Auxiliary Regressions (Full Model)

Dependent Variable	R-square McCurtain County	 Pushmataha County
TranCost	0.68	0.97
DistCity	0.55	0.97
PopGro	0.30	0.61
DistHwy	0.50	0.33
OPEN	0.23	0.49
DistNat	0.27	0.33
LAcres	0.15	0.34
FRONT	0.19	0.18
TmProd	0.17	0.16
Estimated Equation	0.43	0.54

In addition to the correlation coefficients and the auxiliary regressions the COLLIN option in SAS was used on the estimated equation. The COLLIN option computes the condition index (CI), which is defined as:

$$CI = \sqrt{\frac{Maximum \quad Eigenvalue}{Minimum \quad Eigenvalu}}. \qquad \text{(A1.3)}$$

The condition index is an overall measure of multicollinearity. The general rule of thumb is that if the condition index is between 10 and 30 there is moderate to strong multicollinearity and if it exceeds 30 there is severe multicollinearity

(Gujarati, 1995). The condition index for the McCurtain County regression is 22 and for the Pushmataha County regression it is 49.

To deal with the multicollinearity the variables *TranCost* and *PopGro* were dropped from the model. *DistCity* was maintained since it captures both timber marketing and urbanization influences on the price of forestland. *TranCost* not only captures the cost of transporting timber to market, but it also has perfect collinearity with distance to mill, and the correlation coefficients between distance to city (*DistCity*) and distance to mill (*DistMill*) are 0.68 and 0.98 for McCurtain and Pushmataha Counties, respectively.

For reasons other than collinearity, the variable *DistNat* was also dropped from the model. The variable *DistNat* measures the distance in miles from the forestland parcel to the center of the nearest natural resource attraction. This particular type of measurement is most likely not capturing the influence that neighboring natural resource and recreational areas may have on the price of forestland parcels in the region. Furthermore, individually the variable has little explanatory power on the price of forestland. A potentially better alternative measure would be a measure of the percentage of land area within a certain radius of the forestland parcel classified as a natural resource attraction, such as the Rec_i variable in Nivens *et al.* (2002).

Results of Multicollinearity Detection (Reduced Models)

In reduced form the data series for the explanatory variables includes *Acres, DistCity, DistHwy, TmProd, FRONT*, and *OPEN*, and two different functional forms – transcendental and an alternative form that allows for additional nonlinearity.

The transcendental model is defined as:

$$PRICE = \beta_0 X_1^{\beta_1} \mathrm{EXP}\left(\sum_{i=2\cdots6} \beta_i X_i\right). \tag{A1.4}$$

Converting this equation to logarithmic form allows estimation using ordinary least squares. Thus the statistical model is:

$$\ln(PRICE) = \ln\beta_0 + \beta_1 \ln X_1 + \left(\sum_{i=2\cdots6} \beta_i X_i\right) + \mu_i. \tag{A1.5}$$

The alternative functional form is defined as:

$$PRICE = \beta_0 X_1^{\beta_1} \mathrm{X}_2^{\beta_2} \mathrm{X}_3^{\beta_3} \mathrm{X}_4^{\beta_4} \mathrm{EXP}\left(\sum_{i=5\cdots6} \beta_i X_i\right). \tag{A1.6}$$

Converting this equation to logarithmic form allows estimation using ordinary least squares. Thus the statistical model is:

$$\begin{aligned}\ln(PRICE) = {} & \ln\beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 \\ & + \beta_4 \ln X_4 + \left(\sum_{i=5\cdots6} \beta_i X_i\right) + \mu_i\end{aligned}. \tag{A1.7}$$

For each model:

X_1 is the parcel size in acres,

X_2 is the roadway mile distance to the nearest city having a population greater than 2000,

X_3 is the linear distance in miles to the nearest major highway (*i.e.,* state or U.S. highway),

X_4 is the expected annual timber productivity for the parcel measured in cubic feet per acre,

X_5 is a binary variable indicating whether the parcel fronts (or is near) a road of any type, and

X_6 is the proportion of open land in the parcel.

The R-square values on the auxiliary regressions for the reduced form transcendental model on McCurtain County data are all less than the R-square for the estimated model, which suggests that multicollinearity is not a severe problem. The condition index for the transcendental model for McCurtain County is 18, which suggests moderate multicollinearity.

The R-square values on the auxiliary regressions for the reduced form transcendental model on Pushmataha County data suggest the presence of strong multicollinearity. The auxiliary regressions having *DistCity* and *OPEN* as the dependent variable have R-square values greater than the estimated equation. The condition index for the estimated equation is 22, which suggests strong multicollinearity.

Table 36 provides the results of the auxiliary regressions for the reduced transcendental form models.

Table 36: Auxiliary Regressions (Reduced Translog Model)

Dependent Variable	R-square McCurtain County	 Pushmataha County
DistCity	0.28	0.52
OPEN	0.09	0.47
DistHwy	0.25	0.19
LAcres	0.10	0.16
FRONT	0.06	0.16
TmProd	0.05	0.14
Estimated Equation	0.31	0.43

The R-square values on the auxiliary regressions for the reduced alternative form model on McCurtain County data are all less than R-square for the estimated model, which suggests that multicollinearity is not a severe problem. However, the condition index is 50, which suggests severe multicollinearity.

The R-square values on the auxiliary regressions for the reduced alternative form model on Pushmataha County data suggest the presence of strong multicollinearity, with *DistCity* and *OPEN* having the greatest influence. The condition index for the estimated equation is 44, which suggests severe multicollinearity.

Table 37 provides the results of the auxiliary regressions for the reduced alternative form models.

Table 37: Auxiliary Regressions (Reduced Alternative Model)

	R-square	
Dependent Variable	McCurtain County	Pushmataha County
DistCity	0.25	0.62
OPEN	0.09	0.56
DistHwy	0.20	0.29
LAcres	0.15	0.10
FRONT	0.06	0.15
TmProd	0.04	0.10
Estimated Equation	0.39	0.44

Summary of Multicollinearity

The reduced transcendental form models exhibit the least amount of multicollinearity. For the McCurtain County data the auxiliary regressions suggests that multicollinearity is not a problem and the conditional index is 18, which is less than any of the other models. For Pushmataha County data the auxiliary regressions suggests multicollinearity with *DistCity* and *OPEN* having the greatest influence, and the conditional index is 22, which is less than any of the other models.

Detecting Influential Observations

To detect influential observations, first an informal analysis was conducted by examining each of the data series and their summary statistics. Observations having extremely large and small values were noted, particularly among the price series data. Since per unit prices were calculated from total parcel sale price and parcel size, each of these observations was inspected to determine whether there were any mistakes made in their calculation. No mistakes were noted. Furthermore, since there is no known information that would justify their removal from the data, the observations were maintained.

Formal testing for influential data points was conducted with the INFLUENCE option in SAS, which calculates DFBETAS, DFFITS, and studentized residuals.

The DFBETAS test whether the estimated coefficients based on the whole dataset are significantly different than the coefficients calculated with the i^{th} observation omitted from the dataset. If the absolute value of the DFBETAS are greater than $2/n^{0.5}$ then the observation is said to be influential and it should be scrutinized and given further study (Roche 2001).

The DFFITS test whether the predicted values based on the whole dataset are significantly different than the predicted values calculated with the i^{th} observation omitted from the dataset. If the absolute value of the DFFITS are greater than $2(k/n)^{0.5}$ then the observation is said to be influential (Roche 2001).

The studentized residual tests whether the omission of the i^{th} observation affects the residual for that observation. If the absolute values of the studentized residuals are greater than 1.96 the observation can be regarded as an outlier (Roche 2001).

Tables 38 and 39 provide the results of the formal tests for McCurtain and Pushmataha Counties, respectively. The McCurtain County data was estimated with the reduced translog model using estimated generalized least squares, whereas the Pushmataha County data was estimated using ordinary least squares.

Table 38: Influential Observations (McCurtain County)

Test	Observation		Cutoff Value	Quantity Value
DFBETAS	2	FRONT	0.2981	0.5325
	13	DistCity	0.2981	0.3024
	13	DistHwy	0.2981	0.3536
	15	Intercept	0.2981	-0.4251
	15	LAcres	0.2981	0.4613
	15	OPEN	0.2981	-0.8783
	23	FRONT	0.2981	-0.3217
	33	DistCity	0.2981	-0.6174
	36	LAcres	0.2981	-0.4866
	36	DistCity	0.2981	0.5817
	36	DistHwy	0.2981	-0.3322
	36	TmProd	0.2981	0.8215
	36	OPEN	0.2981	0.4947
	38	LAcres	0.2981	0.3546
	38	DistHwy	0.2981	0.6496
	38	TmProd	0.2981	-1.0509
	38	OPEN	0.2981	-0.5033
	40	OPEN	0.2981	1.4524
	43	Intercept	0.2981	0.3373
	43	LAcres	0.2981	-0.4119
	43	DistHwy	0.2981	0.3601
	45	Intercept	0.2981	0.9318
	45	LAcres	0.2981	-0.3860
	45	DistCity	0.2981	-0.7705
	45	DistHwy	0.2981	-0.3140
	45	TmProd	0.2981	-1.2470
DFFITS	15		0.7888	-1.0663
	33		0.7888	1.1264
	36		0.7888	-1.0820
	38		0.7888	1.5955
	45		0.7888	-2.4639
Studentized Residuals	2		1.96	2.41
	15		1.96	-2.19
	38		1.96	4.14

Table 39: Influential Observations (Pushmataha County)

Test	Observation		Cutoff Value	Quantity Value
DFBETAS	3	Intercept	0.3333	-0.3464
	3	DistCity	0.3333	0.4752
	3	OPEN	0.3333	0.4588
	4	DistHwy	0.3333	0.6797
	6	Intercept	0.3333	0.7525
	6	LAcres	0.3333	-0.6232
	6	TmProd	0.3333	-1.2588
	6	FRONT	0.3333	-0.4569
	6	OPEN	0.3333	0.5203
	7	Intercept	0.3333	-0.3720
	7	TmProd	0.3333	0.3671
	9	Intercept	0.3333	0.4605
	9	DistCity	0.3333	-0.6710
	9	FRONT	0.3333	-0.4138
	9	OPEN	0.3333	-0.4673
	10	TmProd	0.3333	0.6697
	20	OPEN	0.3333	0.3345
	26	Intercept	0.3333	-0.3996
	26	LAcres	0.3333	0.3978
	26	FRONT	0.3333	0.3524
	32	DistCity	0.3333	0.7002
	32	DistHwy	0.3333	-0.6565
	32	FRONT	0.3333	0.6284
	36	LAcres	0.3333	-0.3411
DFFITS	6		0.8819	-1.5110
	9		0.8819	1.0398
Studentized Residuals	9		1.96	2.41
	32		1.96	2.36

Summary of Influential Observations

Influential data points are important because they have the potential to substantially affect the results. To determine whether they are problematic it is often suggested to report regression results both with and without the influential observations if the results of the two regressions are substantially different. However, it is also suggested that without good justification, it may not be wise to drop the observations. Thus, no observations were dropped.

Tests for Non-normal Residuals

A further assumption of the OLS model is that the error terms are normally distributed, $\mu_i \sim N$. If this assumption is violated the statistical tests are no longer strictly valid and the estimated coefficients are no longer efficient.

To evaluate whether the residuals are normally distributed the NORMAL option was specified in the PROC UNIVARIATE statement in SAS. This provided measures of skewness and kurtosis and the Shapiro-Wilk (1965) test. From the SAS output measures of skewness and kurtosis were obtained and used to calculate the Bera-Jarque (1981) tests on skewness, kurtosis, and normality.

Under a normal distribution the skewness, S (*i.e.*, lack of symmetry), in the μ_i will be zero and the kurtosis, K (*i.e.*, tallness or flatness), in the μ_i will be equal to three (Gujarati 1995). The Bera-Jarque skewness test determines whether skewness is significantly different from 0, the kurtosis test determines whether kurtosis is significantly different from 3, and the joint test for normality determines whether the residuals are normally distributed.

The test for skewness in the residuals utilizes the third moment for a random error, which is defined as

$$\mu_3 = \frac{\sum_{i=1}^{n} \mu_i^3}{n} \tag{A1.8}$$

The null and alternative hypotheses are

$$H_0: \text{ Skewness in the } \mu_i = 0$$
$$H_A: \text{ Skewness in the } \mu_i \neq 0$$

The Bera-Jarque (1981) LM test statistic for skewness in the residuals is defined as

$$LM_{sk} = n\left(\frac{S}{6}\right) \sim X_{(1)}^2 \tag{A1.9}$$

S represents skewness and is defined as the square of the third moment about the mean divided by the cube of the second moment about the mean, and n is the number of observations.

$$S = \frac{\left(\frac{\sum_{i=1}^{n} \hat{\mu}_i^3}{n}\right)^2}{\left(\frac{\sum_{i=1}^{n} \hat{\mu}_i^2}{n}\right)^3} \tag{A1.10}$$

If the computed LM_{sk} test statistic exceeds the critical chi-squared value at the chosen level of significance, we reject the null hypothesis of zero skewness.

The test for kurtosis in the residuals utilizes the fourth moment for a random error, which is defined as

$$\mu_4 = \frac{\sum_{i=1}^{n} \mu_i^4}{n} \tag{A1.11}$$

The null and alternative hypotheses are

$$H_0: \text{ Kurtosis in the } \mu_i = 3$$
$$H_A: \text{ Kurtosis in the } \mu_i \neq 3$$

The Bera-Jarque (1981) LM test statistic for kurtosis in the residuals is defined as

$$LM_{ku} = n\left(\frac{(K-3)^2}{24}\right) \sim X_{(1)}^2 \tag{A1.12}$$

K represents kurtosis and is defined as the fourth moment about the mean divided by the square of the second moment about the mean, and n is the number of observations.

$$K = \frac{\left(\frac{\sum_{i=1}^{n} \hat{\mu}_i^4}{n}\right)}{\left(\frac{\sum_{i=1}^{n} \hat{\mu}_i^2}{n}\right)^2} \tag{A1.13}$$

If the computed LM_{ku} test statistic exceeds the critical chi-squared value at the chosen level of significance, we reject the null hypothesis of kurtosis equal to 3.

The Bera-Jarque test of for normality combines the skewness and kurtosis test statistics, and it is distributed as a chi-square with 2 degrees of freedom. The test statistic is defined as:

$$BJ = n\left[\frac{S^2}{6} + \frac{(K-3)^2}{24}\right] \sim X^2_{(df=2)} \qquad \text{(A1.14)}$$

The null and alternative hypotheses are:

H_0: the μ_i have a normal distribution

H_A: the μ_i do NOT have a normal distribution

If the computed BJ test statistic exceeds the critical chi-squared value at the chosen level of significance, we reject the null hypothesis that the μ_i have a normal distribution.

The Shapiro-Wilk W-statistic is calculated as:

$$W = \frac{\left(\sum_{i=1}^{n} a_i x_{(i)}\right)^2}{\sum_{i=1}^{n}\left(x_i - \bar{x}\right)^2} \qquad \text{(A1.15)}$$

The $x_{(i)}$ are the ordered sample values ($x_{(1)}$ is the smallest) and the a_i are constants generated from the means, variances and co-variances of the order statistics of a sample of size n from a normal distribution. The Shapiro-Wilk W-statistic is based on an empirical distribution function. The computed statistic ranges between 0 and 1, with small values leading to rejection of the null hypothesis of normality.

The null and alternative hypotheses are:

H_0: the μ_i have a normal distribution

H_A: the μ_i do NOT have a normal distribution

To determine whether to reject the null hypothesis of normality, we examine the probability associated with the test statistic. If this value is less than the level of significance (*i.e.,* 0.05 for 95%), then the null hypothesis is rejected, and we can conclude that the μ_i are not normally distributed.

Normality Test Results (McCurtain County)

The measure of skewness was -0.20 indicating that the distribution is slightly skewed to the right (relatively longer right tail with hump left of center). The p-value on the Bera-Jarque skewness test is 0.65, and thus we fail-to-reject the null hypothesis that skewness is equal to zero. Thus, by the test, the distribution of the residuals is near symmetrical.

The measure of kurtosis was 2.84 indicating that the distribution is platykurtic (slightly flat, fat short tails). The p-value on the Bera-Jarque kurtosis test is 0.86, and we fail-to-reject the null hypothesis that kurtosis is equal to three.

The p-value on the Bera-Jarque joint normality test is 0.87 and on the Shapiro-Wilk test it is 0.72. In both cases we fail-to-reject the null hypothesis that the residuals are normally distributed. Table 40 summarizes the test results.

Table 40: Results of the Tests of Normality (McCurtain County)

Test	Value of Test Statistic	P-Value
Bera-Jarque test for skewness	0.2391	0.6529
Bera-Jarque test for kurtosis	0.0361	0.8648
Bera-Jarque joint normality test	0.2752	0.8737
Shapiro-Wilk test for normality	0.9825	0.7213

Normality Test Results (Pushmataha County)

The measure of skewness was 0.37 indicating that the distribution is slightly skewed to the left (relatively longer left tail with hump right of center). The p-value on the Bera-Jarque skewness test is 0.40, and thus we fail-to-reject the null hypothesis that skewness is equal to zero. Thus, by the test, the distribution of the residuals is near symmetrical.

The measure of kurtosis was 2.63 indicating that the distribution is platykurtic (slightly flat, fat short tails). The p-value on the Bera-Jarque kurtosis test is 0.67, and we fail-to-reject the null hypothesis that kurtosis is equal to three.

The p-value on the Bera-Jarque joint normality test is 0.61 and on the Shapiro-Wilk test it is 0.45. In both cases we fail-to-reject the null hypothesis that the residuals are normally distributed. Table 41 summarizes the test results.

Table 41: Results of the Tests of Normality (Pushmataha County)

Test	Value of Test Statistic	P-Value
Bera-Jarque test for skewness	0.8047	0.4000
Bera-Jarque test for kurtosis	0.2108	0.6729
Bera-Jarque joint normality test	1.0155	0.6145
Shapiro-Wilk test for normality	0.9707	0.4456

Summary of Tests for Non-normal Residuals

The results for both McCurtain and Pushmataha Counties indicate that we fail-to-reject the null hypothesis of normality and thus conclude that the residuals have a normal distribution.

Tests for Heteroskedastic Residuals

An important assumption of the OLS model is that the variance of each disturbance term μ_i is some constant number equal to σ^2 (Gujarati 1995). If the assumption of homoskedasticity, or equal variance, is violated the residuals are said to be heteroskedastic. The consequences of heteroskedastic residuals for OLS are that the coefficient estimators will be unbiased but inefficient (Roche 2001). There are numerous formal tests for heteroskedastic residuals. The Ramsey (1969), Koenker (1981), and Lagrange-Multiplier tests were used to detect heteroskedastic residuals.

The Ramsey test involves regressing the residuals squared $\hat{\mu}_i^2$ on a constant and the squares of the fitted values $\hat{Y}_i^2$. Under the null hypothesis the right hand side variables except the constant should have no explanatory power for the residuals squared. The test statistic is nR^2 and has a chi-squared distribution with 1-degree of freedom, where n is the number of observations.

$$\begin{aligned}
&\hat{\mu}_i^2 = \alpha_1 + \alpha_2 \hat{Y}_i^2 + e_i, \\
&H_0: \quad \alpha_2 = 0, \\
&H_1: \quad \alpha_2 \neq 0, \\
&\text{Test}: \quad nR^2 \sim \mathrm{X}_{(1)}^2
\end{aligned} \tag{A1.16}$$

The Koenker test takes a similar form, except that its explanatory variables are the same as that of the original model. Again, under the null hypothesis the right hand side variables except the constant should have no explanatory power for the residuals squared, and the test statistic is nR^2 and has a chi-squared distribution with $K-1$ degree of freedom.

$$\begin{aligned}
&\hat{\mu}_i^2 = \alpha_1 + \sum_{k=2}^{K} \alpha_k Z_{ki} + e_i, \\
&H_0: \quad \alpha_k = 0 \ \text{ for } k = 2, \cdots, K, \\
&H_1: \quad \alpha_2 \neq 0 \ \text{ for } k = 2, \cdots, K, \\
&\text{Test}: \quad nR^2 \sim \mathrm{X}_{(K-1)}^2
\end{aligned} \tag{A1.17}$$

The Lagrange-Multiplier involves regressing the log of the residuals squared $\ln(\hat{\mu}_i^2)$ on a constant and the explanatory variables of the original model. Again, under the null hypothesis the right hand side variables except the constant should have no explanatory power for the residuals squared, and the test statistic has an F-distribution with $K-1$ degrees of freedom in the numerator and $n-K$ degrees of freedom in the denominator.

$$\ln\left(\hat{\mu}_i^2\right) = \alpha_1 + \sum_{k=2}^{K} \alpha_k Z_{ki} + e_i,$$
$$H_0: \quad \alpha_k = 0 \;\; \text{for } k = 2, \cdots, K,$$
$$H_1: \quad \alpha_2 \neq 0 \;\; \text{for } k = 2, \cdots, K, \qquad \text{(A1.18)}$$
$$\text{Test}: \quad F_{(K-1,\, n-K)}$$

<u>SAS Model for Tests of Heteroskedasticity</u>

The following code is an example of the SAS program that calculates the Ramsey, Koenker, and Lagrange Multiplier test statistics.

```
/**********************Tests for Heteroskedastic Error Terms********************/
filename HPMmc dde 'excel| HPMmc_Data! R2C2:R46C11';
data HPMmc; infile HPMmc;
INPUT PRICE ACRES OPEN TmProd FRONT DistHwy DistCity PopGro
TranCost DistNat;
LPrice = LOG(PRICE);
LAcres = LOG(ACRES);
proc print;

/*Estimated Reduced Model with Translog Functional Form*/
proc reg data = HPMmc;
model LPrice = LAcres DistCity DistHwy TmProd FRONT OPEN;
output out = one R = UHAT P = YHAT;
data two; set one;

UHAT2 = UHAT**2;
YHAT2 = YHAT**2;
LUHAT2 = LOG(UHAT2);

/*Plot of UHAT2 and YHAT*/
proc plot; plot UHAT2 * YHAT = '*';

/*Ramsey Test for Heteroskedastic Errors*/
proc reg; model UHAT2 = YHAT2;

/*Koenker Test for Heteroskedastic Errors*/
proc reg; model UHAT2 = LAcres DistCity DistHwy TmProd FRONT OPEN;

/*LM Test for Heteroskedastic Errors*/
proc reg; model LUHAT2 = LAcres DistCity DistHwy TmProd FRONT OPEN;

run;
```

Heteroskedasticity Test Results (McCurtain County)

The tests for heteroskedastic residuals for McCurtain County were conducted using the reduced translog functional form model. The results of the Ramsey test indicate the presence of heteroskedastic residuals. The p-value is 0.0457, which is sufficiently low, and thus, we reject the null hypothesis of homoskedastic residuals. The p-value on the Koenker test is 0.3037, thus we fail-to-reject the null hypothesis of homoskedastic residuals. The p-value on the LM test is 0.0222 and thus we reject the null hypothesis of homoskedastic residuals. Since the results suggest the presence of heteroskedasticity the McCurtain County data in the final model were estimated using a reduced translog form model and estimated generalized least squares. Table 42 summarizes the test results.

Table 42: Tests for Heteroskedastic Residuals (McCurtain County)

Test	Value of Test Statistic	P-Value
Ramsey	4.0365	0.0457
Koenker	7.4115	0.3037
LM Test	2.8400	0.0222

Heteroskedasticity Test Results (Pushmataha County)

The tests for heteroskedastic residuals for Pushmataha County were conducted using the reduced translog functional form model. The results of the tests do not indicate the presence of heteroskedastic residuals. The p-value on the Ramsey test is 0.9851, on the Koenker test it is 0.7911, and on the LM test it is 0.5166, and thus in all cases we fail-to-reject the null hypothesis of homoskedastic residuals. Table 43 summarizes the test results.

Table 43: Tests for Heteroskedastic Residuals (Pushmataha County)

Test	Value of Test Statistic	P-Value
Ramsey	0.0036	0.9581
Koenker	3.4740	0.7911
LM Test	0.8900	0.5166

Summary of Tests for Heteroskedastic Residuals

The results of the test indicate the presence of heteroskedasticity in the McCurtain County data. Thus, the estimated generalized least squares procedure was used on the reduced translog model for the McCurtain County data. The results for the Pushmataha County data do not indicate the presence of heteroskedastic residuals and therefore the ordinary least squares estimation was maintained.

Final Model Selection

Data

The data series for the explanatory variables are size of parcel, distance to the nearest city having a population of 2000 or more, distance to the nearest major roadway, expected timber productivity of the parcel, a binary variable indicating whether the parcel fronts a road, and the percentage of the parcel that is classified as open space. Tables 41 and 42 list the data used for the final hedonic land pricing models for McCurtain and Pushmataha Counties, respectively.

Table 44: Data for the Forestland Pricing Model (McCurtain County)

TRACTID	PRICE	ACRES	DistCity	DistHwy	TmProd	FRONT	OPEN
4507052124	500.00	40.00	28.69	3.46	102.63	1	0.00
4512052114	65.58	91.49	22.87	2.12	96.94	0	0.00
4531052125	200.00	20.00	24.39	3.96	102.00	1	0.00
4531052122	200.00	20.00	24.39	3.96	102.00	1	0.00
4534052143	375.00	40.00	22.37	4.76	117.00	1	0.00
4520062136	909.09	55.00	20.30	0.35	94.50	1	0.00
4522062111	601.18	39.09	18.33	0.81	102.64	1	0.00
4521032221	250.00	40.00	29.85	8.13	145.44	1	0.00
4528052232	731.71	41.00	18.52	2.86	95.60	1	0.00
4512062222	300.00	40.00	16.33	4.58	71.38	1	0.00
4501072215	1000.00	40.00	11.92	0.81	255.00	0	0.00
4501072241	1450.00	160.00	11.92	0.81	119.00	0	0.00
4524022321	1000.00	30.00	24.95	1.61	178.50	1	0.00
4501062312	2012.50	40.00	7.60	1.02	91.06	1	0.00
4509062333	100.00	40.00	10.40	3.19	142.00	1	50.00
4525062311	4602.99	17.38	8.84	4.37	102.00	1	0.00
4525062312	1021.43	59.72	8.84	4.37	94.00	1	0.00
4525062313	403.07	101.72	8.84	4.37	93.42	1	0.00
4519022412	1397.36	19.68	25.09	0.66	162.53	1	0.00
4526052427	400.00	5.00	4.73	1.10	102.00	1	0.00
4501062416	9329.65	14.47	1.93	0.20	83.86	1	0.00
4534062421	297.98	49.50	7.98	1.81	67.00	1	50.51

Table 44: Data for the Forestland Pricing Model (McCurtain County)

TRACTID	PRICE	ACRES	DistCity	DistHwy	TmProd	FRONT	OPEN
4507072432	2843.75	80.00	4.04	2.33	142.00	0	0.00
4508072423	887.31	112.70	5.96	2.95	102.00	0	0.00
4518072413	701.37	10.93	3.00	1.56	142.00	1	32.02
4509012512	594.80	107.60	29.87	1.28	74.62	0	53.07
4505032512	750.00	40.00	26.21	3.72	102.00	1	0.00
4522032522	600.00	50.00	40.67	6.88	67.00	0	0.00
4522032531	98.36	76.25	40.67	6.88	67.00	0	0.00
4536032532	1000.00	10.00	44.47	8.40	67.00	0	0.00
4521062521	6203.47	16.12	4.73	1.68	88.71	1	0.00
4513072532	250.00	40.00	14.04	6.70	102.00	0	0.00
4521072533	414.78	66.30	10.86	4.08	255.00	1	0.00
4517082535	300.00	20.00	9.79	5.06	117.00	0	0.00
4517082541	2237.50	20.00	9.79	5.06	117.00	0	0.00
4522082521	125.93	134.00	13.44	5.75	102.00	1	0.00
4515092511	400.00	20.00	18.05	2.80	102.00	1	0.00
4510022632	1467.40	87.57	25.83	6.34	102.00	1	0.00
4505062636	516.67	30.00	9.58	1.07	90.33	1	0.00
4526062631	370.37	94.50	14.22	3.59	136.29	1	62.96
4509082432	140.63	160.00	17.53	5.71	102.00	1	46.88
4509022721	500.00	80.00	27.32	2.76	102.00	1	0.00
4509022712	266.67	120.00	27.32	2.76	102.00	1	0.00
4531092723	700.00	20.00	27.78	7.62	102.00	1	0.00
4521102711	200.00	80.00	20.51	5.49	255.00	1	0.00

Table 45: Dataset for the Forestland Pricing Model (Pushmataha County)

TRACTID	PRICE	ACRES	DistCity	DistHwy	TmProd	FRONT	OPEN
6436011521	375.00	40.00	21.97	2.80	67.00	1	0.00
6407021591	555.56	90.00	16.33	2.43	61.87	1	0.00
6428031571	282.05	39.00	7.67	1.55	88.05	1	0.00
6433041512	400.00	150.00	10.75	4.96	54.40	1	30.00
6413011651	400.00	80.00	19.01	0.72	67.00	0	0.00
6415011621	333.33	150.00	19.86	2.70	182.31	1	0.00
6428021661	250.00	30.00	9.77	0.18	35.65	1	33.33
6429021671	250.00	40.00	8.98	0.42	61.23	0	0.00
6429021641	1100.00	80.00	8.98	0.42	75.16	0	0.00
6401041618	1153.85	13.00	3.19	0.82	255.00	1	69.23
6417041641	600.00	80.00	3.46	1.04	34.00	1	62.50
6422041631	558.44	77.00	3.47	0.04	50.59	1	46.75
6401011721	200.00	150.00	31.88	2.67	55.34	0	0.00
6423011771	177.78	45.00	26.34	0.67	67.00	0	0.00
6423011701	155.56	90.00	26.34	0.67	67.00	0	0.00
6431011721	149.68	157.00	30.47	1.99	67.00	0	0.00
6425021771	175.62	68.33	41.89	4.50	67.00	0	0.00
6425021781	85.69	11.67	41.89	4.50	67.00	0	0.00
6410031711	300.00	260.00	16.51	1.21	40.97	0	0.00
6420031751	325.00	40.00	11.30	1.85	84.70	1	75.00

Table 45: Dataset for the Forestland Pricing Model (Pushmataha County)

TRACTID	PRICE	ACRES	DistCity	DistHwy	TmProd	FRONT	OPEN
6421041791	500.00	80.00	6.99	0.89	79.90	0	0.00
6410011821	400.00	80.00	32.37	0.55	61.61	1	0.00
6410011822	550.00	80.00	32.37	0.55	56.80	1	0.00
6420011891	416.67	12.00	32.46	0.58	114.00	0	0.00
6426011861	325.00	40.00	21.97	0.73	50.50	1	0.00
6429011831	918.75	160.00	31.45	1.53	67.00	1	0.00
6435041804	228.13	160.00	18.73	1.92	91.63	0	26.25
6403021921	368.75	80.00	23.79	1.41	67.00	0	0.00
6412021971	200.00	40.00	26.87	2.83	67.00	1	0.00
6412041921	150.00	120.00	26.37	2.16	47.75	0	0.00
6408022011	417.86	140.00	35.57	2.55	67.00	1	0.00
6414022014	1250.00	40.00	37.43	0.80	67.00	1	0.00
6416022081	100.00	40.00	35.70	1.22	67.00	0	0.00
6436022061	300.00	20.00	42.99	2.45	67.00	0	0.00
6416022013	125.00	20.00	35.79	3.74	34.00	1	0.00
6419022241	325.00	20.00	34.64	3.30	72.60	0	0.00

Functional Form and Estimation Procedures

Based upon theory, review of literature, and the results of specification tests the translog functional form was chosen. Due to heteroskedasticity in the McCurtain County data an estimated generalized least squares procedure was used. For the Pushmataha County data, tests did not indicate the presence of heteroskedastic residuals, thus the ordinary least squares estimation procedure was used.

SAS Code for the Hedonic Forestland Pricing Model

The following econometric code is an example of the SAS program for the final models.

```
/******************Hedonic Price Model for McCurtain Forestland********************/
filename HPMmc dde 'excel| HPMmc_Data! R2C2:R46C11';
data HPMmc; infile HPMmc;
INPUT PRICE ACRES OPEN TmProd FRONT DistHwy DistCity PopGro
TranCost DistNat; LPrice = LOG(PRICE); LAcres = LOG(ACRES); proc print;

/*Estimated Reduced Model with Translog Functional Form*/
proc reg data = HPMmc;
model LPrice = LAcres DistCity DistHwy TmProd FRONT OPEN / ACOV;

/*From this point forward the code applies only to McCurtain County*/
/*creation of weight for EGLS*/
output out = one R = UHAT; data two; set one;
UHAT2 = UHAT**2; LUHAT2 = LOG(UHAT2);

proc reg; model LUHAT2 = LAcres DistCity DistHwy TmProd FRONT OPEN;
output out = three P=V; data three; set three;
VARHAT = exp(V); WT = 1/VARHAT;

/*Estimated Generalized Least Squares Model*/
PROC REG; Model LPrice = LAcres DistCity DistHwy TmProd FRONT OPEN;
Weight WT;

run;
```

Estimation Results (McCurtain County)

The following is the SAS output for the reduced translog functional form model using the estimated generalized least squares procedure.

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	6	170.36313	28.39385	7.45	<.0001
Error	38	144.92306	3.81376		
Corrected Total	44	315.28618			

Root MSE	1.95289	R-Square	0.5403
Dependent Mean	5.86933	Adj R-Sq	0.4678
Coeff Var	33.27271		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	1	9.55791	0.85668	11.16	<.0001
LAcres	1	-0.43063	0.18940	-2.27	0.0287
DistCity	1	-0.02133	0.01416	-1.51	0.1403
DistHwy	1	-0.15744	0.05833	-2.70	0.0103
TmProd	1	-0.00272	0.00135	-2.02	0.0505
FRONT	1	-0.26865	0.31400	-0.86	0.3976
OPEN	1	-0.01221	0.00650	-1.88	0.0678

Estimation Results (Pushmataha County)

The following is the SAS output for the reduced translog functional form model using the ordinary least squares procedure.

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	6	6.49048	1.08175	3.67	0.0078
Error	29	8.53627	0.29435		
Corrected Total	35	15.02675			

Root MSE	0.54254	R-Square	0.4319
Dependent Mean	5.77567	Adj R-Sq	0.3144
Coeff Var	9.38873		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	1	5.17592	0.71432	7.25	<.0001
LAcres	1	0.11581	0.12388	0.93	0.3576
DistCity	1	-0.00529	0.01099	-0.48	0.6338
DistHwy	1	-0.17563	0.07865	-2.23	0.0334
TmProd	1	0.00438	0.00246	1.78	0.0856
FRONT	1	0.50055	0.19673	2.54	0.0165
OPEN	1	-0.00085	0.00592	-0.14	0.8874

Summary of Forestland Price Estimation

The estimation of forestland prices in McCurtain and Pushmataha Counties was conducted on a series of explanatory variables describing the size of the forestland parcel, the distance to the nearest city having a population of 2000 or more, the distance to the nearest major roadway, the expected timber productivity of the forestland parcel, a binary variable indicating whether the parcel fronts on a road of any type, and the proportion of the parcel having open land.

The data for McCurtain County exhibited heteroskedasticity and the data for Pushmataha County did not exhibit heteroskedasticity. The estimated generalized least squares procedure was used on the McCurtain County data and ordinary least squares procedure for the Pushmataha County data. Both McCurtain and Pushmataha County forestland pricing models used a transcendental logarithmic functional form.

APPENDIX-2

ANNUALIZED VALUE OF TIMBER AND NON-TIMBER OUTPUTS

Expected Annual Removals

Growing stock removals, for this research, was used as a proxy for timber outputs. The expected annual removals per acre for each forestland parcel in the forestland sales transactions dataset was calculated as follows:

$$ExRem_{i_j} = \left(\frac{TmProd_{i_j}}{\sum_{i=1}^{n_j} TmProd_{i_j} \Big/ n_j} \right) \left(\frac{Removals_j}{Acres_j} \right), \quad j = 0, 1; i_0 = 1, \cdots, 36; i_1 = 1, \cdots, 45.$$

Where:

$ExRem_{i_j}$ is the expected annual removals per acre for forestland parcel i in county j, (ft^3/acre),

$TmProd_{i_j}$ is the expected annual timber productivity per acre for forestland parcel i in county j, (ft^3/acre),

$Removals_j$ is the total annual growing stock removals on NIPF as reported by the Southern FIA for county j, (ft^3),

$Acres_j$ is the total NIPF acres in county j, and

n_j is the total number of forestland sales transactions parcels in county j.

Recalling that the total number of NIPF acres in McCurtain County is 178,000 and that the annualized growing stock removals for the county are 12.6 million cubic feet, the calculation for the expected removals for observation #1 in McCurtain County is as follows:

$$ExRem = \left(\frac{102.63}{114.65}\right)\left(\frac{12{,}600{,}000}{178{,}000}\right) = 63.36.$$

Thus, for this parcel the expected annualized removals are 63.36 ft^3/acre.

For Pushmataha County the total number of NIPF acres is 375,800 and the annualized growing stock removals are 5.9 million cubic feet, for observation #1 in Pushmataha County, the calculation for the expected annualized removals is as follows:

$$ExRem = \left(\frac{67}{72.95}\right)\left(\frac{5{,}900{,}000}{375{,}800}\right) = 14.42.$$

Thus, for this parcel the expected annualized removals are 14.42 ft^3/acre.

Table 46 lists the expected annualized removals per acre for the forestland parcels in McCurtain County and Table 47 lists the removals for Pushmataha County.

Table 46: Expected Annualized Removals (McCurtain County)

TRACTID	County	QUARTER	SECTION	TWP	NS	RNG	EW	PRICE	ACRES	TmProd	Removals
4507052124	McCurtain	SE/4	7	5	S	21	E	500.00	40.00	102.63	63.36
4512052114	McCurtain	SE/4	12	5	S	21	E	65.58	91.49	96.94	59.85
4531052125	McCurtain	SE/4	31	5	S	21	E	200.00	20.00	102.00	62.97
4531052122	McCurtain	SE/4	31	5	S	21	E	200.00	20.00	102.00	62.97
4534052143	McCurtain	SE/4	34	5	S	21	E	375.00	40.00	117.00	72.23
4520062136	McCurtain	SE/4	20	6	S	21	E	909.09	55.00	94.50	58.34
4522062111	McCurtain	SE/4	22	6	S	21	E	601.18	39.09	102.64	63.37
4521032221	McCurtain	SE/4	21	3	S	22	E	250.00	40.00	145.44	89.79
4528052232	McCurtain	SE/4	28	5	S	22	E	731.71	41.00	95.60	59.02
4512062222	McCurtain	SE/4	12	6	S	22	E	300.00	40.00	71.38	44.07
4501072215	McCurtain	SE/4	1	7	S	22	E	1,000.00	40.00	255.00	157.43
4501072241	McCurtain	SE/4	1	7	S	22	E	1,450.00	160.00	119.00	73.47
4524022321	McCurtain	SE/4	24	2	S	23	E	1,000.00	30.00	178.50	110.20
4501062312	McCurtain	SE/4	1	6	S	23	E	2,012.50	40.00	91.06	56.22
4509062333	McCurtain	SE/4	9	6	S	23	E	100.00	40.00	142.00	87.67
4525062311	McCurtain	SE/4	25	6	S	23	E	4,602.99	17.38	102.00	62.97
4525062312	McCurtain	SE/4	25	6	S	23	E	1,021.43	59.72	94.00	58.04
4525062313	McCurtain	SE/4	25	6	S	23	E	403.07	101.72	93.42	57.68
4519022412	McCurtain	SE/4	19	2	S	24	E	1,397.36	19.68	162.53	100.34
4526052427	McCurtain	SE/4	26	5	S	24	E	400.00	5.00	102.00	62.97
4501062416	McCurtain	SE/4	1	6	S	24	E	9,329.65	14.47	83.86	51.77
4534062421	McCurtain	SE/4	34	6	S	24	E	297.98	49.50	67.00	41.37
4507072432	McCurtain	SE/4	7	7	S	24	E	2,843.75	80.00	142.00	87.67
4508072423	McCurtain	SE/4	8	7	S	24	E	887.31	112.70	102.00	62.97

Table 46: Expected Annualized Removals (McCurtain County)

TRACTID	County	QUARTER	SECTION	TWP	NS	RNG	EW	PRICE	ACRES	TmProd	Removals
4518072413	McCurtain	SE/4	18	7	S	24	E	701.37	10.93	142.00	87.67
4509012512	McCurtain	SE/4	9	1	S	25	E	594.80	107.60	74.62	46.07
4505032512	McCurtain	SE/4	5	3	S	25	E	750.00	40.00	102.00	62.97
4522032522	McCurtain	SE/4	22	3	S	25	E	600.00	50.00	67.00	41.37
4522032531	McCurtain	SE/4	22	3	S	25	E	98.36	76.25	67.00	41.37
4536032532	McCurtain	SE/4	36	3	S	25	E	1,000.00	10.00	67.00	41.37
4521062521	McCurtain	SE/4	21	6	S	25	E	6,203.47	16.12	88.71	54.77
4513072532	McCurtain	SE/4	13	7	S	25	E	250.00	40.00	102.00	62.97
4521072533	McCurtain	SE/4	21	7	S	25	E	414.78	66.30	255.00	157.43
4517082535	McCurtain	SE/4	17	8	S	25	E	300.00	20.00	117.00	72.23
4517082541	McCurtain	SE/4	17	8	S	25	E	2,237.50	20.00	117.00	72.23
4522082521	McCurtain	SE/4	22	8	S	25	E	125.93	134.00	102.00	62.97
4515092511	McCurtain	SE/4	15	9	S	25	E	400.00	20.00	102.00	62.97
4510022632	McCurtain	SE/4	10	2	S	26	E	1,467.40	87.57	102.00	62.97
4505062636	McCurtain	SE/4	5	6	S	26	E	516.67	30.00	90.33	55.77
4526062631	McCurtain	SE/4	26	6	S	26	E	370.37	94.50	136.29	84.14
4509082432	McCurtain	SE/4	22	7	S	26	E	140.63	160.00	102.00	62.97
4509022721	McCurtain	SE/4	9	2	S	27	E	500.00	80.00	102.00	62.97
4509022712	McCurtain	SE/4	9	2	S	27	E	266.67	120.00	102.00	62.97
4531092723	McCurtain	SE/4	31	9	S	27	E	700.00	20.00	102.00	62.97
4521102711	McCurtain	SE/4	21	10	S	27	E	200.00	80.00	255.00	157.43
Average								1,082.59	55.11	114.65	70.79
Minimum								65.58	5.00	67.00	41.37
Maximum								9,329.65	160.00	255.00	157.43
Number of observations								45.00	45.00	45.00	45.00

Table 47: Expected Annualized Removals (Pushmataha County)

TRACTID	County	QUARTER	SECTION	TWP	NS	RNG	EW	PRICE	ACRES	TmProd	Removals
6436011521	Pushmataha	SE/4	36	1	S	15	E	375.00	40.00	67.00	14.42
6407021591	Pushmataha	SE/4	7	2	S	15	E	555.56	90.00	61.87	13.32
6428031571	Pushmataha	SE/4	28	3	S	15	E	282.05	39.00	88.05	18.95
6433041512	Pushmataha	SE/4	33	4	S	15	E	400.00	150.00	54.40	11.71
6413011651	Pushmataha	SE/4	13	1	S	16	E	400.00	80.00	67.00	14.42
6415011621	Pushmataha	SE/4	15	1	S	16	E	333.33	150.00	182.31	39.24
6428021661	Pushmataha	SE/4	28	2	S	16	E	250.00	30.00	35.65	7.67
6429021671	Pushmataha	SE/4	29	2	S	16	E	250.00	40.00	61.23	13.18
6429021641	Pushmataha	SE/4	29	2	S	16	E	1,100.00	80.00	75.16	16.18
6401041618	Pushmataha	SE/4	1	4	S	16	E	1,153.85	13.00	255.00	54.88
6417041641	Pushmataha	SE/4	17	4	S	16	E	600.00	80.00	34.00	7.32
6422041631	Pushmataha	SE/4	22	4	S	16	E	558.44	77.00	50.59	10.89
6401011721	Pushmataha	SE/4	1	1	S	17	E	200.00	150.00	55.34	11.91
6423011771	Pushmataha	NE/4	23	1	N	17	E	177.78	45.00	67.00	14.42
6423011701	Pushmataha	NE/4	23	1	N	17	E	155.56	90.00	67.00	14.42
6431011721	Pushmataha	NE/4	31	1	N	17	E	149.68	157.00	67.00	14.42
6425021771	Pushmataha	NE/4	25	2	N	17	E	175.62	68.33	67.00	14.42
6425021781	Pushmataha	NE/4	25	2	N	17	E	85.69	11.67	67.00	14.42
6410031711	Pushmataha	SE/4	10	3	S	17	E	300.00	260.00	40.97	8.82
6420031751	Pushmataha	SE/4	20	3	S	17	E	325.00	40.00	84.70	18.23
6421041791	Pushmataha	SE/4	21	4	S	17	E	500.00	80.00	79.90	17.20
6410011821	Pushmataha	NE/4	10	1	N	18	E	400.00	80.00	61.61	13.26
6410011822	Pushmataha	NE/4	10	1	N	18	E	550.00	80.00	56.80	12.22
6420011891	Pushmataha	NE/4	20	1	N	18	E	416.67	12.00	114.00	24.54
6426011861	Pushmataha	SE/4	26	1	S	18	E	325.00	40.00	50.50	10.87

Table 47: Expected Annualized Removals (Pushmataha County)

TRACTID	County	QUARTER	SECTION	TWP	NS	RNG	EW	PRICE	ACRES	TmProd	Removals
6429011831	Pushmataha	NE/4	29	1	N	18	E	918.75	160.00	67.00	14.42
6435041804	Pushmataha	SE/4	35	4	S	18	E	228.13	160.00	91.63	19.72
6403021921	Pushmataha	NE/4	3	2	N	19	E	368.75	80.00	67.00	14.42
6412021971	Pushmataha	NE/4	12	2	N	19	E	200.00	40.00	67.00	14.42
6412041921	Pushmataha	SE/4	12	4	S	19	E	150.00	120.00	47.75	10.28
6408022011	Pushmataha	NE/4	8	2	N	20	E	417.86	140.00	67.00	14.42
6414022014	Pushmataha	NE/4	14	2	N	20	E	1,250.00	40.00	67.00	14.42
6416022081	Pushmataha	NE/4	16	2	N	20	E	100.00	40.00	67.00	14.42
6436022061	Pushmataha	NE/4	36	2	N	20	E	300.00	20.00	67.00	14.42
6416022013	Pushmataha	NE/4	16	2	N	22	E	125.00	20.00	34.00	7.32
6419022241	Pushmataha	NE/4	19	2	N	22	E	325.00	20.00	72.60	15.63
Average								400.07	78.42	72.95	15.70
Minimum								85.69	11.67	34.00	7.32
Maximum								1,250.00	260.00	255.00	54.88
Number of observations								36	36	36	36

Adjusted Stumpage Prices

The following equation was used to obtain the adjusted stumpage price for each observation:

$$p_{adj} = p_{Tran}\left(\overline{D} - D_i\right) + p_{avg}$$

where:

p_{adj} is the adjusted stumpage price (\$/ft^3),

p_{Tran} is the price per cubic foot mile to transport timber equal to \$0.0024,

p_{avg} is the average stumpage price (\$/ft^3) equal to \$0.6942/ft^3,

$\overline{D} = \frac{\sum_{i=1}^{81} D_i}{81}$ is the average distance in roadway miles to the nearest community with two or more wood processing facilities, and

D_i is the distance in roadway miles from parcel i to the nearest community with two or more wood processing facilities.

The divisor for $\overline{D}$ is 81 since there are a total of 81 observations throughout the region and in some cases the closest wood processing facility to the forestland parcel is outside of the county in which the forestland parcel resides. As an example calculation consider the first observation in Table-45:

$$p_{adj} = 0.0024(15.89 - 11.27) + 0.6942 = 0.7053.$$

Thus, the first observation has an adjusted stumpage price of \$0.7053/ft^3. Table 48 lists the adjusted stumpage prices for all 81 observations.

Table 48: Adjusted Stumpage Prices

TRACTID	County	QUARTER	SECTION	TWP	NS	RNG	EW	PRICE	DistMill	Mill Town	Adjusted Stumpage Price
4507052124	McCurtain	SE/4	7	5	S	21	E	500.00	11.27	Valliant	0.7053
4512052114	McCurtain	SE/4	12	5	S	21	E	65.58	7.15	Wright City	0.7151
4531052125	McCurtain	SE/4	31	5	S	21	E	200.00	6.96	Valliant	0.7156
4531052122	McCurtain	SE/4	31	5	S	21	E	200.00	6.96	Valliant	0.7156
4534052143	McCurtain	SE/4	34	5	S	21	E	375.00	4.97	Valliant	0.7203
4520062136	McCurtain	SE/4	20	6	S	21	E	909.09	2.88	Valliant	0.7253
4522062111	McCurtain	SE/4	22	6	S	21	E	601.18	0.93	Valliant	0.7299
4521032221	McCurtain	SE/4	21	3	S	22	E	250.00	13.30	Battiest	0.7005
4528052232	McCurtain	SE/4	28	5	S	22	E	731.71	2.78	Wright City	0.7255
4512062222	McCurtain	SE/4	12	6	S	22	E	300.00	5.31	Wright City	0.7195
4501072215	McCurtain	SE/4	1	7	S	22	E	1,000.00	9.43	Valliant	0.7097
4501072241	McCurtain	SE/4	1	7	S	22	E	1,450.00	9.43	Valliant	0.7097
4524022321	McCurtain	SE/4	24	2	S	23	E	1,000.00	7.26	Battiest	0.7149
4501062312	McCurtain	SE/4	1	6	S	23	E	2,012.50	7.44	Broken Bow	0.7145
4509062333	McCurtain	SE/4	9	6	S	23	E	100.00	9.13	Wright City	0.7104
4525062311	McCurtain	SE/4	25	6	S	23	E	4,602.99	8.05	Broken Bow	0.7130
4525062312	McCurtain	SE/4	25	6	S	23	E	1,021.43	8.05	Broken Bow	0.7130
4525062313	McCurtain	SE/4	25	6	S	23	E	403.07	8.05	Broken Bow	0.7130
4519022412	McCurtain	SE/4	19	2	S	24	E	1,397.36	8.28	Battiest	0.7125
4526052427	McCurtain	SE/4	26	5	S	24	E	400.00	5.03	Broken Bow	0.7202

Table 48: Adjusted Stumpage Prices

TRACTID	County	QUARTER	SECTION	TWP	NS	RNG	EW	PRICE	DistMill	Mill Town	Adjusted Stumpage Price
4501062416	McCurtain	SE/4	1	6	S	24	E	9,329.65	2.24	Broken Bow	0.7268
4534062421	McCurtain	SE/4	34	6	S	24	E	297.98	7.18	Broken Bow	0.7151
4507072432	McCurtain	SE/4	7	7	S	24	E	2,843.75	4.59	Idabel	0.7212
4508072423	McCurtain	SE/4	8	7	S	24	E	887.31	6.51	Idabel	0.7167
4518072413	McCurtain	SE/4	18	7	S	24	E	701.37	3.55	Idabel	0.7237
4509012512	McCurtain	SE/4	9	1	S	25	E	594.80	17.44	Cove	0.6907
4505032512	McCurtain	SE/4	5	3	S	25	E	750.00	18.51	Battiest	0.6881
4522032522	McCurtain	SE/4	22	3	S	25	E	600.00	25.58	Cove	0.6713
4522032531	McCurtain	SE/4	22	3	S	25	E	98.36	25.58	Cove	0.6713
4536032532	McCurtain	SE/4	36	3	S	25	E	1,000.00	29.38	Cove	0.6623
4521062521	McCurtain	SE/4	21	6	S	25	E	6,203.47	4.64	Broken Bow	0.7211
4513072532	McCurtain	SE/4	13	7	S	25	E	250.00	13.46	Idabel	0.7001
4521072533	McCurtain	SE/4	21	7	S	25	E	414.78	10.28	Idabel	0.7077
4517082535	McCurtain	SE/4	17	8	S	25	E	300.00	9.21	Idabel	0.7102
4517082541	McCurtain	SE/4	17	8	S	25	E	2,237.50	9.21	Idabel	0.7102
4522082521	McCurtain	SE/4	22	8	S	25	E	125.93	12.85	Idabel	0.7016
4515092511	McCurtain	SE/4	15	9	S	25	E	400.00	17.46	Idabel	0.6906
4510022632	McCurtain	SE/4	10	2	S	26	E	1,467.40	10.74	Cove	0.7066
4505062636	McCurtain	SE/4	5	6	S	26	E	516.67	9.57	Broken Bow	0.7094
4526062631	McCurtain	SE/4	26	6	S	26	E	370.37	14.22	Broken Bow	0.6983
4509082432	McCurtain	SE/4	22	7	S	26	E	140.63	14.90	Idabel	0.6918
4509022721	McCurtain	SE/4	9	2	S	27	E	500.00	12.31	Cove	0.7029

Table 48: Adjusted Stumpage Prices

TRACTID	County	QUARTER	SECTION	TWP	NS	RNG	EW	PRICE	DistMill	Mill Town	Adjusted Stumpage Price
4509022712	McCurtain	SE/4	9	2	S	27	E	266.67	12.31	Cove	0.7029
4531092723	McCurtain	SE/4	31	9	S	27	E	700.00	27.60	Ashdown	0.6665
4521102711	McCurtain	SE/4	21	10	S	27	E	200.00	20.26	New Boston	0.6835
6436011521	Pushmataha	SE/4	36	1	S	15	E	375.00	22.09	Antlers	0.6796
6407021591	Pushmataha	SE/4	7	2	S	15	E	555.56	16.54	Antlers	0.6928
6428031571	Pushmataha	SE/4	28	3	S	15	E	282.05	7.87	Antlers	0.7134
6433041512	Pushmataha	SE/4	33	4	S	15	E	400.00	10.47	Antlers	0.7073
6413011651	Pushmataha	SE/4	13	1	S	16	E	400.00	19.13	Antlers	0.6867
6415011621	Pushmataha	SE/4	15	1	S	16	E	333.33	19.98	Antlers	0.6846
6428021661	Pushmataha	SE/4	28	2	S	16	E	250.00	9.89	Antlers	0.7086
6429021671	Pushmataha	SE/4	29	2	S	16	E	250.00	9.10	Antlers	0.7105
6429021641	Pushmataha	SE/4	29	2	S	16	E	1,100.00	9.10	Antlers	0.7105
6401041618	Pushmataha	SE/4	1	4	S	16	E	1,153.85	2.79	Antlers	0.7255
6417041641	Pushmataha	SE/4	17	4	S	16	E	600.00	3.18	Antlers	0.7105
6422041631	Pushmataha	SE/4	22	4	S	16	E	558.44	3.19	Antlers	0.7246
6401011721	Pushmataha	SE/4	1	1	S	17	E	200.00	31.55	Antlers	0.6596
6423011771	Pushmataha	NE/4	23	1	N	17	E	177.78	29.05	Antlers	0.6631
6423011701	Pushmataha	NE/4	23	1	N	17	E	155.56	29.05	Antlers	0.6631
6431011721	Pushmataha	NE/4	31	1	N	17	E	149.68	30.51	Antlers	0.6571
6425021771	Pushmataha	NE/4	25	2	N	17	E	175.62	41.51	Wilburton	0.6335
6425021781	Pushmataha	NE/4	25	2	N	17	E	85.69	41.51	Wilburton	0.6335
6410031711	Pushmataha	SE/4	10	3	S	17	E	300.00	16.17	Antlers	0.6937

Table 48: Adjusted Stumpage Prices

TRACTID	County	QUARTER	SECTION	TWP	NS	RNG	EW	PRICE	DistMill	Mill Town	Adjusted Stumpage Price
6420031751	Pushmataha	SE/4	20	3	S	17	E	325.00	10.96	Antlers	0.7061
6421041791	Pushmataha	SE/4	21	4	S	17	E	500.00	6.59	Antlers	0.7165
6410011821	Pushmataha	NE/4	10	1	N	18	E	400.00	31.60	Antlers	0.6570
6410011822	Pushmataha	NE/4	10	1	N	18	E	550.00	31.60	Antlers	0.6570
6420011891	Pushmataha	NE/4	20	1	N	18	E	416.67	26.25	Antlers	0.6611
6426011861	Pushmataha	SE/4	26	1	S	18	E	325.00	21.64	Antlers	0.6807
6429011831	Pushmataha	NE/4	29	1	N	18	E	918.75	29.35	Antlers	0.6624
6435041804	Pushmataha	SE/4	35	4	S	18	E	228.13	18.33	Antlers	0.6886
6403021921	Pushmataha	NE/4	3	2	N	19	E	368.75	23.83	Wilburton	0.6755
6412021971	Pushmataha	NE/4	12	2	N	19	E	200.00	26.52	Wilburton	0.6691
6412041921	Pushmataha	SE/4	12	4	S	19	E	150.00	22.83	Valliant	0.6779
6408022011	Pushmataha	NE/4	8	2	N	20	E	417.86	34.21	Wilburton	0.6508
6414022014	Pushmataha	NE/4	14	2	N	20	E	1,250.00	36.24	Wilburton	0.6460
6416022081	Pushmataha	NE/4	16	2	N	20	E	100.00	34.39	Wilburton	0.6504
6436022061	Pushmataha	NE/4	36	2	N	20	E	300.00	33.02	Battiest	0.6536
6416022013	Pushmataha	NE/4	16	2	N	22	E	125.00	34.45	Battiest	0.6502
6419022241	Pushmataha	NE/4	19	2	N	22	E	325.00	30.18	Battiest	0.6604
Average									15.89		0.69
Minimum									0.93		0.63
Maximum									41.51		0.73
Number of observations									81		81

Tests for Significant Difference in Removals and Timber Productivity between Forestlands in McCurtain and Pushmataha Counties

The regression analyses of forestland sales prices and the shares, and the calculations of the elasticities were on each county rather than combining the two counties. This was done due to the fact that there are significant differences in the observed sales prices, reported timber productivities, and expected annual removals between the two counties.

Procedures for Tests for Two or More Means[15]

Suppose we have two populations with means μ_1 and μ_2. The null and alternative hypotheses are:

$$H_0: \quad \mu_1 = \mu_2$$

$$H_A: \quad \mu_1 \neq \mu_2$$

For the null hypothesis of no difference, t is defined by:

$$t = \frac{\overline{Y_1} - \overline{Y_2}}{\sqrt{\left(\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}\right)}}$$

The above t-statistic is appropriate if the two populations do not have common variances. The effective degrees of freedom of the t-statistic is given as:

[15] The procedures for the tests for two or means are from: Steel, Robert G. D.; James H. Torrie; and David A. Dickey. 1997. *Principles and Procedures of Statistics: A Biometrical Approach, Third Edition.* McGraw-Hill, New York, NY. 666 pp.

$$df = \frac{\left(\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}\right)^2}{\frac{\left(s_1^2/n_1\right)^2}{n_1 - 1} + \frac{\left(s_2^2/n_2\right)^2}{n_2 - 1}}.$$

If the calculated t- statistic is less than the critical value, we fail to reject the null hypothesis of no differences between means, otherwise we reject the null hypothesis and conclude that there is a significant difference between the means.

To determine whether we use the preceding t-statistic we must test for homogeneity of variance. The null and alternative hypotheses are:

$$H_0: \quad \sigma_1 = \sigma_2$$

$$H_A: \quad \sigma_1 \neq \sigma_2 .$$

The test statistic is defined as:

$$F = \frac{s^2 \max}{s^2 \min}, \quad df = 1, n_1 + n_2 .$$

If $F_{calc} < F^{\alpha}_{(1, n_1 + n_2)}$ then we fail to reject H_0 and conclude that the two populations have common variances, otherwise we reject H_0 and conclude that the two populations do not have common variances.

If we fail to reject H_0 and conclude that the two populations have common variances, then we use the following t-statistic:

$$t = \frac{\overline{Y_1} - \overline{Y_2}}{\sqrt{s_p^2\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}},$$

which has $n_1 + n_2 - 2$ degrees of freedom. s_p^2 is the pooled variance estimator and is defined by:

$$s_p^2 = \frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{(n_1 + n_2 - 2)}.$$

Test for Significant Difference between Forestland Sale Prices

The results of the test indicate that there is a significant difference between the sale prices of forestland in McCurtain and Pushmataha Counties.

Let the subscript 1 denote McCurtain County and the subscript 2 denote Pushmataha County.

$s_1^2 = 2{,}920{,}014.45$	$\overline{Y_1} = 1{,}082.59$	$n_1 = 45$	$F_{(1,\,81)}^{0.05} = 3.97$
$s_2^2 = 83{,}791.87$	$\overline{Y_2} = 400.07$	$n_2 = 36$	

First test for homogeneity of variances using the F - statistic.

$$F = \frac{s_{\max}^2}{s_{\min}^2} = \frac{s_1^2}{s_2^2} = \frac{2{,}920{,}014.45}{83{,}791.87} = 34.85$$

Since the calculated F - statistic = 34.85 is greater than $F_{(1,\,81)}^{0.05} = 3.97$, we reject the null hypothesis of homogeneity and conclude that the variances are heterogeneous. Thus we use the following t - statistic:

$$t = \frac{\overline{Y_1} - \overline{Y_2}}{\sqrt{\left(\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}\right)}}$$

$$t = \frac{1{,}082.59 - 400.07}{\sqrt{\left(\frac{2{,}920{,}014.45}{45} + \frac{8{,}3791.87}{36}\right)}} = \frac{682.52}{259.26} = 2.633$$

The effective degrees of freedom for the t- statistic are 47.

$$df = \frac{\left(\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}\right)^2}{\frac{\left(s_1^2/n_1\right)^2}{n_1 - 1} + \frac{\left(s_2^2/n_2\right)^2}{n_2 - 1}} = \frac{\left(\frac{2{,}920{,}014.45}{45} + \frac{83{,}791.87}{36}\right)^2}{\left(\frac{(2{,}920{,}014.45/45)^2}{45-1} + \frac{(83{,}791.87/36)^2}{36-1}\right)}$$

$$= \frac{(64{,}889.21 + 2{,}327.55)^2}{95{,}695{,}672.14 + 154{,}785.4} = \frac{(67{,}216.76)^2}{95{,}850{,}457.54} \cong 47$$

$$t_{47}^{0.05} = 1.679$$

Since the calculated t-statistic of 2.633 is greater than $t_{47}^{0.05} = 1.679$ we reject the null hypothesis of no difference between the mean sale price of forestland and conclude that there is a significant difference in the mean sale price of forestland between McCurtain and Pushmataha Counties.

<u>Test for Significant Difference between Timber Productivities</u>

The results of the test indicate that there is a significant difference between timber productivity of forestlands in McCurtain and Pushmataha Counties.

Let the subscript 1 denote McCurtain County and the subscript 2 denote Pushmataha County.

$s_1^2 = 2{,}022.12$	$\overline{Y}_1 = 114.65$	$n_1 = 45$	$F_{(1,81)}^{0.05} = 3.97$
$s_2^2 = 1{,}612.61$	$\overline{Y}_2 = 72.95$	$n_2 = 36$	

First test for homogeneity of variances using the F - statistic.

$$F = \frac{s_{max}^2}{s_{min}^2} = \frac{s_1^2}{s_2^2} = \frac{2{,}022.12}{1{,}612.61} = 1.25$$

Since the calculated F - statistic = 1.25 is less than $F^{0.05}_{(1,81)} = 3.97$, we fail to reject the null hypothesis of homogeneity and conclude that the variances are homogeneous. Thus we use the following t - statistic:

$$t = \frac{\overline{Y_1} - \overline{Y_2}}{\sqrt{s_p^2\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}},$$

which requires the use of the pooled variance estimator. The pooled variance estimator is given by:

$$s_p^2 = \frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{(n_1 + n_2 - 2)} = \frac{(45-1)2{,}022.12 + (36-1)1{,}612.61}{(45+36-2)}$$
$$= \frac{88{,}973.28 + 56{,}441.35}{79} = \frac{145{,}414.63}{79} = 1{,}840.69$$

The t - statistic is:

$$t = \frac{\overline{Y_1} - \overline{Y_2}}{\sqrt{s_p^2\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}} = \frac{114.65 - 72.95}{\sqrt{1{,}840.69\left(\frac{1}{45} + \frac{1}{36}\right)}} = \frac{41.7}{9.59} = 4.347.$$

$$t_{79}^{0.05} = 1.667$$

Since the calculated t-statistic of 4.347 is greater than $t_{79}^{0.05} = 1.667$ we reject the null hypothesis of no difference between the mean timber productivities and conclude that there is a significant difference in the mean timber productivities of forestlands in McCurtain and Pushmataha Counties.

Test for Significant Difference between Removals

The results of the test indicate that there is a significant difference in the mean removals between forestlands in McCurtain and Pushmataha Counties.

Let the subscript 1 denote McCurtain County and the subscript 2 denote Pushmataha County.

$s_1^2 = 770.77$ $\quad \overline{Y_1} = 70.79$ $\quad n_1 = 45$ $\quad F_{(1,81)}^{0.05} = 3.97$

$s_2^2 = 74.70$ $\quad \overline{Y_2} = 15.70$ $\quad n_2 = 36$

First test for homogeneity of variances using the F - statistic.

$$F = \frac{s_{\max}^2}{s_{\min}^2} = \frac{s_1^2}{s_2^2} = \frac{770.77}{74.70} = 10.32$$

Since the calculated F - statistic = 10.32 is greater than $F_{(1,81)}^{0.05} = 3.97$, we reject the null hypothesis of homogeneity and conclude that the variances are heterogeneous. Thus we use the following t - statistic:

$$t = \frac{\overline{Y_1} - \overline{Y_2}}{\sqrt{\left(\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}\right)}}$$

$$t = \frac{70.79 - 15.70}{\sqrt{\left(\frac{770.77}{45} + \frac{74.70}{36}\right)}} = \frac{55.09}{4.38} = 12.578$$

The effective degrees of freedom for the t - statistic are 55.

$$df = \frac{\left(\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}\right)^2}{\frac{(s_1^2/n_1)^2}{n_1 - 1} + \frac{(s_2^2/n_2)^2}{n_2 - 1}} = \frac{\left(\frac{770.77}{45} + \frac{74.70}{36}\right)^2}{\left(\frac{(770.77/45)^2}{45-1} + \frac{(74.70/36)^2}{36-1}\right)}$$

$$= \frac{(17.13 + 2.08)^2}{6.67 + 0.12} = \frac{(19.21)^2}{6.69} \cong 55$$

$$t_{55}^{0.05} = 1.674$$

Since the calculated t-statistic of 12.578 is greater than $t_{55}^{0.05} = 1.674$ we reject the null hypothesis of no difference between the mean timber removals and conclude that there is a significant difference in the mean timber removals from forestlands in McCurtain and Pushmataha Counties.

Discounted Average Annual per Acre Timber Production Costs for McCurtain County

Due to the fact that there is a significant difference in the timber productivity and removals between McCurtain and Pushmataha it is assumed that there are two different timber management levels: a level of management involving silvicultural activities, and therefore production costs, in McCurtain County, and a level of management not involving prescribed silvicultural activities in Pushmataha County, and therefore no production costs. The calculation of the discounted average annual timber production costs for McCurtain County appears in Table 49.

Table 49: Discounted Timber Production Costs for McCurtain County

Assumed Silvicultural Activities for McCurtain County NIPF	Cost/Acre ($)	Year	Discount Factor	NPV
Site Prep with Chemical Treatment	85	0	1.00	85.00
Seedlings plus Planting	65	0	1.00	65.00
Early Release of Herbaceous Weeds (Chemical Treatment)	55	0	1.00	55.00
Mid-rotation Release of Herbaceous Weeds and Wood Plants (Chemical Treatment)	70	15	0.48	33.67
Timber Marking for Thinning	15	15	0.48	7.22
Thinning (could be sold as pulp or firewood)	70	15	0.48	33.67
Harvest (rotation age)		30		
Total Expenditures	360			279.56
Average Annual Cost Per Acre (Total/Rotation Age)	12			9.32

Alternative Real Rate of Return = 0.05

The Expected Net Annualized Value of Removals

Under the preceding assumptions, the expected net annualized value of removals per acre for each observation was calculated using the following equation:

$$P_{Rem} = (ExRem)(p_{adj}) - C_{Prod}$$

where:

P_{Rem} is the expected net annualized value of removals per acre for parcel i,

$ExRem$ is the expected annual removals per acre for forestland parcel i,

p_{adj} is the adjusted stumpage price ($/ft^3) for forestland parcel i, and

C_{Prod} is the discounted annualized production cost per acre, $C_{Prod} = \$9.32$ in McCurtain County and zero in Pushmataha County.

Table 50 lists the expected net annualized value of removals per acre for the forestland parcels in McCurtain County and Table 51 list those for Pushmataha County.

Table 50: Expected Net Annualized Value of Removals Per Acre (McCurtain County)

TRACTID	County	QTR	SEC	TWP	NS	RNG	EW	PRICE	Exp. Rem.	Adj. Stump. Price	Gross Rev.	Avg. Annual Prod. Cost	Avg. Annual Net Timber Rev.
4507052124	McCurtain	SE/4	7	5	S	21	E	500.00	63.36	0.7053	44.69	9.32	35.37
4512052114	McCurtain	SE/4	12	5	S	21	E	65.58	59.85	0.7151	42.80	9.32	33.48
4531052125	McCurtain	SE/4	31	5	S	21	E	200.00	62.97	0.7156	45.06	9.32	35.74
4531052122	McCurtain	SE/4	31	5	S	21	E	200.00	62.97	0.7156	45.06	9.32	35.74
4534052143	McCurtain	SE/4	34	5	S	21	E	375.00	72.23	0.7203	52.03	9.32	42.71
4520062136	McCurtain	SE/4	20	6	S	21	E	909.09	58.34	0.7253	42.32	9.32	33.00
4522062111	McCurtain	SE/4	22	6	S	21	E	601.18	63.37	0.7299	46.25	9.32	36.93
4521032221	McCurtain	SE/4	21	3	S	22	E	250.00	89.79	0.7005	62.90	9.32	53.58
4528052232	McCurtain	SE/4	28	5	S	22	E	731.71	59.02	0.7255	42.82	9.32	33.50
4512062222	McCurtain	SE/4	12	6	S	22	E	300.00	44.07	0.7195	31.71	9.32	22.39
4501072215	McCurtain	SE/4	1	7	S	22	E	1,000.00	157.43	0.7097	111.74	9.32	102.42
4501072241	McCurtain	SE/4	1	7	S	22	E	1,450.00	73.47	0.7097	52.14	9.32	42.82
4524022321	McCurtain	SE/4	24	2	S	23	E	1,000.00	110.20	0.7149	78.78	9.32	69.46
4501062312	McCurtain	SE/4	1	6	S	23	E	2,012.50	56.22	0.7145	40.17	9.32	30.85
4509062333	McCurtain	SE/4	9	6	S	23	E	100.00	87.67	0.7104	62.28	9.32	52.96
4525062311	McCurtain	SE/4	25	6	S	23	E	4,602.99	62.97	0.7130	44.90	9.32	35.58
4525062312	McCurtain	SE/4	25	6	S	23	E	1,021.43	58.04	0.7130	41.38	9.32	32.06
4525062313	McCurtain	SE/4	25	6	S	23	E	403.07	57.68	0.7130	41.12	9.32	31.80

Table 50: Expected Net Annualized Value of Removals Per Acre (McCurtain County)

TRACTID	County	QTR	SEC	TWP	NS	RNG	EW	PRICE	Exp. Rem.	Adj. Stump. Price	Gross Rev.	Avg. Annual Prod. Cost	Avg. Annual Net Timber Rev.
4519022412	McCurtain	SE/4	19	2	S	24	E	1,397.36	100.34	0.7125	71.49	9.32	62.17
4526052427	McCurtain	SE/4	26	5	S	24	E	400.00	62.97	0.7202	45.35	9.32	36.03
4501062416	McCurtain	SE/4	1	6	S	24	E	9,329.65	51.77	0.7268	37.63	9.32	28.31
4534062421	McCurtain	SE/4	34	6	S	24	E	297.98	41.37	0.7151	29.58	9.32	20.26
4507072432	McCurtain	SE/4	7	7	S	24	E	2,843.75	87.67	0.7212	63.23	9.32	53.91
4508072423	McCurtain	SE/4	8	7	S	24	E	887.31	62.97	0.7167	45.13	9.32	35.81
4518072413	McCurtain	SE/4	18	7	S	24	E	701.37	87.67	0.7237	63.45	9.32	54.13
4509012512	McCurtain	SE/4	9	1	S	25	E	594.80	46.07	0.6907	31.82	9.32	22.50
4505032512	McCurtain	SE/4	5	3	S	25	E	750.00	62.97	0.6881	43.33	9.32	34.01
4522032522	McCurtain	SE/4	22	3	S	25	E	600.00	41.37	0.6713	27.77	9.32	18.45
4522032531	McCurtain	SE/4	22	3	S	25	E	98.36	41.37	0.6713	27.77	9.32	18.45
4536032532	McCurtain	SE/4	36	3	S	25	E	1,000.00	41.37	0.6623	27.40	9.32	18.08
4521062521	McCurtain	SE/4	21	6	S	25	E	6,203.47	54.77	0.7211	39.50	9.32	30.18
4513072532	McCurtain	SE/4	13	7	S	25	E	250.00	62.97	0.7001	44.09	9.32	34.77
4521072533	McCurtain	SE/4	21	7	S	25	E	414.78	157.43	0.7077	111.42	9.32	102.10
4517082535	McCurtain	SE/4	17	8	S	25	E	300.00	72.23	0.7102	51.30	9.32	41.98
4517082541	McCurtain	SE/4	17	8	S	25	E	2,237.50	72.23	0.7102	51.30	9.32	41.98
4522082521	McCurtain	SE/4	22	8	S	25	E	125.93	62.97	0.7016	44.18	9.32	34.86
4515092511	McCurtain	SE/4	15	9	S	25	E	400.00	62.97	0.6906	43.49	9.32	34.17
4510022632	McCurtain	SE/4	10	2	S	26	E	1,467.40	62.97	0.7066	44.50	9.32	35.18

Table 50: Expected Net Annualized Value of Removals Per Acre (McCurtain County)

TRACTID	County	QTR	SEC	TWP	NS	RNG	EW	PRICE	Exp. Rem.	Adj. Stump. Price	Gross Rev.	Avg. Annual Prod. Cost	Avg. Annual Net Timber Rev.
4505062636	McCurtain	SE/4	5	6	S	26	E	516.67	55.77	0.7094	39.56	9.32	30.24
4526062631	McCurtain	SE/4	26	6	S	26	E	370.37	84.14	0.6983	58.76	9.32	49.44
4509082432	McCurtain	SE/4	22	7	S	26	E	140.63	62.97	0.6918	43.57	9.32	34.25
4509022721	McCurtain	SE/4	9	2	S	27	E	500.00	62.97	0.7029	44.26	9.32	34.94
4509022712	McCurtain	SE/4	9	2	S	27	E	266.67	62.97	0.7029	44.26	9.32	34.94
4531092723	McCurtain	SE/4	31	9	S	27	E	700.00	62.97	0.6665	41.97	9.32	32.65
4521102711	McCurtain	SE/4	21	10	S	27	E	200.00	157.43	0.6835	107.61	9.32	98.29
Average								1,082.59	70.79	0.71	50.04	9.32	40.72
Minimum								65.58	41.37	0.66	27.40	9.32	18.08
Maximum								9,329.65	157.43	0.73	111.74	9.32	102.42
Number of observations								45.00	45.00	45.00	45.00	45.00	45.00

Table 51: Expected Net Annualized Value of Removals Per Acre (Pushmataha County)

TRACTID	County	QTR	SEC	TWP	NS	RNG	EW	PRICE	Exp. Rem.	Adj. Stump. Price	Gross Rev.	Avg. Annual Prod. Cost	Avg. Annual Net Timber Rev.
6436011521	Pushmataha	SE/4	36	1	S	15	E	375.00	14.42	0.6796	9.80	0.00	9.80
6407021591	Pushmataha	SE/4	7	2	S	15	E	555.56	13.32	0.6928	9.23	0.00	9.23
6428031571	Pushmataha	SE/4	28	3	S	15	E	282.05	18.95	0.7134	13.52	0.00	13.52
6433041512	Pushmataha	SE/4	33	4	S	15	E	400.00	11.71	0.7073	8.28	0.00	8.28
6413011651	Pushmataha	SE/4	13	1	S	16	E	400.00	14.42	0.6867	9.90	0.00	9.90
6415011621	Pushmataha	SE/4	15	1	S	16	E	333.33	39.24	0.6846	26.86	0.00	26.86
6428021661	Pushmataha	SE/4	28	2	S	16	E	250.00	7.67	0.7086	5.44	0.00	5.44
6429021671	Pushmataha	SE/4	29	2	S	16	E	250.00	13.18	0.7105	9.36	0.00	9.36
6429021641	Pushmataha	SE/4	29	2	S	16	E	1,100.00	16.18	0.7105	11.49	0.00	11.49
6401041618	Pushmataha	SE/4	1	4	S	16	E	1,153.85	54.88	0.7255	39.82	0.00	39.82
6417041641	Pushmataha	SE/4	17	4	S	16	E	600.00	7.32	0.7105	5.20	0.00	5.20
6422041631	Pushmataha	SE/4	22	4	S	16	E	558.44	10.89	0.7246	7.89	0.00	7.89
6401011721	Pushmataha	SE/4	1	1	S	17	E	200.00	11.91	0.6596	7.86	0.00	7.86
6423011771	Pushmataha	NE/4	23	1	N	17	E	177.78	14.42	0.6631	9.56	0.00	9.56
6423011701	Pushmataha	NE/4	23	1	N	17	E	155.56	14.42	0.6631	9.56	0.00	9.56
6431011721	Pushmataha	NE/4	31	1	N	17	E	149.68	14.42	0.6571	9.48	0.00	9.48

Table 51: Expected Net Annualized Value of Removals Per Acre (Pushmataha County)

TRACTID	County	QTR	SEC	TWP	NS	RNG	EW	PRICE	Exp. Rem.	Adj. Stump. Price	Gross Rev.	Avg. Annual Prod. Cost	Avg. Annual Net Timber Rev.
6425021771	Pushmataha	NE/4	25	2	N	17	E	175.62	14.42	0.6335	9.13	0.00	9.13
6425021781	Pushmataha	NE/4	25	2	N	17	E	85.69	14.42	0.6335	9.13	0.00	9.13
6410031711	Pushmataha	SE/4	10	3	S	17	E	300.00	8.82	0.6937	6.12	0.00	6.12
6420031751	Pushmataha	SE/4	20	3	S	17	E	325.00	18.23	0.7061	12.87	0.00	12.87
6421041791	Pushmataha	SE/4	21	4	S	17	E	500.00	17.20	0.7165	12.32	0.00	12.32
6410011821	Pushmataha	NE/4	10	1	N	18	E	400.00	13.26	0.6570	8.71	0.00	8.71
6410011822	Pushmataha	NE/4	10	1	N	18	E	550.00	12.22	0.6570	8.03	0.00	8.03
6420011891	Pushmataha	NE/4	20	1	N	18	E	416.67	24.54	0.6611	16.22	0.00	16.22
6426011861	Pushmataha	SE/4	26	1	S	18	E	325.00	10.87	0.6807	7.40	0.00	7.40
6429011831	Pushmataha	NE/4	29	1	N	18	E	918.75	14.42	0.6624	9.55	0.00	9.55
6435041804	Pushmataha	SE/4	35	4	S	18	E	228.13	19.72	0.6886	13.58	0.00	13.58
6403021921	Pushmataha	NE/4	3	2	N	19	E	368.75	14.42	0.6755	9.74	0.00	9.74
6412021971	Pushmataha	NE/4	12	2	N	19	E	200.00	14.42	0.6691	9.65	0.00	9.65
6412041921	Pushmataha	SE/4	12	4	S	19	E	150.00	10.28	0.6779	6.97	0.00	6.97
6408022011	Pushmataha	NE/4	8	2	N	20	E	417.86	14.42	0.6508	9.38	0.00	9.38
6414022014	Pushmataha	NE/4	14	2	N	20	E	1,250.00	14.42	0.6460	9.32	0.00	9.32
6416022081	Pushmataha	NE/4	16	2	N	20	E	100.00	14.42	0.6504	9.38	0.00	9.38
6436022061	Pushmataha	NE/4	36	2	N	20	E	300.00	14.42	0.6536	9.43	0.00	9.43
6416022013	Pushmataha	NE/4	16	2	N	22	E	125.00	7.32	0.6502	4.76	0.00	4.76
6419022241	Pushmataha	NE/4	19	2	N	22	E	325.00	15.63	0.6604	10.32	0.00	10.32

Table 51: Expected Net Annualized Value of Removals Per Acre (Pushmataha County)

TRACTID	County	QTR	SEC	TWP	NS	RNG	EW	PRICE	Exp. Rem.	Adj. Stump. Price	Gross Rev.	Avg. Annual Prod. Cost	Avg. Annual Net Timber Rev.
Average								400.07	15.70	0.68	10.70	0.00	10.70
Minimum								85.69	7.32	0.63	4.76	0.00	4.76
Maximum								1,250.00	54.88	0.73	39.82	0.00	39.82
Number of observations								36	36	36	36	36	36

Expected Annualized Value of Non-timber Output

The expected annualized value of non-timber output per acre for each observation was estimated using the following equation:

$$\hat{p}_{NT} = \hat{p}_L - p_T$$

where:

$\hat{p}_{NT}$ is the expected annualized value of non-timber output per acre,

$\hat{p}_L$ is the annualized price per acre for forestland, and

p_T is the expected net annualized value of removals per acre, where removals is being used as a proxy for timber harvest.

In this calculation, it is assumed that the per-acre sales price of forestland p_L incorporates the total value, or full-income M, of the forestland such that $\hat{p}_L = F(p_T, \hat{p}_{NT})$. Table 51 lists the expected annualized value of non-timber output per acre for McCurtain County and Table 53 list those for Pushmataha County. Note, due to the fact that prices must be greater than or equal to zero, negative values were truncated to zero.

Table 52: Expected Annualized Value of Non-timber Output per Acre (McCurtain County)

TRACTID	County	QTR	SEC	TWP	NS	RNG	EW	PRICE	ACRES	Discounted Land Value (5%, 30Yrs)	Avg. Annual Net Timber Revenue	Avg. Annual Non-timber Value
4507052124	McCurtain	SE/4	7	5	S	21	E	500.00	40.00	115.69	35.37	80.32
4512052114	McCurtain	SE/4	12	5	S	21	E	65.58	91.49	15.17	33.48	0.00
4531052125	McCurtain	SE/4	31	5	S	21	E	200.00	20.00	46.28	35.74	10.53
4531052122	McCurtain	SE/4	31	5	S	21	E	200.00	20.00	46.28	35.74	10.53
4534052143	McCurtain	SE/4	34	5	S	21	E	375.00	40.00	86.77	42.71	44.05
4520062136	McCurtain	SE/4	20	6	S	21	E	909.09	55.00	210.34	33.00	177.35
4522062111	McCurtain	SE/4	22	6	S	21	E	601.18	39.09	139.10	36.93	102.16
4521032221	McCurtain	SE/4	21	3	S	22	E	250.00	40.00	57.84	53.58	4.26
4528052232	McCurtain	SE/4	28	5	S	22	E	731.71	41.00	169.30	33.50	135.80
4512062222	McCurtain	SE/4	12	6	S	22	E	300.00	40.00	69.41	22.39	47.03
4501072215	McCurtain	SE/4	1	7	S	22	E	1,000.00	40.00	231.38	102.42	128.96
4501072241	McCurtain	SE/4	1	7	S	22	E	1,450.00	160.00	335.50	42.82	292.67
4524022321	McCurtain	SE/4	24	2	S	23	E	1,000.00	30.00	231.38	69.46	161.91
4501062312	McCurtain	SE/4	1	6	S	23	E	2,012.50	40.00	465.65	30.85	434.80
4509062333	McCurtain	SE/4	9	6	S	23	E	100.00	40.00	23.14	52.96	0.00
4525062311	McCurtain	SE/4	25	6	S	23	E	4,602.99	17.38	1,065.03	35.58	1,029.45
4525062312	McCurtain	SE/4	25	6	S	23	E	1,021.43	59.72	236.34	32.06	204.28
4525062313	McCurtain	SE/4	25	6	S	23	E	403.07	101.72	93.26	31.80	61.46

Table 52: Expected Annualized Value of Non-timber Output per Acre (McCurtain County)

TRACTID	County	QTR	SEC	TWP	NS	RNG	EW	PRICE	ACRES	Discounted Land Value (5%, 30Yrs)	Avg. Annual Net Timber Revenue	Avg. Annual Non-timber Value
4519022412	McCurtain	SE/4	19	2	S	24	E	1,397.36	19.68	323.32	62.17	261.15
4526052427	McCurtain	SE/4	26	5	S	24	E	400.00	5.00	92.55	36.03	56.52
4501062416	McCurtain	SE/4	1	6	S	24	E	9,329.65	14.47	2,158.67	28.31	2,130.36
4534062421	McCurtain	SE/4	34	6	S	24	E	297.98	49.50	68.95	20.26	48.69
4507072432	McCurtain	SE/4	7	7	S	24	E	2,843.75	80.00	657.98	53.91	604.07
4508072423	McCurtain	SE/4	8	7	S	24	E	887.31	112.70	205.30	35.81	169.49
4518072413	McCurtain	SE/4	18	7	S	24	E	701.37	10.93	162.28	54.13	108.16
4509012512	McCurtain	SE/4	9	1	S	25	E	594.80	107.60	137.62	22.50	115.12
4505032512	McCurtain	SE/4	5	3	S	25	E	750.00	40.00	173.53	34.01	139.52
4522032522	McCurtain	SE/4	22	3	S	25	E	600.00	50.00	138.83	18.45	120.38
4522032531	McCurtain	SE/4	22	3	S	25	E	98.36	76.25	22.76	18.45	4.31
4536032532	McCurtain	SE/4	36	3	S	25	E	1,000.00	10.00	231.38	18.08	213.30
4521062521	McCurtain	SE/4	21	6	S	25	E	6,203.47	16.12	1,435.34	30.18	1,405.17
4513072532	McCurtain	SE/4	13	7	S	25	E	250.00	40.00	57.84	34.77	23.07
4521072533	McCurtain	SE/4	21	7	S	25	E	414.78	66.30	95.97	102.10	0.00
4517082535	McCurtain	SE/4	17	8	S	25	E	300.00	20.00	69.41	41.98	27.43
4517082541	McCurtain	SE/4	17	8	S	25	E	2,237.50	20.00	517.71	41.98	475.72
4522082521	McCurtain	SE/4	22	8	S	25	E	125.93	134.00	29.14	34.86	0.00
4515092511	McCurtain	SE/4	15	9	S	25	E	400.00	20.00	92.55	34.17	58.38
4510022632	McCurtain	SE/4	10	2	S	26	E	1,467.40	87.57	339.52	35.18	304.34

Table 52: Expected Annualized Value of Non-timber Output per Acre (McCurtain County)

TRACTID	County	QTR	SEC	TWP	NS	RNG	EW	PRICE	ACRES	Discounted Land Value (5%, 30Yrs)	Avg. Annual Net Timber Revenue	Avg. Annual Non-timber Value
4505062636	McCurtain	SE/4	5	6	S	26	E	516.67	30.00	119.55	30.24	89.30
4526062631	McCurtain	SE/4	26	6	S	26	E	370.37	94.50	85.70	49.44	36.26
4509082432	McCurtain	SE/4	22	7	S	26	E	140.63	160.00	32.54	34.25	0.00
4509022721	McCurtain	SE/4	9	2	S	27	E	500.00	80.00	115.69	34.94	80.75
4509022712	McCurtain	SE/4	9	2	S	27	E	266.67	120.00	61.70	34.94	26.76
4531092723	McCurtain	SE/4	31	9	S	27	E	700.00	20.00	161.96	32.65	129.31
4521102711	McCurtain	SE/4	21	10	S	27	E	200.00	80.00	46.28	98.29	0.00
Average								1,082.59	55.11	250.49	40.72	212.29
Minimum								65.58	5.00	15.17	18.08	0.00
Maximum								9,329.65	160.00	2,158.67	102.42	2,130.36
Number of observations								45.00	45.00	45.00	45.00	45.00

Table 53: Expected Annualized Value of Non-timber Output per Acre (Pushmataha County)

TRACTID	County	QTR	SEC	TWP	NS	RNG	EW	PRICE	ACRES	Discounted Land Value (5%, 30Yrs)	Avg. Annual Net Timber Rev.	Avg. Annual Non-timber Value
6436011521	Pushmataha	SE/4	36	1	S	15	E	375.00	40.00	86.77	9.80	76.97
6407021591	Pushmataha	SE/4	7	2	S	15	E	555.56	90.00	128.54	9.23	119.32
6428031571	Pushmataha	SE/4	28	3	S	15	E	282.05	39.00	65.26	13.52	51.74
6433041512	Pushmataha	SE/4	33	4	S	15	E	400.00	150.00	92.55	8.28	84.27
6413011651	Pushmataha	SE/4	13	1	S	16	E	400.00	80.00	92.55	9.90	82.65
6415011621	Pushmataha	SE/4	15	1	S	16	E	333.33	150.00	77.13	26.86	50.26
6428021661	Pushmataha	SE/4	28	2	S	16	E	250.00	30.00	57.84	5.44	52.41
6429021671	Pushmataha	SE/4	29	2	S	16	E	250.00	40.00	57.84	9.36	48.48
6429021641	Pushmataha	SE/4	29	2	S	16	E	1,100.00	80.00	254.52	11.49	243.02
6401041618	Pushmataha	SE/4	1	4	S	16	E	1,153.85	13.00	266.97	39.82	227.16
6417041641	Pushmataha	SE/4	17	4	S	16	E	600.00	80.00	138.83	5.20	133.63
6422041631	Pushmataha	SE/4	22	4	S	16	E	558.44	77.00	129.21	7.89	121.32
6401011721	Pushmataha	SE/4	1	1	S	17	E	200.00	150.00	46.28	7.86	38.42
6423011771	Pushmataha	NE/4	23	1	N	17	E	177.78	45.00	41.13	9.56	31.57
6423011701	Pushmataha	NE/4	23	1	N	17	E	155.56	90.00	35.99	9.56	26.43
6431011721	Pushmataha	NE/4	31	1	N	17	E	149.68	157.00	34.63	9.48	25.16

Table 53: Expected Annualized Value of Non-timber Output per Acre (Pushmataha County)

TRACTID	County	QTR	SEC	TWP	NS	RNG	EW	PRICE	ACRES	Discounted Land Value (5%, 30Yrs)	Avg. Annual Net Timber Rev.	Avg. Annual Non-timber Value
6425021771	Pushmataha	NE/4	25	2	N	17	E	175.62	68.33	40.63	9.13	31.50
6425021781	Pushmataha	NE/4	25	2	N	17	E	85.69	11.67	19.83	9.13	10.69
6410031711	Pushmataha	SE/4	10	3	S	17	E	300.00	260.00	69.41	6.12	63.30
6420031751	Pushmataha	SE/4	20	3	S	17	E	325.00	40.00	75.20	12.87	62.33
6421041791	Pushmataha	SE/4	21	4	S	17	E	500.00	80.00	115.69	12.32	103.37
6410011821	Pushmataha	NE/4	10	1	N	18	E	400.00	80.00	92.55	8.71	83.84
6410011822	Pushmataha	NE/4	10	1	N	18	E	550.00	80.00	127.26	8.03	119.23
6420011891	Pushmataha	NE/4	20	1	N	18	E	416.67	12.00	96.41	16.22	80.19
6426011861	Pushmataha	SE/4	26	1	S	18	E	325.00	40.00	75.20	7.40	67.80
6429011831	Pushmataha	NE/4	29	1	N	18	E	918.75	160.00	212.58	9.55	203.03
6435041804	Pushmataha	SE/4	35	4	S	18	E	228.13	160.00	52.78	13.58	39.20
6403021921	Pushmataha	NE/4	3	2	N	19	E	368.75	80.00	85.32	9.74	75.58
6412021971	Pushmataha	NE/4	12	2	N	19	E	200.00	40.00	46.28	9.65	36.63
6412041921	Pushmataha	SE/4	12	4	S	19	E	150.00	120.00	34.71	6.97	27.74
6408022011	Pushmataha	NE/4	8	2	N	20	E	417.86	140.00	96.68	9.38	87.30
6414022014	Pushmataha	NE/4	14	2	N	20	E	1,250.00	40.00	289.22	9.32	279.91
6416022081	Pushmataha	NE/4	16	2	N	20	E	100.00	40.00	23.14	9.38	13.76
6436022061	Pushmataha	NE/4	36	2	N	20	E	300.00	20.00	69.41	9.43	59.99
6416022013	Pushmataha	NE/4	16	2	N	22	E	125.00	20.00	28.92	4.76	24.16
6419022241	Pushmataha	NE/4	19	2	N	22	E	325.00	20.00	75.20	10.32	64.88

Table 53: Expected Annualized Value of Non-timber Output per Acre (Pushmataha County)

TRACTID	County	QTR	SEC	TWP	NS	RNG	EW	PRICE	ACRES	Discounted Land Value (5%, 30Yrs)	Avg. Annual Net Timber Rev.	Avg. Annual Non-timber Value
Average								400.07	78.42	92.57	10.70	81.87
Minimum								85.69	11.67	19.83	4.76	10.69
Maximum								1,250.00	260.00	289.22	39.82	279.91
Number of observations								36	36	36	36	36

APPENDIX-3

TIMBER AND NON-TIMBER SHARES

Summary of Equations to Obtain the Timber and Non-timber Shares

(1) $$\ln Price_i = \ln\beta_0 + \beta_1 \ln Acres_i + \beta_2 DistCity_i + \beta_3 DistHwy_i + \beta_4 TmProd_i + \beta_5 Front_i + \beta_6 OPEN_i + \mu_i$$

(2) $p_{L_i} = \exp(\ln Price_i)$ (Endogenous)

(3) p_{T_i} (Exogenous)

(4) $p_{NT_i} = p_{L_i} - p_{T_i}$ (Endogenous)

(5) $$s_{T_i} = \frac{p_{T_i}}{p_{L_i}} = \alpha_T + \beta_T \ln\left(\frac{p_{T_i}}{p_{NT_i}}\right) + \varepsilon_{T_i}$$

(6) $$s_{NT} = \frac{p_{NT_i}}{p_{L_i}} = \alpha_{NT} + \beta_{NT} \ln\left(\frac{p_{NT_i}}{p_{T_i}}\right) + \varepsilon_{NT_i}$$

(7) By definition $s_{T_i} + s_{NT_i} = 1$

Equation-1 was used to estimate the log of the price of forestland for McCurtain and Pushmataha counties, independently. Estimation for McCurtain County was done using estimated generalized least squares and for Pushmataha county ordinary least squares was used. The results of Equation-1 were placed into the right-hand-side of Equation-2 to obtain estimated forestland sale prices per acre for each observation.

Equation-3 is a non-stochastic estimate of timber output value per acre for each forestland parcel. It is based upon market prices and estimated timber output per acre for each observation.

Equation-4 is an estimate of the non-timber value per acre for each observation. The right-hand-side variables are the per acre value of forestland, a stochastic estimate, and the per acre value of timber output, a non-stochastic estimate. It is assumed that the full value of forestland is reflected by its market price, and that this hedonic price is made up of two components, timber value and non-timber value. It thus follows, per acre value of non-timber is the difference between the per acre market values of the forestland and timber output.

The results of the equations 3 and 4 are then used as the right-hand-side variables in the timber and non-timber share equations, equations 5 and 6, respectively. Equations 5 and 6 were estimated using estimated generalized least squares. Equation-7 states that the share of timber and non-timber per acre must equal one.

Estimated Values of Forestland, Timber, and Non-Timber

The estimated per acre values for forestland, timber outputs, and non-timber outputs for McCurtain and Pushmataha counties are in Tables 55 and 56, respectively.

In McCurtain County there were five observations with discounted estimated land values less than the value of expected annualized timber removals. This situation resulted in the associated observations having negative values for non-timber outputs. A list of these five observations appears in Table 54. In each of these five cases the timber shares are more than 100% of land value. To correct this problem an adjusted discounted land value (ADiscPL) was calculated as follows:

If DiscPL > PTim then ADiscPL = DiscPL, otherwise ADiscPL = PTim + 1

The interpretation of the columns for in Tables 54, 55, and 56 are as follows:

Obs	The observation number,
Phat	The predicted value of $\ln Price$,
Pobs	The observed value of $\ln Price$,
PLhat	The predicted value of $Price$,
PRICE	The observed value of $Price$,
DiscPL	The discounted $\left(1/(1+0.05)^{30}\right)$ value of PLhat ,
ADiscPL	If DiscPL > PTim then ADiscPL = DiscPL, otherwise ADiscPL = PTim + 0.01 (Applies to McCurtain County only.),
PTim	The expected annualized value of timber removals, and
PNTim	The expected annualized value of nontimber output.

Table 54: Observations for McCurtain County with DiscPL < PTim

Obs	Phat	Pobs	PLhat	PRICE	DiscPL	PTim	PNTim
8	5.3880	2.3979	218.76	250.00	50.62	53.58	-2.97
33	5.9146	2.6178	370.41	414.78	85.70	102.10	-16.39
40	5.3219	2.5686	204.77	370.37	47.38	49.44	-2.06
41	4.9805	2.1481	145.55	140.63	33.68	34.25	-0.57
45	5.4059	2.3010	222.72	200.00	51.53	98.29	-46.75

Table 55: Annualized Forestland, Timber, and Non-timber Values (McCurtain County)

Obs	Phat	Pobs	PLhat	PRICE	DiscPL	ADiscPL	PTim	PNTim
1	6.2645	2.6990	525.6	500.00	121.61	121.61	35.37	86.24
2	6.5275	1.8168	683.68	65.58	158.19	158.19	33.48	124.71
3	6.5777	2.3010	718.91	200.00	166.34	166.34	35.74	130.60
4	6.5777	2.3010	718.91	200.00	166.34	166.34	35.74	130.60
5	6.1555	2.5740	471.31	375.00	109.05	109.05	42.71	66.34
6	6.8181	2.9586	914.27	909.09	211.54	211.54	33.00	178.55
7	6.9126	2.7790	1004.85	601.18	232.50	232.50	36.93	195.56
8	5.3880	2.3979	218.76	250.00	50.62	54.58	53.58	1.00
9	6.5844	2.8643	723.73	731.71	167.45	167.45	33.50	133.95
10	6.4369	2.4771	624.49	300.00	144.49	144.49	22.39	122.11
11	6.8931	3.0000	985.43	1000.00	228.01	228.01	102.42	125.59
12	6.6665	3.1614	785.64	1450.00	181.78	181.78	42.82	138.96
13	6.5528	3.0000	701.22	1000.00	162.25	162.25	69.46	92.78
14	7.1300	3.3037	1248.89	2012.50	288.96	288.96	30.85	258.12
15	5.9793	2.0000	395.16	100.00	91.43	91.43	52.96	38.47
16	6.9053	3.6630	997.55	4602.99	230.81	230.81	35.58	195.23
17	6.3955	3.0092	599.17	1021.43	138.63	138.63	32.06	106.57
18	6.1678	2.6054	477.13	403.07	110.40	110.40	31.80	78.59
19	6.9245	3.1453	1016.83	1397.36	235.27	235.27	62.17	173.10
20	8.0443	2.6021	3116.01	400.00	720.97	720.97	36.03	684.94
21	7.8375	3.9699	2533.92	9329.65	586.29	586.29	28.31	557.98
22	6.3545	2.4742	575.04	297.98	133.05	133.05	20.26	112.79
23	6.8311	3.4539	926.21	2843.75	214.30	214.30	53.91	160.39
24	6.6539	2.9481	775.81	887.31	179.50	179.50	35.81	143.69
25	7.1720	2.8459	1302.46	701.37	301.36	301.36	54.13	247.23
26	5.8533	2.7744	348.38	594.80	80.61	80.61	22.50	58.11
27	6.2782	2.8751	532.84	750.00	123.29	123.29	34.01	89.27

Table 55: Annualized Forestland, Timber, and Non-timber Values (McCurtain County)

Obs	Phat	Pobs	PLhat	PRICE	DiscPL	ADiscPL	PTim	PNTim
28	5.7402	2.7782	311.12	600.00	71.99	71.99	18.45	53.54
29	5.5585	1.9928	259.42	98.36	60.02	60.02	18.45	41.57
30	6.1129	3.0000	451.65	1000.00	104.50	104.50	18.08	86.43
31	7.4851	3.7926	1781.27	6203.47	412.15	412.15	30.18	381.97
32	6.3373	2.3979	565.24	250.00	130.78	130.78	34.77	96.01
33	5.9146	2.6178	370.41	414.78	85.70	103.10	102.10	1.00
34	6.9437	2.4771	1036.63	300.00	239.85	239.85	41.98	197.87
35	6.9437	3.3498	1036.63	2237.50	239.85	239.85	41.98	197.87
36	5.7104	2.1001	301.98	125.93	69.87	69.87	34.86	35.01
37	6.8956	2.6021	987.91	400.00	228.58	228.58	34.17	194.41
38	5.5364	3.1665	253.76	1467.40	58.71	58.71	35.18	23.54
39	7.2058	2.7132	1347.2	516.67	311.71	311.71	30.24	281.47
40	5.3219	2.5686	204.77	370.37	47.38	50.44	49.44	1.00
41	4.9805	2.1481	145.55	140.63	33.68	35.25	34.25	1.00
42	6.1072	2.6990	449.07	500.00	103.90	103.90	34.94	68.96
43	5.9326	2.4260	377.13	266.67	87.26	87.26	34.94	52.32
44	5.9292	2.8451	375.85	700.00	86.96	86.96	32.65	54.31
45	5.4059	2.3010	222.72	200.00	51.53	99.29	98.29	1.00
Min	4.9805	1.8168	145.55	65.58	33.68	35.25	18.08	1.00
Max	8.0443	3.9699	3116.01	9329.65	720.97	720.97	102.42	684.94
Mean	6.4210	2.7550	764.46	1082.59	176.88	178.52	40.72	137.79
Std. Dev.	0.6613	0.4667	576.71	1708.80	133.44	132.16	19.56	134.35

Table 56: Annualized Forestland, Timber, and Non-timber Values (Pushmataha County)

Obs	Phat	Pobs	PLhat	PRICE	DiscPL	PTim	PNTim
1	5.7893	2.5740	326.77	375.00	75.61	9.80	65.81
2	5.9555	2.7447	385.87	555.56	89.28	9.23	80.06
3	6.1737	2.4503	479.96	282.05	111.05	13.52	97.53
4	5.5418	2.6021	255.12	400.00	59.03	8.28	50.75
5	5.7500	2.6021	314.17	400.00	72.69	9.90	62.79
6	6.4762	2.5229	649.51	333.33	150.28	26.86	123.42
7	6.1151	2.3979	452.64	250.00	104.73	5.44	99.29
8	5.7501	2.3979	314.23	250.00	72.71	9.36	63.34
9	5.8914	3.0414	361.92	1100.00	83.74	11.49	72.25
10	6.8713	3.0621	964.17	1153.85	223.09	39.82	183.27
11	6.0791	2.7782	436.65	600.00	101.03	5.20	95.83
12	6.3363	2.7470	564.69	558.44	130.66	7.89	122.77
13	5.3611	2.3010	212.96	200.00	49.28	7.86	41.42
14	5.6533	2.2499	285.24	177.78	66.00	9.56	56.44
15	5.7336	2.1919	309.08	155.56	71.51	9.56	61.95
16	5.5444	2.1752	255.79	149.68	59.18	9.48	49.71
17	4.9468	2.2446	140.73	175.62	32.56	9.13	23.43
18	4.7421	1.9329	114.68	85.69	26.53	9.13	17.40
19	5.6996	2.4771	298.74	300.00	69.12	6.12	63.00
20	6.0267	2.5119	414.34	325.00	95.87	12.87	83.00
21	5.8402	2.6990	343.84	500.00	79.56	12.32	67.24
22	6.1861	2.6021	485.94	400.00	112.44	8.71	103.72
23	6.1650	2.7404	475.81	550.00	110.09	8.03	102.06
24	5.6896	2.6198	295.78	416.67	68.44	16.22	52.22
25	6.0805	2.5119	437.26	325.00	101.17	7.40	93.77
26	6.1227	2.9632	456.11	918.75	105.53	9.55	95.98

Table 56: Annualized Forestland, Timber, and Non-timber Values (Pushmataha County)

Obs	Phat	Pobs	PLhat	PRICE	DiscPL	PTim	PNTim
27	5.7067	2.3582	300.87	228.13	69.61	13.58	56.03
28	5.6035	2.5667	271.37	368.75	62.79	9.74	53.05
29	5.7581	2.3010	316.74	200.00	73.29	9.65	63.64
30	5.4207	2.1761	226.05	150.00	52.30	6.97	45.34
31	5.9063	2.6210	367.36	417.86	85.00	9.38	75.61
32	6.0588	3.0969	427.85	1250.00	98.99	9.32	89.68
33	5.4936	2.0000	243.13	100.00	56.25	9.38	46.88
34	5.1587	2.4771	173.95	300.00	40.25	9.43	30.82
35	5.3262	2.0969	205.66	125.00	47.59	4.76	42.83
36	5.0782	2.5119	160.48	325.00	37.13	10.32	26.81
Min	4.7421	1.9329	114.68	85.69	26.53	4.76	17.40
Max	6.8713	3.0969	964.17	1250.00	223.09	39.82	183.27
Mean	5.7787	2.5096	353.49	400.07	81.79	10.70	71.09
Std. Dev.	0.4306	0.2846	159.22	289.47	36.84	6.24	32.90

SAS Programs for the Estimation of the Share Equations

Timber Share Equation Model

```
filename SHRmc dde 'excel| SHRmc_Data! R2C2:R46C9';
data SHRmc; infile SHRmc;
INPUT Phat Pobs PLhat PRICE DiscPL ADiscPL PTim PNTim;
PtPnt = PTim/PNTim; PntPt = PNTim/PTim; LPtPnt = LOG(PtPnt);
LPntPt = LOG(PntPt); ST=PTim/ADiscPL; SNT=PNTim/ADiscPL;
proc print;

/*Timber Share Equation*/
proc reg data = SHRmc; model ST = LPtPnt;
output out = one R = EHat P = YHat; proc print; var EHat YHat;

data two; set one; EHat2=EHat**2; YHat2=YHat**2; LEHat2=LOG(EHat2);

/*Shapiro-Wilk Test for Normality*/
proc univariate freq plot normal data = two; var EHAT;

/*Plot of EHat2 and YHat*/
proc plot; plot EHat2*YHat='*';

/*Ramsey Test for Heteroskedasticity*/
proc reg; model EHat2 = YHat2;

/*Koenker Test for Heteroskedasticity*/
proc reg; model EHat2 = LPtPnt;

/*LM Test for Heteroskedasticity*/
proc reg; model LEHat2 = LPtPnt;

/*creation of weights for EGLS*/
output out = three P = V;
data three; set three;
varhat=exp(V);
WT=1/varhat;

/*Estimated Generalized Least Squares Model*/
Proc Reg; model ST = LPtPnt; Weight WT;

/*Shapiro-Wilk Test for Normality on EGLS*/
output out = four R = U P = VHat; proc print; var U VHat;
data four; set four; proc univariate freq plot normal data = four; var U;
Run;
```

Non-Timber Share Equation Model

```
filename SHRmc dde 'excel| SHRmc_Data! R2C2:R46C9';
data SHRmc; infile SHRmc;
INPUT Phat Pobs PLhat PRICE DiscPL ADiscPL PTim PNTim;
PtPnt = PTim/PNTim; PntPt = PNTim/PTim; LPtPnt = LOG(PtPnt);
LPntPt = LOG(PntPt); ST=PTim/ADiscPL; SNT=PNTim/ADiscPL;
proc print;

/*Non-timber Share Equation*/
proc reg data = SHRmc; model SNT = LPntPt;
output out = one R = EHat P = Yhat; proc print; var EHat YHat;

data two; set one; EHat2=EHat**2; YHat2=YHat**2; LEHat2=LOG(EHat2);

/*Shapiro-Wilk Test for Normality*/
proc univariate freq plot normal data = two; var EHAT;

/*Plot of EHat2 and YHat*/
proc plot; plot EHat2*YHat='*';

/*Ramsey Test for Heteroskedasticity*/
proc reg; model EHat2 = YHat2;

/*Koenker Test for Heteroskedasticity*/
proc reg; model EHat2 = LPntPt;

/*LM Test for Heteroskedasticity*/
proc reg; model LEHat2 = LPntPt;

/*creation of weights for EGLS*/
output out = three P = V; data three; set three; varhat=exp(V); WT=1/varhat;

/*Estimated Generalized Least Squares Model*/
Proc Reg; model SNT = LPntPt; Weight WT;

/*Shapiro-Wilk Test for Normality on EGLS*/
output out = four R = U P = VHat;
data four; set four;
proc univariate freq plot normal data = four; var U;

Run;
```

Estimation Results (McCurtain County)

McCurtain County Timber Share Equation

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	2461.35258	2461.35258	552.30	<.0001
Error	43	191.63055	4.45652		
Corrected Total	44	2652.98313			

Root MSE	2.11105	R-Square	0.9278
Dependent Mean	0.33697	Adj R-Sq	0.9261
Coeff Var	626.47054		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	1	0.34349	0.01098	31.28	<.0001
LPtPnt	1	0.07948	0.00338	23.50	<.0001

McCurtain County Non-timber Share Equation

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	6372.53053	6372.53053	1634.37	<.0001
Error	43	167.66065	3.89908		
Corrected Total	44	6540.19118			

Root MSE	1.97461	R-Square	0.9744
Dependent Mean	0.67899	Adj R-Sq	0.9738
Coeff Var	290.81654		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	1	0.57904	0.00661	87.66	<.0001
LPntPt	1	0.14127	0.00349	40.43	<.0001

Estimation Results (Pushmataha County)

Pushmataha County Timber Share Equation

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	1330.54311	1330.54311	528.73	<.0001
Error	34	85.56063	2.51649		
Corrected Total	35	1416.10374			

Root MSE	1.58634	R-Square	0.9396
Dependent Mean	0.12541	Adj R-Sq	0.9378
Coeff Var	1264.92732		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	1	0.34773	0.00997	34.88	<.0001
LPtPnt	1	0.10904	0.00474	22.99	<.0001

Pushmataha County Non-timber Share Equation

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	1326.85719	1326.85719	528.14	<.0001
Error	34	85.41918	2.51233		
Corrected Total	35	1412.27637			

Root MSE	1.58503	R-Square	0.9395
Dependent Mean	0.87458	Adj R-Sq	0.9377
Coeff Var	181.23353		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	1	0.65229	0.00997	65.40	<.0001
LPntPt	1	0.10904	0.00474	22.98	<.0001

APPENDIX-4

OWN-PRICE, CROSS-PRICE, AND MORISHIMA ELASTICITIES

Calculation of Elasticities for McCurtain County

Own-price Elasticities (McCurtain County)

$$\hat{\eta}_{T,T} = -1 + \frac{\partial s_T}{\partial p_T}\frac{p_T}{s_T} = -1 + \frac{\hat{\beta}_T}{\hat{\alpha}_T + \hat{\beta}_T \ln\left(\frac{p_T}{\hat{p}_{NT}}\right) + \hat{\varepsilon}_T} = -1 + \frac{0.1447}{0.2484} = -0.4175$$

$$\hat{\eta}_{NT,NT} = -1 + \frac{\partial s_{NT}}{\partial p_{NT}}\frac{p_{NT}}{s_{NT}} = -1 + \frac{\hat{\beta}_{NT}}{\hat{\alpha}_{NT} + \hat{\beta}_{NT} \ln\left(\frac{\hat{p}_{NT}}{p_T}\right) + \hat{\varepsilon}_{NT}} = -1 + \frac{0.1413}{0.7530} = -0.8124$$

Cross-price Elasticities (McCurtain County)

$$\hat{\eta}_{T,NT} = \frac{\partial s_T}{\partial p_{NT}}\frac{p_{NT}}{s_T} = -\frac{\hat{\beta}_T}{\hat{\alpha}_T + \hat{\beta}_T \ln\left(\frac{p_T}{\hat{p}_{NT}}\right) + \hat{\varepsilon}_T} = -\frac{0.1447}{0.2484} = -0.5825$$

$$\hat{\eta}_{NT,T} = \frac{\partial s_{NT}}{\partial p_T}\frac{p_T}{s_{NT}} = -\frac{\hat{\beta}_{NT}}{\hat{\alpha}_{NT} + \hat{\beta}_{NT} \ln\left(\frac{\hat{p}_{NT}}{p_T}\right) + \hat{\varepsilon}_{NT}} = -\frac{0.1413}{0.7530} = -0.1876$$

Morishima Elasticity of Substitution (McCurtain County)

$$\hat{M}_{NT,T} = \hat{\eta}_{NT,T} - \hat{\eta}_{T,T} = -0.1876 - (-0.4175) = 0.2299$$

Calculation of Elasticities for Pushmataha County

Own-price Elasticities (Pushmataha County)

$$\hat{\eta}_{T,T} = -1 + \frac{\partial s_T}{\partial p_T}\frac{p_T}{s_T} = -1 + \frac{\hat{\beta}_T}{\hat{\alpha}_T + \hat{\beta}_T \ln\left(\frac{p_T}{\hat{p}_{NT}}\right) + \hat{\varepsilon}_T} = -1 + \frac{0.1090}{0.1413} = -0.2286$$

$$\hat{\eta}_{NT,NT} = -1 + \frac{\partial s_{NT}}{\partial p_{NT}}\frac{p_{NT}}{s_{NT}} = -1 + \frac{\hat{\beta}_{NT}}{\hat{\alpha}_{NT} + \hat{\beta}_{NT} \ln\left(\frac{\hat{p}_{NT}}{p_T}\right) + \hat{\varepsilon}_{NT}} = -1 + \frac{0.1090}{0.8587} = -0.8731$$

Cross-price Elasticities (Pushmataha County)

$$\hat{\eta}_{T,NT} = \frac{\partial s_T}{\partial p_{NT}}\frac{p_{NT}}{s_T} = -\frac{\hat{\beta}_T}{\hat{\alpha}_T + \hat{\beta}_T \ln\left(\frac{p_T}{\hat{p}_{NT}}\right) + \hat{\varepsilon}_T} = -\frac{0.1090}{0.1413} = -0.7714$$

$$\hat{\eta}_{NT,T} = \frac{\partial s_{NT}}{\partial p_T}\frac{p_T}{s_{NT}} = -\frac{\hat{\beta}_{NT}}{\hat{\alpha}_{NT} + \hat{\beta}_{NT} \ln\left(\frac{\hat{p}_{NT}}{p_T}\right) + \hat{\varepsilon}_{NT}} = -\frac{0.1090}{0.8587} = -0.1269$$

Morishima Elasticity of Substitution (Pushmataha County)

$$\hat{M}_{NT,T} = \hat{\eta}_{NT,T} - \hat{\eta}_{T,T} = -0.1269 - (-0.2286) = 0.1017$$

VITA (2)

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Doctor of Philosophy

Thesis: SUBSTITUTION BETWEEN TIMBER AND NON-TIMBER OUTPUTS ON PRIVATE FORESTLANDS IN OKLAHOMA

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