Title: An Econometric Analysis of Timber Demand and Supply Relationships on the Siuslaw National Forest

Abstract approved: ________________________________

Dr. J. Douglas Brodie

To abstract the fundamental market structures of stumpage sold from the Siuslaw National Forest, a three-equation structural model with different assumptions on private cut was empirically derived. Under the private cut price-fixed assumption, the structural model can be simplified as a single-equation model with stumpage price as dependent variable and ordinary least squares (OLS) methods can be employed. If private cut is price responsive, two-stage least square (2SLS) methods must be applied. In both models, annual stumpage price can be predicted and forecasted into the future. With a private cut price responsive assumption, the stumpage price, private cut and total stumpage traded within the marketing area were determined simultaneously by systems of equations.

For both models, classical negatively-sloping demand curves were obtained with stumpage price as the dependent variable. Also, final product prices and lumber production costs were found to be significant factors in the demand
for stumpage. On the supply side for private cut, classical positively-sloping supply curves were obtained with private cut volume as a dependent variable, and growing stock inventory as an important factor that influences the private cut.

The estimates of the short-run price elasticities of stumpage demand and private supply within the specified marketing area were both highly inelastic, while the demand for Siuslaw timber was highly elastic. It is felt that the overall results of the analysis compelled tentative acceptance of the hypothesis that the economic models for the stumpage market, developed in this thesis, are generally consistent with the true market structure of stumpage demand and supply and are useful for economic analysis and forecasting.

Finally, the effects of alternative schedules for timber harvest from the Siuslaw National Forest on stumpage price, private cut, and total stumpage traded are examined. The estimated model is used to project market behavior under three alternative harvesting schedules on national forests for the period 1977 to 2030.
An Econometric Analysis of Timber Demand and Supply Relationships on the Siuslaw National Forest

by

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# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>I</strong></td>
<td></td>
</tr>
<tr>
<td>Introduction</td>
<td>1</td>
</tr>
<tr>
<td>Objectives</td>
<td>4</td>
</tr>
<tr>
<td>Methods</td>
<td>4</td>
</tr>
<tr>
<td>Marketing Area</td>
<td>5</td>
</tr>
<tr>
<td>Stumpage Supply within the Market Area</td>
<td>6</td>
</tr>
<tr>
<td>Apparent Demand for Stumpage within the Marketing Area</td>
<td>8</td>
</tr>
<tr>
<td>Factors Which Influence Market Demand</td>
<td>9</td>
</tr>
<tr>
<td>Summary</td>
<td>10</td>
</tr>
<tr>
<td><strong>II</strong></td>
<td>12</td>
</tr>
<tr>
<td>Study Tasks and Procedure</td>
<td>12</td>
</tr>
<tr>
<td>Study Tasks</td>
<td>13</td>
</tr>
<tr>
<td>Procedure</td>
<td>13</td>
</tr>
<tr>
<td><strong>III</strong></td>
<td>17</td>
</tr>
<tr>
<td>Stumpage Price Responses to Changes in Volume of Timber Sold</td>
<td>17</td>
</tr>
<tr>
<td>Long-term Price Trends</td>
<td>19</td>
</tr>
<tr>
<td>Regional Timber Supply</td>
<td>19</td>
</tr>
<tr>
<td>Average Stumpage Price Trends</td>
<td>22</td>
</tr>
<tr>
<td>Shortrun Price Changes</td>
<td>24</td>
</tr>
<tr>
<td>Nature of the Shortrun Regional Stumpage Demand Curve</td>
<td>25</td>
</tr>
<tr>
<td>Stumpage Price-Sale Volume Relationships</td>
<td>28</td>
</tr>
<tr>
<td>Summary</td>
<td>29</td>
</tr>
<tr>
<td><strong>IV</strong></td>
<td>31</td>
</tr>
<tr>
<td>Derived Demand -- The Linkage Between Stumpage and Lumber Markets</td>
<td>31</td>
</tr>
<tr>
<td>Elasticity of Price Transmission</td>
<td>34</td>
</tr>
<tr>
<td>Marketing Margins</td>
<td>36</td>
</tr>
<tr>
<td>Constant Marketing Margins</td>
<td>37</td>
</tr>
<tr>
<td>Constant Percentage Marketing Margins</td>
<td>39</td>
</tr>
</tbody>
</table>
### TABLE OF CONTENTS

(continued)

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summary</td>
<td>46</td>
</tr>
<tr>
<td>V Model Specification and Empirical Results</td>
<td>47</td>
</tr>
<tr>
<td>Demand Relation</td>
<td>47</td>
</tr>
<tr>
<td>Supply Relation</td>
<td>48</td>
</tr>
<tr>
<td>Private Stumpage Supply Fixed</td>
<td>49</td>
</tr>
<tr>
<td>Models to be Fitted</td>
<td>52</td>
</tr>
<tr>
<td>Empirical Results</td>
<td>53</td>
</tr>
<tr>
<td>Multicollinearity</td>
<td>55</td>
</tr>
<tr>
<td>Autocorrelation Problems</td>
<td>56</td>
</tr>
<tr>
<td>Heteroskedasticity</td>
<td>58</td>
</tr>
<tr>
<td>Private Stumpage Supply Price Elastic</td>
<td>58</td>
</tr>
<tr>
<td>Stumpage Supply Model</td>
<td>60</td>
</tr>
<tr>
<td>Private Timber Inventory</td>
<td>61</td>
</tr>
<tr>
<td>Simultaneous Equations Model</td>
<td>62</td>
</tr>
<tr>
<td>VI Empirical Results, Implications, and Historical Simulation</td>
<td>65</td>
</tr>
<tr>
<td>Quantitative Analysis of Market Structure</td>
<td>65</td>
</tr>
<tr>
<td>Historical Simulation</td>
<td>69</td>
</tr>
<tr>
<td>Model Solution Procedure</td>
<td>69</td>
</tr>
<tr>
<td>Testing the Forecasting Power of a Model</td>
<td>74</td>
</tr>
<tr>
<td>Prediction-Realization Diagram</td>
<td>74</td>
</tr>
<tr>
<td>Other Measurements of Forecasting Errors</td>
<td>74</td>
</tr>
<tr>
<td>VII Policy Simulation</td>
<td>78</td>
</tr>
<tr>
<td>Projections of Exogenous Variables</td>
<td>80</td>
</tr>
<tr>
<td>Projections of Policy Variables and Baseline Simulations</td>
<td>82</td>
</tr>
<tr>
<td>Summary</td>
<td>86</td>
</tr>
</tbody>
</table>
## TABLE OF CONTENTS (continued)

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>VIII Conclusion</td>
<td>80</td>
</tr>
<tr>
<td>Market Impacts of Alternative Harvest Schedules</td>
<td>89</td>
</tr>
<tr>
<td>Problems and Extensions</td>
<td>89</td>
</tr>
<tr>
<td>Bibliography</td>
<td>93</td>
</tr>
<tr>
<td>Appendices</td>
<td></td>
</tr>
<tr>
<td>I Base Data: Sources and Definitions</td>
<td>96</td>
</tr>
<tr>
<td>II Base Data Listings</td>
<td>102</td>
</tr>
<tr>
<td>III Linear Models for Different Combinations of Variable P</td>
<td>106</td>
</tr>
<tr>
<td>IV Different Functional Forms Fitted for Stumpage Demand</td>
<td>108</td>
</tr>
<tr>
<td>V Correcting for Autocorrelation Problem</td>
<td>109</td>
</tr>
<tr>
<td>VI Heteroskedasticity Test</td>
<td>114</td>
</tr>
<tr>
<td>VII Different Functional Form Estimates for Private Supply Equations</td>
<td>117</td>
</tr>
<tr>
<td>VIII Non-linear Computer Program Used to Estimate Non-linear Functional Form in Appendix VII</td>
<td>120</td>
</tr>
<tr>
<td>IX Regional Gross Growth Rate $c_t$ on Private Forest Lands within the Siuslaw Marketing Area</td>
<td>124</td>
</tr>
<tr>
<td>X Identification in a Simultaneous Equation System</td>
<td>125</td>
</tr>
</tbody>
</table>
## LIST OF ILLUSTRATIONS

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-1</td>
<td>(a) Nonstochastic demand (b) Stochastic demand.</td>
<td>2</td>
</tr>
<tr>
<td>1-2</td>
<td>Timber flows from the Siuslaw National Forest.</td>
<td>5</td>
</tr>
<tr>
<td>3-1</td>
<td>Public and private timber supply in the Siuslaw marketing area, 1954-1976.</td>
<td>21</td>
</tr>
<tr>
<td>3-2</td>
<td>Average stumpage price and National Forest stumpage supply within the Siuslaw marketing area, 1954-1976.</td>
<td>23</td>
</tr>
<tr>
<td>3-3</td>
<td>An inelastic demand curve; a given percentage change of stumpage volume supplied (from Q₁ to Q₂) will be associated with a larger percentage change in stumpage price (from P₁ to P₂).</td>
<td>24</td>
</tr>
<tr>
<td>3-4</td>
<td>An elastic demand curve; a shift from supply curve S₁ to supply curve S₂ will have little effect on stumpage prices.</td>
<td>25</td>
</tr>
<tr>
<td>4-1</td>
<td>Measuring the price elasticities of demand at final product and factor levels.</td>
<td>31</td>
</tr>
<tr>
<td>4-2</td>
<td>Representation of definitions of the marketing margin and marketing costs and charges.</td>
<td>36</td>
</tr>
<tr>
<td>4-3</td>
<td>Two possible relationships between product demand and factor demand.</td>
<td>38</td>
</tr>
<tr>
<td>4-4</td>
<td>Unit price of lumber and stumpage within the Siuslaw marketing area, 1954-1976.</td>
<td>44</td>
</tr>
<tr>
<td>Figure</td>
<td>Description</td>
<td></td>
</tr>
<tr>
<td>--------</td>
<td>-------------</td>
<td></td>
</tr>
<tr>
<td>5-1</td>
<td>Three possible forms for the gross growth rate $a_t$.</td>
<td></td>
</tr>
<tr>
<td>6-1</td>
<td>Historical simulation of the bid price of stumpage (p) over the sample period 1954-1976 by OLS (private stumpage supply exogenous) and 2SLS (private stumpage supply price elastic).</td>
<td></td>
</tr>
<tr>
<td>6-2</td>
<td>Historical simulation of the private stumpage supply $S_p$ over the sample period 1954-1976 by OLS (single equation model) and 2SLS (simultaneous equation system).</td>
<td></td>
</tr>
<tr>
<td>6-3</td>
<td>Historical simulation of the total volume of stumpage demanded (Q) within the marketing area over the sample period 1954-1976 by 2SLS (private stumpage supply price elastic).</td>
<td></td>
</tr>
<tr>
<td>7-1</td>
<td>Predicted schedules for national forest harvest under INCREASE, CONSTANT, and DECREASE policies.</td>
<td></td>
</tr>
</tbody>
</table>
### LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-1</td>
<td>Public and private apparent stumpage supply in the Siuslaw marketing area, 1954-1976.</td>
</tr>
<tr>
<td>4-1</td>
<td>Unit price (1967$/MBF, lumber tally) of Douglas-fir lumber and average stumpage price within the Siuslaw marketing area, 1954-1976.</td>
</tr>
<tr>
<td>6-2</td>
<td>Estimated elasticities of $p$ with respect to $Q$ and $PC$.</td>
</tr>
<tr>
<td>7-1</td>
<td>Predicted schedules for lumber price and non-stumpage production cost (1967$/MBF, lumber tally).</td>
</tr>
<tr>
<td>7-2</td>
<td>Predicted schedules for $V_{-1}$, $\bar{I}$, $\bar{E}$, and other public stumpage supply within the marketing area.</td>
</tr>
<tr>
<td>7-3</td>
<td>Projected baseline bid prices of stumpage ($p$), private supply ($S_p$), and total stumpage traded from INCREASE, CONSTANT, and DECREASE policies.</td>
</tr>
<tr>
<td>8-1</td>
<td>The estimated demand elasticities for national forests under INCREASE, CONSTANT, and DECREASE policies within the Siuslaw marketing area.</td>
</tr>
</tbody>
</table>
AN ECONOMETRIC ANALYSIS OF TIMBER DEMAND AND SUPPLY RELATIONSHIPS ON THE SIUSLAW NATIONAL FOREST

CHAPTER I

INTRODUCTION

Alternate harvest levels and land-use allocation on public forests may have substantial impacts on both local and national welfare. An understanding of the economic structure of these decisions should contribute to better decisions and policy analysis. In this study, the local marketing area for the Siuslaw National Forest was selected and various econometric relations established, these relations were then used to demonstrate and project alternate policies.

Demand is the functional relationship between the price of a given commodity and the quantity of that commodity that will be sold in a market specified as to time and place, i.e., a demand function describes the relationship between various quantities of a good that a buyer may obtain and the unit price the buyer would be willing to pay for these quantities. Therefore, demand embodies the buyer's response to price changes; it is a "buyer's response curve".

According to the law of demand, quantity demanded varies inversely with price. Another way of expressing
this principle is to say that the demand curve is negatively sloped. Changes in nominal price cause movements along a given demand function, the movements representing the opposite changes in quantities demanded.

The observed market price and quantity at a given period are determined by both demand and supply factors. Moreover, the demand relationship (abstracting from other factors of demand) may be written with quantity demanded as a function of the demand price, \( Q = f(P) \) or vice versa as \( P = f^{-1}(Q) \).

![Diagram of demand curves](image)

**Figure 1-1** (a) Nonstochastic demand (b) Stochastic demand

Suppose we wish to estimate a demand function for a given commodity. We posit that quantity demanded is inversely related to its price, as in Figure 1-1 and the equation

\[
Q = \alpha_1 + \alpha_2 P \quad \text{where} \quad \alpha_2 < 0 \quad (1.1)
\]

If equation (1.1) is nonstochastic, any two observations such as points 1 and 2 in Figure 1-1 (a) are sufficient to estimate the two parameters \( \alpha_1 \) and \( \alpha_2 \). If the demand
function is stochastic, as in Figure 1-1 (b) and the equation

\[ Q = \alpha_1 + \alpha_2 P + u \]  

we can use an ordinary least squares estimator to obtain unbiased and consistent estimates \( \alpha_1 \) and \( \alpha_2 \).

Mathematically, there is no difference between the equation \( Q = \alpha + \beta P \) and \( P = \left( -\frac{\alpha}{\beta} \right) + \left( \frac{1}{\beta} \right) Q \). However, statistically, based on time series of \( P \) and \( Q \), the least squares estimate of \( \beta \) in the first equation will not equal the reciprocal of the least square estimate of \( \frac{1}{\beta} \) in the second equation.

The demand concept is an instantaneous one. Theoretically, every time a sale is made the curve should be reconstructed. Practically, however, time intervals are usually specified. Thus, one may meaningfully speak of the demand for stumpage during 1954 or 1976. When comparing the demand schedules for different time periods one usually speaks of demand "shifts". A demand curve shifts from year to year.

Demand for timber products in the United States has been projected to increase steadily (USDA Forest Service, 1974). Yet the supply of timber products potentially available from U.S. forests show limited increases. Substantial increases in stumpage prices appear necessary to balance potential timber demands with available timber supplies. This structure is best described by demand, supply and other market relationships which simultaneously determine price,
quantity of stumpage, and other market variables.

The purposes of this thesis are primarily empirical in nature. The approach to model specification, the estimation procedures employed, the evaluation techniques utilized --- all are related to the primary objectives of: (1) discovering and analyzing the effects of important factors influencing stumpage demand and supply within the Siuslaw marketing area, (2) making predictions of market behavior, and (3) forecasting and policy simulation of the demand relationship for timber sold on the Siuslaw National Forest.

I. OBJECTIVES

The objectives of this study are to develop statistical approximations of short-term models of the demand relationship for timber sold on the Siuslaw National Forest, and then use these models for forecasting and policy simulation analysis on the Forest.

II. METHODS

In this section, first the marketing area for timber sold from the Siuslaw National Forest will be described, and then within this marketing area the stumpage supply, apparent stumpage demand, and factors which influence the market demand will be discussed. Finally, we will build a theoretical model used to describe the market for timber sold from the Siuslaw National Forest.
Figure 1-2 Timber flows from the Siuslaw National Forest

For the purpose of this study our initial concern is with the "timbershed" or marketing area for stumpage sold from the Siuslaw National Forest. The Siuslaw National Forest is located in the northern and central coast range of Oregon and its stumpage is processed in coast range and Willamette Valley mills. Austin (1969) indicated that nearly 74 percent of the timber purchased on the Siuslaw was processed in Lane, Linn, Benton, Lincoln, Polk, and Marion counties. An additional 18 percent was processed in the northern Willamette Valley counties (Yamhill, Clackmas,
Washington, Columbia, Hood River, and Multnomah). Small amounts also went to Coos, Clatsop and Tillamook counties as shown in Figure 1-2. Although Austin's study is ten years old, his findings are still indicative of the principal flows of timber from the Siuslaw National Forest. In this study the marketing area will be expanded to include all the counties of Northwest and West Central Oregon which include Benton, Lane, Lincoln, Linn, Clackmas, Clatsop, Folk, Columbia, Hood River, Marion, Multnomah, Tillamook, Washington and Yamhill. This region is larger by three counties (Hood River, Clackmas, and Multnomah) than the region used by Adams and Kao (1977).

B. Stumpage Supply within the Marketing Area

Within the marketing area, wood products processors also obtain timber from: other national forests (primarily the Willamette and Mt. Hood, and some fraction from the Umpqua and Gifford Pinchot National Forests); other public lands (county, State of Oregon, Bureau of Land Management, Bureau of Indian Affairs, and other federal lands); and from both integrated and non-integrated private lands. These lands provide supplies of timber which are readily (though not perfectly) substitutable for timber from the Siuslaw National Forest.

Timber sales volumes on all public ownerships (including the Siuslaw) are determined by the allowable cut or
harvest scheduling procedures of the several agencies within the limits imposed by available timber sales budgets and manpower. In general, public sales volumes do not depend on the current price of stumpage or on other economic factors. As a result, the supply function for timber from public lands may be viewed as "perfectly price inelastic", that is, the volume of sales offered does not vary in any direct, causal fashion with stumpage price. This volume may fluctuate from year to year as timber management policy and budgets change (Adams and Kao, 1977). The amounts of timber sold on these forest lands may affect the average stumpage price over the marketing area. Such effect will be discussed in Chapter III.

Private timber supply is composed of an "integrated" or forest industry component and a "non-integrated" or farm and miscellaneous private component. In general, for private forest land-owners the hypothesis is that the cut volumes are positively related to stumpage price. In the Siuslaw marketing area, Adams and Kao (1977) assumed that private response was perfectly price inelastic for both integrated and non-integrated timber supply. In this study, private supply will be treated under two assumptions. First, supply relations that are price responsive and second, an alternative model structure where private supply is exogenous (perfectly inelastic).
C. Apparent Demand for Stumpage within the Marketing Area

In attempting to explain the stumpage price (bid price) for timber at public sales, the relevant supply volumes are the amounts sold by the several ownership classes rather than the volumes actually harvested, i.e., for demand analysis it would be preferable to have market sales data rather than production figures. Measures of these transaction volumes are readily available for national forest lands but not for other ownerships. As a result, we have substituted estimates of harvest or sales volume for all non-Forest Service public lands and for all private land. To this approximation to sales we must add 'imports' (flows into the marketing area) and subtract 'exports' (flows out of the marketing area). The result is called "apparent demand" for stumpage in the Siuslaw marketing area, i.e.,

\[
\text{Apparent demand for stumpage} = \text{National Forest volume sold} + \text{other public volume cut} + \text{private volume cut} + \text{imports} - \text{exports}
\]

The errors introduced by this approximation are likely to be small, since the average size of sales on other ownerships is smaller and the average duration is somewhat shorter (approximately one year). For the annual data employed here, therefore, the differences between sold and cut volumes are probably negligible.
D. Factors Which Influence Market Demand

Besides the stumpage price itself, there are other factors which may affect the market demand for stumpage.

1. **Final products price:** The demand for stumpage is a "derived demand"; that is, it is dependent on the demand for final products made from stumpage. In general, the demand for stumpage is a derived demand depending on the demand for secondary products such as lumber, plywood, pulp products, and log export, the efficiency and production characteristics of secondary processing facilities, and on the prices of other inputs to manufacturing processes such as labor and energy. People demand housing for which lumber is needed; lumber requires sawlogs, and sawlogs must come from stumpage. A similar chain stretches from paper to pulp to pulpwood to stumpage, and if an understanding of stumpage price formation is sought none of these steps can be bypassed. Since lumber is still the most important single wood product in the marketing area, the development of stumpage demand will be based primarily on factors relating to the demand for lumber (Haynes, 1977). A detailed discussion of the derived demand for stumpage will be presented in Chapter IV.

2. **Timber inventory under contract:** In the short-term, inventories of raw material at various stages of processing between woods and mill may also influence the stumpage buyer's demand -- specifically, level of uncut volume under
contract on public lands (timber sold but not cut) and levels of log inventories at mills or in the woods. Unfortunately estimates of log inventory are unavailable. Thus uncut volume alone will be used as an indicator of these inventory influences. Public timber sale contracts are usually made for a period of three or more years. Because of this, timber buyers are able to hold an inventory of timber purchased but uncut. This ability to "store" timber on the public forest lands would also tend to increase the elasticity of demand for stumpage.

(3) Costs of non-stumpage inputs (lumber production costs): Costs of other inputs for lumber manufacturing and logging such as labor and energy will also affect the demand for stumpage.

III. SUMMARY

The material presented in this chapter provide a fundamental basis for analysis. With this background, a set of hypothetical market relationships will be constructed and investigated.

(1) Total timber supply in the Siuslaw marketing area is obtained by summing the three component supply functions: (a) total timber supply on all public lands (Siuslaw S S and all other public sales excluding Siuslaw SOG), (2) volume of timber harvested from integrated private or "forest industry" lands (S I), and (3) volume of timber harvested
from non-integrated, farm and miscellaneous private ownerships ($S_N$), i.e., total timber supply, $S$, is

$$S = \bar{S}_S + \bar{S}_{OG} + S_I + S_N$$

(2) The market demand for stumpage is a function of stumpage price ($p$), prices of final product ($P$), inventories of timber under contract ($I$), and costs of non-stumpage inputs ($C$):

$$D = D (p, P, I, C)$$

(3) In short-term market equilibrium, supply equals apparent demand and the demand-supply relations within the marketing area may be written in structural form as:

$$D = D (p, P, I, C)$$

$$S = \bar{S}_S + \bar{S}_{OG} + S_I + S_N$$

$$D = S + \bar{I} - \bar{E} = Q$$

where:

$$\bar{I} = \text{total log imports from outside of the Siuslaw marketing area and}$$

$$\bar{E} = \text{total log exports from the Siuslaw marketing area.}$$

(4) Finally, the demand relation for Siuslaw timber can be derived from the estimated system above as:

$$\hat{D}_S = \hat{Q} - \bar{S}_{OG} - \hat{S}_I - \hat{S}_N - \bar{I} + \bar{E}$$

where $\hat{D}_S$ is the estimated market demand for the Siuslaw timber.
CHAPTER II

STUDY TASKS AND PROCEDURE

I. STUDY TASKS

The study tasks can be divided into five categories: data collection and collation; model specification; regression estimation; discussion of empirical results and a technical, policy-making and forecasting evaluation. Each of these tasks is described below.

(1) Collect, collate, and encode the harvest volumes, stumpage price, costs of non-stumpage inputs, and inventory of timber under contract data for each county and owner group in the Siuslaw marketing area. Specific definition of the relevant data variables is provided in Appendix I.

(2) Specify the theoretical model for the market demand and supply relationships:
   (a) variables to be included
   (b) preliminary model specification
   (c) hypotheses to be tested

(3) Develop regression estimates of demand and supply relationships.

(4) Discuss the empirical results, including the hypothesis testing and testing (and correcting if needed) for various econometric problems.
(5) An evaluation of the analysis and the resulting implications:

(a) analysis: testing economic theory of demand-supply relationships, i.e., obtaining empirical evidence to test the explanatory power of demand-supply theories.

(b) policy-making: obtaining numerical estimates of the coefficients of demand-supply relationships on the Siuslaw National Forest for policy simulations.

(c) forecasting: using the numerical estimates of the coefficients in order to forecast the future values of the economic magnitudes.

II. PROCEDURE

After data collection and collation, the procedure can be divided into three stages. These are: model form specification; estimation of alternate forms and evaluation of the models developed using economic, statistical and econometric criteria. Each of these stages is described below.

(1) STAGE 1: The theoretical mathematical form of the demand and supply models will be explored in linear and nonlinear form (logarithm, exponential, and semilogarithm), single equation and simultaneous equation system.

(2) STAGE 2: For any single equation model the estimates of coefficients will be developed by using the ordinary least squares (OLS) method. For the demand-supply simultaneous equations system, the two-stage least squares
(2SLS) method will be employed.

(3) **STAGE 3: EVALUATION OF ESTIMATES:** After the estimation of the model we must proceed with the evaluation of the results of the calculations, that is, with determination of the reliability of these results. The evaluation consists of deciding whether the estimates of the parameters are theoretically meaningful and statistically satisfactory. For this purpose we use various criteria which may be classified into three items:

(a) **Economic a priori criteria:** These are determined by the principles of economic theory and refer to the 'sign' and the 'size' of the parameters of economic relationships. If the estimates of the parameters have sign or size not conforming to economic theory, they should be rejected, unless there is good reason to believe that in the particular instance the principles of economic theory do not hold.

(b) **First-order statistical criteria:** These are determined by statistical theory and aim at the evaluation of the statistical reliability of the estimates of the parameters of the model. The most widely used statistical criteria are the coefficient of multiple determination ($R^2$), standard error of the estimate (S.E.), t and F statistics. It should be noted that the statistical criteria are
secondary only to the *a priori* theoretical criteria. The estimates of the parameters should be rejected in general if they have the 'wrong' sign (or size) even though the $R^2$ is high or the S.E. suggests that the estimates are statistically significant.

(c) Second-order statistical criteria: These criteria are concerned with whether the assumptions of the estimation method employed are satisfied or not. The second-order statistical criteria determine the reliability of the first-order statistical criteria. They help us establish that the estimates have the desirable properties of unbiasedness, consistency, etc. Usually we will test for autocorrelation (by a Durbin-Watson d statistic), multicollinearity, and heteroscedasticity of the specified models. If the assumptions of the estimation method applied by the investigator are not satisfied, either the estimates of the parameters cease to possess some of their desirable properties or the first-order statistical criteria lose their validity and become unreliable for the determination of the significance of these estimates. When the assumptions of an estimation technique are not satisfied, it is customary to respecify the model (e.g. introduce new variables or omit some others, transform the
original variables, etc.) so as to produce a new form which meets the assumptions of the method. We then proceed with re-estimation of the new model and with re-application of all tests. This process of re-specification of the model and re-estimation continues until the results pass all the economic and statistical tests.
CHAPTER III

STUMPAGE PRICE RESPONSES TO CHANGES IN VOLUME OF TIMBER SOLD

The level of stumpage prices in relation to the quantity of public timber sold is important in formulating timber sale policies. The purpose of this chapter is to explore in several fashions the effect on stumpage prices of changes in quantities of timber made available for harvest on the public forests in the Siuslaw marketing area. If this relationship is known, the probable returns from alternative timber sale programs can be estimated and incorporated into the decision-making process.

The demand for stumpage (in the aggregate) is generally considered to be inelastic and less elastic than final product demand. Public stumpage supply is assumed to be price inelastic, and private stumpage supply is also generally viewed by economists as inelastic and is so treated here. But this elasticity clearly could differ substantially from region to region. Under these elasticity conditions, a shift in public stumpage supply would yield a percentage change in equilibrium quantity of stumpage traded that is smaller than the percentage change in equilibrium price (this follows from inelastic demand).

Following Adams (1977), the demand and supply relations in an hypothetical stumpage market can be written as:
\[ D = D(p, P) \quad (3.1) \]
\[ S = S(p) + \overline{S}_G \quad (3.2) \]

where \( p \) is stumpage price, \( P \) is product price, and \( \overline{S}_G \) is public stumpage supply. Equilibrium in the market requires that \( D = S \), or
\[ D(p, P) = S(p) + \overline{S}_G \quad (3.3) \]

Taking the total differential of equation (3)
\[ \left( \frac{dD}{dp} \right) dp + \left( \frac{dD}{dP} \right) dP = \left( \frac{dS}{dp} \right) dp + d\overline{S}_G \]

Ignoring the term in product price momentarily:
\[ \left( \frac{dD}{dp} \right) dp = \left( \frac{dS}{dp} \right) dp + d\overline{S}_G \]

then
\[ \left( \frac{dD}{dp} \right) dp = \left( \frac{dS}{dp} \right) dp + \left( \frac{d\overline{S}_G}{dp} \right) dp \]

and
\[ \left( \frac{dD}{dp} \right) = \left( \frac{dS}{dp} \right) + \left( \frac{d\overline{S}_G}{dp} \right) \]

i.e.,
\[ \frac{dp}{d\overline{S}_G} = \frac{1}{\left( \frac{dD}{dp} \right) - \left( \frac{dS}{dp} \right)} \quad (3.4) \]

The impact of a change in public supply on equilibrium stumpage price varies inversely with the difference between the slopes of the demand and supply curves in price-quantity space. The denominator of equation (3.4) is negative because the demand curve is negatively sloped. An increase in this slope (roughly, an increase in elasticity) reduces the price impact of \( d\overline{S}_G \). An increase in the supply slope (roughly, an increase in elasticity) also reduces the impact.
I. LONG-TERM PRICE TRENDS

For perspective on the general level of stumpage price, long-term demand, supply, and price trends will be examined first. We will then look more closely at National Forest price-quantity relationships.

A. Regional Timber Supply

The available timber supply (volume sold) from the Siuslaw marketing area National Forests (including Siuslaw, Willamette, and Mt. Hood) increased 30 percent from 1954 to 1976; in 1954 the volume sold was 795.9 million board feet and in 1976 the volume sold was 1034.5 million board feet. Comparable information is not available for all ownerships in the region, most notably for private lands; however, timber harvest information gives a reasonable indication of timber supplies made available over the 1954-1976 time period. The apparent volume of timber supply from all ownerships was 3958.8 million board feet in 1954; in 1976, total timber supply was 3411.5 million board feet (Table 3-1, Figure 3-1).

Long-term changes in the study region's timber supply are primarily a result of shifts in the supply curve rather than movements along the curve, i.e., the changes in National Forest cut came about through increased knowledge of present and future timber management and utilization rather
<table>
<thead>
<tr>
<th>YEAR</th>
<th>USDA Forest Service</th>
<th>other public</th>
<th>total private</th>
<th>all ownerships</th>
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<tr>
<td>1954</td>
<td>795,867</td>
<td>736,730</td>
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<td>784,094</td>
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<td>867,401</td>
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<td>896,139</td>
<td>530,470</td>
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<td>1,466,509</td>
<td>387,382</td>
<td>1,909,759</td>
<td>3,761,650</td>
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<td>1,273,620</td>
<td>467,169</td>
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<td>1,229,282</td>
<td>454,420</td>
<td>2,077,653</td>
<td>3,761,355</td>
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<td>1,898,073</td>
<td>680,139</td>
<td>1,953,669</td>
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<td>1,404,026</td>
<td>599,526</td>
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<td>2,030,904</td>
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<td>4,318,069</td>
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<tr>
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<td>1,321,877</td>
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<td>1974</td>
<td>1,497,705</td>
<td>540,315</td>
<td>1,672,132</td>
<td>3,710,152</td>
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<tr>
<td>1975</td>
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<td>334,710</td>
<td>1,824,334</td>
<td>3,739,498</td>
</tr>
<tr>
<td>1976</td>
<td>1,034,535</td>
<td>531,782</td>
<td>1,845,221</td>
<td>3,411,538</td>
</tr>
</tbody>
</table>

Source: see Appendix I
Figure 3-1 Public and private timber supply in the Siuslaw marketing area, 1954-1976.
than from direct price influence. The quantity of private timber supplied is more likely to be affected by price changes, although any such effect would be more important in the short run.

A timber supply curve is a schedule showing quantities of timber that will be offered on the market at different prices during a given time period. With a change in time period, factors such as technology, management, and utilization may cause a change in the quantities offered at these prices representing a shift in the supply curve.

B. Average Stumpage Price Trend

Average stumpage price in the Siuslaw marketing area has also shown a long-term increasing trend since 1954, although it has fluctuated considerably from year to year (Figure 3-2). Part of this increase can be attributed to demand for additional logs; in earlier years for rising plywood production, and more recently for log export. In addition, logs have attained a greater value through more complete utilization. Finally, technological advances have decreased the cost of some other factors of production, leaving a larger proportion of total revenue for stumpage purchasers.

1/ Stumpage prices here are constant dollar prices determined by dividing the current price in each year by the producer price index for all commodities (1967=100.00).
Figure 3-2. Average stumpage price and National Forest stumpage supply within the Siuslaw marketing area, 1954-1976.
II. SHORTRUN PRICE CHANGES

In the short run, economic theory suggests that prices for stumpage will rise when the amount of timber offered for sale decreases and fall when timber offerings increase under stationary demand for stumpage. In the national stumpage market, the demand curve is traditionally thought to be very inelastic (Figure 3-3). This is due to the predominant role of wood as a building material for residential construction and the short-term technological limitations on substitution. Local public stumpage demand need not be as inelastic however due to substitution from private stumpage, imports or other alternate sources.

Figure 3-3 An inelastic demand curve: a given percentage change of stumpage volume supplied (from Q1 to Q2) will be associated with a larger percentage change in stumpage price (from P1 to P2).
A. Nature of the Shortrun Regional Stumpage Demand Curve

In the Douglas-fir region, there is evidence to suggest that, except for extreme changes in stumpage availability, the demand curve for National Forest timber is highly elastic, taking the form shown in Figure 3-4. Because of this, changes in the quantity of timber offered for sale under various harvest alternatives will have no appreciable effect on stumpage prices. This hypothesis is based on the following propositions:

(1) SUBSTITUTION: The greater the suitability and availability of substitutes, the greater the price elasticity of demand for products. Since the demand for stumpage depends on the demand of finished products, we are interested in the availability of substitutes in both the
stumpage and the final product market. The relationships between stumpage and final product market will be discussed in Chapter IV.

In the stumpage market, changes in the volume of timber sold on National Forest lands may bring about a response from private timberland owners. During the 1954-76 period, timber harvest on private lands declined 24 percent from 2426 million board feet to 1845 million board feet. During the same period timber sold on National Forest lands increased 30 percent from 795 million board feet to 1034 million board feet. The long term decline on private lands has been attributed primarily to decreased private timber availability (timber inventory) rather than a response to increased public timber sales. However, during this period, fluctuations in private harvest were somewhat larger than were public fluctuations. It therefore appears that timber harvest on private lands is responsive to market conditions and that, if actions by public land managers increase or decrease available timber supplies and result in changed market conditions, these changes might be offset somewhat by private landowners' actions.

In the final product market, wood products and products made from other raw materials have frequently been interchanged, especially in the construction industry. A traditional concern in the forest products industry has been loss of markets to other materials. This interchange
between products should increase the demand elasticity in the final products market and in the stumpage market.

(2) TIME: The time period under consideration also affects demand elasticity. Generally, as the time period grows longer, more adjustments to a change in quantity supplied can be made and the effect of that change will be smaller. We are concerned with the effect on stumpage prices over a one- or two- year period following a change in annual timber sale volume on National Forests. A large change in volume of timber sold could have an immediate effect on regional prices. Any price effect should be at least dampened somewhat by substitution effects.

(3) INDUSTRY AND MARKET CHARACTERISTICS: Economic theory suggests that the demand curve which an individual seller faces slopes downward to the right. Under this condition, a shift in either the demand or supply curve without a corresponding shift in the other will bring about a change in the equilibrium price. In practice, only one situation exists where a shift in supply has no effect on price; this will happen when the supplier faces a perfectly elastic demand curve. Generally, when there are a large number of sellers, none of whom sell enough to influence price through individual supply action, the demand curve for each firm is perfectly elastic. Therefore we would expect the demand curve facing individual firms in the lumber market to be very elastic even though the total
national demand curve may be much less elastic.

The same firms that sell lumber on the national market are the buyers of Federal timber on the local markets. However, in the timber market, the number of firms competing for an individual sale is much smaller. Given this type of market structure, we would expect the demand curve facing timber sellers to be quite inelastic (Hamilton, 1970).

Also, the demand for stumpage is a derived demand; that is, it is dependent on the demand for products made from the stumpage. It is expected that fluctuations in prices for final products would produce similar price fluctuations in the stumpage market, and that high elasticity in final-product demand should produce high elasticity in the demand for stumpage.

B. Stumpage Price - Sale Volume Relationships

There is an imperfect year-by-year relationship between sale volume and allowable cut levels on National Forest Lands. The allowable cut has increased steadily over the period we have been considering. Since we are concerned with the price effects of changes in available timber supply, sale volume rather than allowable cut is the important variable. Over the period 1954-1976, the volume of Forest Service timber sold in the Siuslaw marketing area fluctuated much more widely than allowable cut. These fluctuations appear to be responses to industry needs. With the large
observed fluctuations in volume sold, we would expect to find corresponding fluctuations in stumpage price in the opposite direction. Nine periods in which sale volume increased substantially were from 1955 to 1958, 1961 to 1962, 1962 to 1963, 1964 to 1966, 1967 to 1968, 1969 to 1970, 1971 to 1972, 1973 to 1974, and 1974 to 1975. In four periods, 1955 to 1958, 1961 to 1962, 1969 to 1970, and 1974 to 1975, the quantity increase was accompanied by a stumpage price decline. In the other five periods, the increases in sale volume were accompanied by stumpage price rises. Also, nine periods of declining sale volume were: 1954 to 1955, 1958 to 1959, 1959 to 1961, 1963 to 1964, 1966 to 1967, 1968 to 1969, 1970 to 1971, 1972 to 1973, and 1975 to 1976. In three periods, 1959 to 1961, 1966 to 1967, and 1975 to 1976, the quantity decrease was accompanied by a stumpage price decline. In the other six periods, the decreases in sale volume were accompanied by stumpage price rises. Part of this behavior may be explained by the indicators of economic activity. From the above data, no direct and simple relationship between National Forest stumpage price and quantity sold emerges.

III. SUMMARY

Average stumpage prices for timber sold on National Forests have shown a longrun increasing trend. Despite the upward trend, these prices have fluctuated a great deal on
a year-to-year basis. From the examination of the market for the region's stumpage, it shows that variations in National Forest timber sale volume did not prove to be good indicators of stumpage price changes; i.e., changes in the volume of National Forest timber offered for sale will have little effect on the general level of stumpage prices in the Siuslaw marketing area (Figure 3-2).
In market and price analysis, we refer to final products demand (consumer demand) as the primary demand because it is to this demand that all other demands in the system relate. The intermediate level demands are called derived demand because they are derived from the primary or consumer demand.

It is possible to directly compare demand curves at two levels of the marketing system only if we express the quantities at one level in terms of quantities at another level. Given our ability to express demands in terms of equivalent price and quantity units, we can draw demand curves for two or more market levels on the same diagram.

**Fig. 4-1** Measuring the price elasticities of demand at final product and factor levels.
Figure 4-1 illustrates hypothetical demand relations at two market levels.

In this figure, D₁ is the final products demand and D₂ is the factors demand. D₁ would also be referred to as the primary demand and D₂ would be called the derived demand. The vertical distance between these two demands is the market costs associated with each quantity of product demanded.

Note that in the diagram D₁ and D₂ are parallel as they will be for any product with a constant factor-to-product mark-up. This means that both lines have the same slope. Recall that \( E_p = \text{percent } \Delta Q/\text{percent } \Delta P \). In practice we would measure elasticity at a point on the lines or over a range of price and quantity changes. Let us assume that we start at factor demand point A and that increase in supply at that level causes a movement of equilibrium price and quantity along the curve to point B. This will be recorded as a \( \Delta Q \) and \( \Delta P \). At the final product level, a movement from A' to B' also means a \( \Delta Q \) and \( \Delta P \) changes. Thus

\[
\frac{\Delta P_2}{\Delta Q} \text{ for } D_2 = \frac{\Delta P_1}{\Delta Q} \text{ for } D_1
\]

over the range of price and quantity change, with the arc-elasticity formula, we take the average of the two P's or Q's as the base to which we relate the change.

\[1/ E_{Y,X} = \frac{\% \text{ change in } Y}{\% \text{ change in } X} = \frac{\% \Delta Y}{\% \Delta X} = \frac{\Delta Y/Y}{\Delta X/X} = \frac{\partial Y}{\partial X} \cdot \frac{X}{Y} \]

= The elasticity of Y with respect to X.
The price elasticity of the final product-level demand is always greater (in absolute terms) than the price elasticity of the factor-level demand across the same quantity range when the demand curves are parallel. In fact, if the demands are parallel, we can generally state that

$$E_{P_2} = E_{P_1} \left( \frac{P_2}{P_1} \right)$$

Demand curves may not be parallel over all quantity ranges, as will be discussed later. What we can point out, though, is that knowledge of the relationship between primary and derived demands permits us to estimate intermediate demand elasticities if we know primary demand elasticity, and vice versa.

As stated in Chapter I, demand for stumpage is a "derived demand". Stumpage, for example, is an input in the lumber industry; thus, the demand for stumpage is derived from the demand for lumber. The derived demand concepts which were used to develop a general statement of the relationship between the elasticity of demand in the product market (such as lumber and plywood) and the elasticity of demand in the factor market (such as stumpage) imply that factor prices can be derived from product prices (Haynes, 1977). Therefore, the purpose of this chapter is to
establish a relationship between lumber (or plywood) and stumpage markets based on "derived demand" concepts.

I. ELASTICITY OF PRICE TRANSMISSION

To illustrate the relationship between stumpage and product prices, let demand and supply in the product market be given by (Adams, 1977):

\[ D = D (P) \]
\[ S = S (P, p) \]

and

\[ D (P) = S (P, p) \] \hspace{1cm} (4.1)

where \( P \) is product price and \( p \) is stumpage price. Taking the total differential of equation \((4.1)\):

\[ \left( \frac{\partial D}{\partial P} \right) dP = \left( \frac{\partial S}{\partial P} \right) dP + \left( \frac{\partial S}{\partial p} \right) dp \]

then

\[ \left( \frac{\partial D}{\partial P} \right) = \left( \frac{\partial S}{\partial P} \right) + \left( \frac{\partial S}{\partial p} \right) \frac{dp}{dP} \]

and

\[ \left( \frac{dp}{dP} \right) = \left( \frac{\partial p}{\partial S} \right) \left[ \left( \frac{\partial D}{\partial P} \right) - \left( \frac{\partial S}{\partial P} \right) \right] \] \hspace{1cm} (4.2)

The impact of a change in product price on equilibrium stumpage price depends directly on the sensitivity of stumpage to change in supply and on the difference between demand and supply slopes. This relationship has been used to apportion stumpage price changes resulting from changes in product prices. From equation \((4.2)\) we obtain:

\[ \frac{dP}{dp} = \frac{\left( \frac{\partial S}{\partial D} \right)}{\left( \frac{\partial D}{\partial P} \right) - \left( \frac{\partial S}{\partial P} \right)} \] \hspace{1cm} (4.3)

Multiplying both sides of equation \((4.3)\) by \( \left( \frac{dP}{P} \right) \), the
ratio of stumpage to product price:

\[
\left(\frac{-dP}{dp}\right)\left(\frac{P}{F}\right) = \frac{\left(\frac{dS}{dF}\right) P}{\left(\frac{dD}{dF}\right) P - \left(\frac{dS}{dF}\right) P}
\]

\[
= \frac{\left(\frac{dS}{dF}\right) P}{D S \left[\left(\frac{dD}{dF}\right)\left(\frac{P}{D}\right)(-1) - \left(\frac{dS}{dF}\right)\left(\frac{P}{S}\right)(-1)\right]}
\]

\[
= \frac{E_{S,F} \cdot S}{E_{D,F} \cdot D - E_{S,F} \cdot S}
\]

where \( E_{Y,X} \) denotes the elasticity of \( Y \) with respect to \( X \).

If \( D = S \) in equilibrium, then

\[
\left(\frac{dP}{dp}\right)\left(\frac{P}{F}\right) = \frac{E_{S,F}}{E_{D,F} - E_{S,F}} \quad (4.4)
\]

The left side of equation (4.4) is referred to as the "elasticity of price transmission (\( \gamma \))" (Adams, 1977). It depends here on the elasticity of supply with respect to the factor price and the difference between demand and supply elasticities, i.e.,

\[
\gamma = \left(\frac{dP}{dp}\right)\left(\frac{P}{F}\right) = \left(\frac{E_{S,F}}{E_{D,F} - E_{S,F}}\right)
\]

(\( \text{elasticity of product supply with respect to price in the stumpage market} \))

(\( \text{elasticity of demand} \) - (\( \text{elasticity of supply in the product market} \)) - (\( \text{elasticity of supply in the product market} \))

The elasticity of price transmission expresses the ratio of the relative change in product price to the relative change in factor price when other factors affecting processor behavior are held constant.
II. MARKETING MARGINS

It is difficult to ascertain the relative demand elasticities in each market of different region or species. Also, a priori information on supply elasticity with respect to stumpage price is limited. These problems can be mitigated by better use of the available data on stumpage and product prices. A key to more detailed analysis of the "linkage" (bridging the gap) between stumpage and product prices will be discussed below.

![Diagram](image)

**Figure 4-2** Representation of definitions of the marketing margin and marking costs and charges.

Figure 4-2 illustrates the product and derived demand functions. It assumes that the product supply function ($S_p$) and the product demand function ($D_p$) intersect to establish the product price ($P$). The factor price ($p$) is based on
derived demand \( (D_p) \) and factor supply \( (S_p) \), the difference in the two prices is the marketing margin. In general, marketing margin refers to the difference between prices at different levels of the marketing systems, i.e., the marketing margin is the difference between the product price \( (P) \) and the factor price \( (p) \). It is also represented as the vertical distance between the demand curve in Figure 4-2.

The marketing margin refers only to the price difference and makes no statement about the quantity of product marketed (Dahl, 1977).

The relationship between price elasticities of demand for product and derived demand relationships, for the same commodity, can be determined provided there exists the knowledge of marketing margins and of the elasticity at one market level (Haynes, 1977). The exact relationship between elasticities depends on how the marketing margin has been assumed to behave.

A. Constant Marketing Margins

If the margin has been assumed to be constant regardless of the amount marketed, the product and derived demand curves would be parallel as shown in Figure 4-3(a) and the relationship can be expressed as:

\[
P = p + m
\]

or

\[
p = P - m
\]

where \( P = \) price in the product market
Figure 4-3 Two possible relationships between product demand and factor demand.

\[ p = \text{price in the factor market} \]
\[ m = \text{the marketing margin} \]

In this case, the supply function of marketing services is assumed to be perfectly elastic. The derived demand \( D_p \) lies below the product demand \( D_p \) by a fixed-absolute amount. The relationship between elasticities of demand can be computed as follow: the change in quantity (\( \Delta Q \)) is the same at product as at factor demand. Thus,

\[ \Delta Q = Q_1 - Q_2 \]

The change in price at product market is

\[ \Delta P = P_1 - P_2 \]

and the change in price at factor market is

\[ \Delta P = p_1 - p_2 \]

Because both product and factor demand curves have the same slopes with constant absolute margins,

\[ \Delta P = \Delta p = p_1 - p_2 = P_1 - P_2 \]
Substituting the appropriate terms in the equation for elasticity, the elasticity of demand at product market is

\[ E_p = \frac{Q_1 - Q_2}{P_1 - P_2} \frac{P}{Q} \]

The elasticity of demand at factor market is

\[ E_p = \frac{Q_1 - Q_2}{P_1 - P_2} \frac{P}{Q} \]

The calculated ratio of \( E_p \) to \( E_p \) is

\[ \frac{E_p}{E_p} = \frac{\left( \frac{Q_1 - Q_2}{P_1 - P_2} \right) \left( \frac{P}{Q} \right)}{\left( \frac{Q_1 - Q_2}{P_1 - P_2} \right) \left( \frac{P}{Q} \right)} = \frac{P}{P} \]  

Thus, the ratio of the elasticities is equal to the ratio of prices. Since product prices always exceed factor prices for the equivalent quantity, the absolute value of the elasticity of demand for the product will always exceed that for the factor, i.e., factor-level demand is always more inelastic than product demand if marketing margins are a constant-absolute amount.

B. Constant Percentage Marketing Margins

If the product price is \( k \) percent of factor price, then \( P = kp \). This relationship holds for the example illustrated in Figure 4-3(b). In this situation, the elasticity of demand at product market for the indicated price-quantity range can be stated as:

\[ E_p = \frac{Q_1 - Q_2}{P_1 - P_2} \frac{P}{Q} \]
or alternately as:

\[ E_P = \frac{Q_1 - Q_2}{kp_1 - kp_2} \frac{kp}{Q} = \frac{Q_1 - Q_2}{p_1 - p_2} \frac{p}{Q} = E_p \quad (4.7) \]

Thus, with an absolute percentage markup, demand elasticities are identical at the two market levels.

Besides the constant and constant-percentage marketing margins, Waugh (1964) has suggested specifying price spreads as a combination of a constant amount and a constant percentage. Here marketing margins are specified as a linear function of product price:

\[ m = \alpha + \beta P \quad (4.8) \]

where \( \alpha \) and \( \beta \) are the slope and intercept of the function respectively. From equation (4.5) and (4.8),

\[ P = p + (\alpha + \beta P) \]

Therefore

\[ p = -\alpha + (1-\beta)P \]

\[ = A + BP \quad (4.9) \]

where \( A = -\alpha \), \( B = 1-\beta \)

Whatever the form is, marketing margins can be best characterized as a descriptive model of the relationship between factor and product market. Assuming the relationship described by equation (4.9) is appropriate and the coefficients \( A \) and \( B \) are significant, George and King (1971) proved that the demand elasticity in the factor market \( (E_P) \) is given by the relationship
where \( E_p = \) elasticity in the product market.
The latter part \([1/(1-\varepsilon)] p/P\) of equation (4.10) has been called the "elasticity of price transmission \( \gamma \)" as defined in equation (4.4), since

\[
\gamma = \frac{dP}{dp} \cdot \frac{P}{P} = \frac{d}{dp} \left[ \frac{(\alpha + p)/(1-\varepsilon)}{P} \right] \cdot \frac{P}{P} = \left[ \frac{1}{1-\varepsilon} \right] \cdot \frac{P}{P}
\]
then \( E_p = E_p \cdot \gamma \) (4.11)
result in a general expression for the relationship between demand elasticities in the product and factor markets.

For equation (4.11), if the marketing margin assumed to be constant, i.e., \( P = p + m \), then

\[
\gamma = \frac{dP}{dp} \cdot \frac{P}{P} = \frac{d}{dp} (p+m) \cdot \frac{P}{P} = \frac{P}{P}
\]
therefore \( E_p = E_p (p/P) \) is the same as equation (4.6). If the marketing margin assumed to be constant-percentage, \( p = kP \), then

\[
\gamma = \frac{dP}{dp} \cdot \frac{P}{P} = \frac{d}{dp} \left( \frac{1}{k} p \right) \cdot \frac{P}{P} = \left( \frac{1}{k} \right) \left( \frac{kP}{P} \right) = 1
\]
therefore \( E_p = E_p \) is the same as equation (4.7).

Among forest economists, the most popular method for relating the two markets is a variant of the constant percentage margin. This method usually involves regressing stumpage on lumber prices and interpreting the relationship between prices as being described by the regression
coefficient associated with lumber prices. In the "Timber Outlook" study (USDA Forest Service 1973) this approach was modified by changing the relationship

\[ p = \gamma P \]

to

\[ p = P_{i-1} + \gamma (P_i - P_{i-1}) \]  \hspace{1cm} (4.12)

where \( i \) refers to the current time period. Solving equation (4.12) for the elasticity of price transmission results in the expression

\[ \eta = \left( \frac{1}{\gamma} \right) \left( \frac{P}{P_i} \right) \]

This expression has been popularized as the "passthrough" technique. The "Timber Outlook" study assumed the stumpage price increased by 75 percent of the change in product price (i.e., \( \gamma = 0.75 \) in equation (4.12)).

The choice of which of the four equations (4.6), (4.7), (4.10) or (4.12) to use depends on what the analyst assumes about the margin. The nature of the margin can be determined by fitting equation (4.9) and testing the significance of the coefficients. For our marketing area and data employed in Table 4-1 the results of equation (4.9) are

<table>
<thead>
<tr>
<th></th>
<th>Coefficient</th>
<th>Significance</th>
<th>R²</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td>( p = -76.85 \times 1.27 \times P )</td>
<td>(-4.64) * (7.28)*</td>
<td>.7165</td>
<td>53.07*</td>
</tr>
<tr>
<td>b.</td>
<td>( p = -82.74 \times 1.35 \times P_{i-1} )</td>
<td>(-4.90) * (7.48)*</td>
<td>.7273</td>
<td>56.00*</td>
</tr>
<tr>
<td>c.</td>
<td>( p = -97.88 \times 1.50 \times \sum P_{t-1} )</td>
<td>(-6.99) * (10.10)*</td>
<td>.8294</td>
<td>102.06*</td>
</tr>
</tbody>
</table>
Table 4-1. Unit price (1967$/MBF, lumber tally) of Douglas-fir lumber and average stumpage price within the Siuslaw marketing area, 1954-1976.

<table>
<thead>
<tr>
<th>Year</th>
<th>D-f lumber price</th>
<th>Avg. stumpage price</th>
<th>Deflated lumber price</th>
<th>Deflated stumpage price</th>
</tr>
</thead>
<tbody>
<tr>
<td>1954</td>
<td>76.50</td>
<td>14.88</td>
<td>87.33</td>
<td>16.98</td>
</tr>
<tr>
<td>1955</td>
<td>83.62</td>
<td>32.16</td>
<td>95.23</td>
<td>36.63</td>
</tr>
<tr>
<td>1956</td>
<td>83.19</td>
<td>30.22</td>
<td>91.72</td>
<td>33.32</td>
</tr>
<tr>
<td>1957</td>
<td>74.87</td>
<td>20.81</td>
<td>80.24</td>
<td>22.31</td>
</tr>
<tr>
<td>1958</td>
<td>73.50</td>
<td>16.59</td>
<td>77.69</td>
<td>17.54</td>
</tr>
<tr>
<td>1959</td>
<td>83.79</td>
<td>28.20</td>
<td>88.38</td>
<td>29.75</td>
</tr>
<tr>
<td>1960</td>
<td>76.58</td>
<td>25.72</td>
<td>80.70</td>
<td>27.11</td>
</tr>
<tr>
<td>1961</td>
<td>73.41</td>
<td>22.91</td>
<td>77.68</td>
<td>24.24</td>
</tr>
<tr>
<td>1962</td>
<td>75.55</td>
<td>20.51</td>
<td>79.70</td>
<td>21.63</td>
</tr>
<tr>
<td>1963</td>
<td>78.47</td>
<td>23.05</td>
<td>83.04</td>
<td>24.39</td>
</tr>
<tr>
<td>1964</td>
<td>79.84</td>
<td>31.46</td>
<td>84.31</td>
<td>33.22</td>
</tr>
<tr>
<td>1965</td>
<td>79.16</td>
<td>37.30</td>
<td>81.94</td>
<td>38.62</td>
</tr>
<tr>
<td>1966</td>
<td>83.02</td>
<td>42.91</td>
<td>83.18</td>
<td>43.00</td>
</tr>
<tr>
<td>1967</td>
<td>85.76</td>
<td>35.04</td>
<td>85.76</td>
<td>35.04</td>
</tr>
<tr>
<td>1968</td>
<td>103.17</td>
<td>52.83</td>
<td>100.65</td>
<td>51.54</td>
</tr>
<tr>
<td>1969</td>
<td>112.94</td>
<td>68.79</td>
<td>106.05</td>
<td>64.60</td>
</tr>
<tr>
<td>1970</td>
<td>93.31</td>
<td>34.04</td>
<td>84.52</td>
<td>30.84</td>
</tr>
<tr>
<td>1971</td>
<td>118.00</td>
<td>36.10</td>
<td>103.60</td>
<td>31.69</td>
</tr>
<tr>
<td>1972</td>
<td>138.16</td>
<td>59.41</td>
<td>116.00</td>
<td>49.89</td>
</tr>
<tr>
<td>1973</td>
<td>179.75</td>
<td>115.88</td>
<td>133.45</td>
<td>86.03</td>
</tr>
<tr>
<td>1974</td>
<td>183.27</td>
<td>159.82</td>
<td>114.47</td>
<td>99.83</td>
</tr>
<tr>
<td>1975</td>
<td>181.81</td>
<td>134.28</td>
<td>103.95</td>
<td>76.77</td>
</tr>
<tr>
<td>1976</td>
<td>215.09</td>
<td>136.60</td>
<td>117.60</td>
<td>74.69</td>
</tr>
</tbody>
</table>

Source: see Appendix I.
Figure 4-4. Unit price of lumber and stumpage within the Siuslaw marketing area, 1954-1976.
where $p = \text{stumpage price}$, $P = \text{lumber price}$; numbers in parentheses below the coefficients are t ratio, those significant at the .05 level or better are denoted by an asterisk. For each of the equations above both the intercept and slope are statistically significant (since t-values are significant for both intercept and slope). This implies that in the Siuslaw marketing area it seems appropriate to view the market margin as a combination of percentage and constant markup. Because the coefficients A and B are significantly different from zero for each equation a, b, and c, equation (4.10) states the general relationship between stumpage and product elasticities. This implies that if the elasticity of price transmission can be computed, the stumpage elasticity then can be computed by knowing only the product elasticity.

The elasticity of price transmission can be derived from the estimates directly by regressing lumber price on stumpage price; for this study the results are

$$P' = 69.86 + 0.55 \frac{p}{P}$$

$$R^2 = .8294$$

$$F = 102.06^*$$

$$t = (26.76)^* (10.10)^*$$

where $P' = \frac{1}{t=0} \sum P_{t-1}$, $P = \text{lumber price}$, $p = \text{stumpage price}$, then the elasticity of price transmission ($\gamma$) is

$$\gamma = \frac{dP'}{dp} \frac{p}{P} = \frac{d}{dp} (69.86 + 0.55 \frac{p}{P})(\frac{p}{P})$$

$$= 0.55 (\frac{p}{P}) = 0.249$$

evaluated at the means of the sample period.
The derived demand elasticity now can be estimated from equation (4.10) if the lumber demand elasticity is known. For example, if the lumber demand elasticity is -0.5, then the derived demand elasticity for stumpage would be

\[ E_p = E_p \cdot \gamma = (-0.5)(0.249) = -0.125 \]

As expected, the derived demand for stumpage is less elastic than lumber demand.

III. SUMMARY

Stumpage is an intermediate goods and analysis of stumpage demand is therefore derived demand analysis. The theory of factor price transmission and linkages was reviewed and a structure developed for this study.

Marketing margin was used to establish a linkage between factor and product prices. The form of this linkage varied with the assumed form of the marketing margin which, in general, was assumed to be a combination of percentage and constant margins. The linkage can be modified, however, either for different margin assumptions or different assumptions about the supply of marketing services.

Finally, it is clear that if we attempt to explain the variations of bid price for stumpage, final product prices (such as lumber or plywood prices) would be a very important factor and should not be ignored.
In this chapter the preceding information about the marketing area will be combined with economic concepts in the specification of mathematical models capable of generating price and quantity forecasts. In addition, estimation and identification problems in simultaneous equation systems are discussed. These models will be analyzed and evaluated according to their apparent predictive capabilities and the information they contain about market relationships.

I. DEMAND RELATION

In obtaining an empirically meaningful relationship for demand, variables which are hypothesized to materially affect market demand are specified. In the final analysis, of course, certain of these variables may be found to be statistically insignificant and thus eliminated.

The demand for stumpage (in the aggregate) may be considered to be less elastic because possibilities for substitution are extremely limited. As stated before, it is clear that within the Siuslaw marketing area timber demand is a function of stumpage price, prices of final products (e.g. lumber or plywood), costs of non-stumpage inputs, and inventories of logs or timber under contract.

Summarizing, it would appear reasonable to formulate a
stumpage market demand equation in the general form:

\[ D = D(p, P, C, I) \]

where:

- \( D \) = total quantity demand within the marketing area
- \( p \) = average stumpage price
- \( P \) = price of products (e.g. lumber or plywood)
- \( C \) = costs of non-stumpage inputs
- \( I \) = inventories of logs or timber under contract

II. SUPPLY RELATION

A supply curve, like a demand curve, is a functional relationship between price and output. Whereas the demand relationship represents a "buyer's response curve", the supply concept represents a "producer's response curve" showing the output schedule for a firm under a variety of possible prices.

Within the Siuslaw marketing area, stumpage supply is composed of public and private components. Public supply is assumed to be price inelastic although, in practice, supplies may be allowed to vary in the long run with changing merchantability standards and hence prices. Private stumpage supply is composed of an "integrated" and a "non-integrated" component.

There are two plausible assumptions for private stumpage supply. First, private stumpage supply is price inelastic; second, private stumpage supply is price responsive.
Under these two assumptions, two sets of market structure models can be built.

A. Private Stumpage Supply Fixed

As noted by Adams and Kao (1977), private stumpage supply is generally viewed by economists as inelastic. Integrated owners do sell small volumes of timber in the open market from time to time, but for the most part timber from these lands flows directly to processing facilities within the firms' ownership. These intra-firm flows are potentially substitutable for externally purchased timber and hence do influence buyers' willingness to pay for market timber. The level of integrated harvest does not appear to be governed strongly by current market stumpage price. The gross statistical correlation between integrated harvest and stumpage price, at least, is low. More significant determinants of integrated harvest levels may be considerations of tax treatment of company timber, the strategic role of company timber-lands in long-term raw material supplies, current mill production or log inventory requirements, and to some extent export log market conditions. As a result of the complex role that company-owned timber lands play in the current and long-term operation and profitability of forest products firms, it is not uncommon to observe integrated harvest levels moving in opposite directions from, or to be unaffected by, fluctuations in market stumpage price. Given these
several considerations, the supply of integrated timber (for current harvest) can be treated as perfectly inelastic with respect to stumpage price.

Non-integrated farmer and miscellaneous private ownerships, as the name of this class suggests, are composed of a large group of owners with varying forest management objectives, dependency on timber production as a source of income, and size and character of timber holdings. Relatively few owners in this category hold timber land primarily as an investment and income source. In many cases sales are offered as the need for funds arises with no necessary relation to the current or prospective future price of stumpage. Thus the sensitivity of supply levels to changes in stumpage price is extremely low for this group. As a result, it can be assumed that the supply function for non-integrated owners is also perfectly inelastic (Adams and Kao, 1977).

Total timber supply in the marketing area is obtained by summing the components of supply:

\[ S = \bar{S}_S + \bar{S}_{OG} + \bar{S}_I + \bar{S}_N \]

where:

- \( S \) = total supply quantity within the marketing area
- \( \bar{S}_S \) = supply of the Siuslaw National Forest stumpage
- \( \bar{S}_{OG} \) = supply of all other public stumpage
- \( \bar{S}_I \) = supply of integrated private stumpage
- \( \bar{S}_N \) = supply of non-integrated private stumpage
In functional form the demand-supply relations within the Siuslaw marketing area under this assumptions may be written as:

\[
D = D(p, P, C, I) \quad \text{total stumpage demand} \quad (5.1)
\]

\[
S = \bar{S} + S_{OG} + \bar{S}_{I} + S_{N} \quad \text{total stumpage supply} \quad (5.2)
\]

\[
D = S + \bar{I} - \bar{E} = Q \quad \text{supply equals demand or the market is in short-term equilibrium} \quad (5.3)
\]

where:

- \( p \) = equilibrium stumpage price,
- \( Q \) = equilibrium quantity of stumpage traded,
- \( \bar{I} \) = total log imports from outside of the Siuslaw marketing area, and
- \( \bar{E} \) = total log exports from the Siuslaw marketing area.

Since the elements of \( S \) are all independent of stumpage price, combining (5.1), (5.2), and (5.3), we obtain:

\[
D(p, P, C, I) = \bar{S} + S_{OG} + \bar{S}_{I} + S_{N} + \bar{I} - \bar{E} = Q \quad (5.4)
\]

or

\[
p = f(Q, P, C, I) \quad (5.5)
\]

Equation (5.4) is transformed to equation (5.5) since the supplies (Q) are all predetermined rather than stumpage price (p). In summary, we would expect the following relationships to hold between the average real bid price for all stumpage sold from the Siuslaw National Forest (p) and each individual factor listed, assuming all other
factors held constant (Adams and Kao, 1977):

bid price would -- if an increase were observed in --
fall quantity of stumpage purchased
rise prices of products such as lumber and plywood
fall costs of other inputs such as labor or energy
fall inventory of logs or timber under contract

Many alternate functional forms have been used to estimate demand in different situations. For the single equation model we decided to examine four alternate forms as we had no preconceived or theoretical basis for rejection of any functional type. The mathematical forms of the single equation model (5.5) we attempt to estimate and the hypotheses to be tested are specified below.

1. Models To Be Fitted

(a) General Linear Model:

\[ p = \alpha_0 + \alpha_1 Q + \alpha_2 P + \alpha_3 C + \alpha_4 I + u \]

(b) Logarithmic Linear Model:

\[ p = \alpha_0 Q^{\alpha_1} P^{\alpha_2} C^{\alpha_3} I^{\alpha_4} e^u \]

(c) Exponential Model:

\[ p = e^{\alpha_0 + \alpha_1 Q + \alpha_2 P + \alpha_3 C + \alpha_4 I + u} \]

(d) Semilogarithmic Model:

\[ p = \log_e \left[ \alpha_0 Q^{\alpha_1} P^{\alpha_2} C^{\alpha_3} I^{\alpha_4} e^u \right] \]
where 'u' is an error term, and $e = 2.718$ = the base of natural logarithms. In all models, current year price of products ($P$), one year lagged price ($P_{t-1}$), and moving average of $P_t$ and $P_{t-1}$ ($\frac{1}{1} \sum_{i=0}^1 P_{t-i}$) were examined as possible price forms.

2. Empirical Results

Estimates of equation (5.5) were developed using annual data for the period 1954-1976 and ordinary least squares (OLS) regression methods. All unit prices expressed in dollars were deflated by the all commodity producer price index ($1967=100.00$). In all models the variable $P$ was taken as the price of lumber in constant dollars per MBF, lumber tally. Unit plywood price and a combination of lumber and plywood prices were explored for inclusion as well but without success (see Appendix III). Among the different functional forms (a)-(d) noted above, the general linear model (a) provided the best fit (Appendix IV). Equation (5.5) then was expressed in a linear form.

Sources and listings of the base data are given in the Appendix I and II. Estimation results are shown below:

\[ p = -36.25 - .000079 Q + 1.73 (\frac{1}{1} \sum_{i=0}^1 P_{t-i}) - 1.43 C + .00001 I \]

\[ (-1.50) \quad (8.35)^* \quad (-2.56)^* \quad (3.04)^* \]

unadjusted $R^2 = .9221$

over-all $F = 53.24^*$

(5.6)

Numbers in parentheses below the estimated coefficients are
t ratios, those significant at the .05 level or better are denoted by an asterisk. $R^2$ is the coefficient of determination unadjusted for degrees of freedom.

The original model in equation (5.6) explains a substantial fraction of the total variation in bid price (92 percent) but the coefficient of uncut volume under contract does not have the expected sign. There are two possible reasons for the unexpected result for variable $I$. Some of the annual data are estimated by interpolation and extrapolation. This tendency process may detract from our prediction results as important relationships between the dependent variable and these independent variables may be subsumed in the extrapolation and interpolation process. Also, the variables $C$ and $I$ are highly correlated ($r_{C,I} = .85$) which may cause a collinearity problem. Before going further, we drop the variable $I$ and obtain the equation (5.7):

$$p = -45.69 - .0000132 Q + 1.76 \left( \frac{1}{T} \sum_{i=0}^{T-1} P_{t-i} \right) - .2999 C$$

(5.7)

<table>
<thead>
<tr>
<th></th>
<th>S.E.</th>
<th>t-ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(.0000059)</td>
<td>(-2.215)*</td>
</tr>
<tr>
<td></td>
<td>(.2477)</td>
<td>(7.110)*</td>
</tr>
<tr>
<td></td>
<td>(.4996)</td>
<td>(-.600)</td>
</tr>
</tbody>
</table>

unadjusted $R^2 = .8820$

over-all $F = 47.33*$

All the coefficients have the expected signs and, except for variable $C$, they all are statistically significant. Some 88 percent of the variation in the bid price is explained by the variables included in the regression. Before going further, we examine the correlation coefficients.
among the independent variables included in the current model and inspect whether there is a multicollinearity problem. The correlation coefficients of Q, P, and C are:

\[
\begin{array}{ccc}
Q & -0.4084 \\
\left(\frac{1}{2} \sum_{i=0}^{1} P_{t-i}\right) & 0.7967 & -0.3203 \\
C & Q
\end{array}
\]

The inter-correlation coefficient of the product price and C terms is high suggesting that there may be a multicollinearity problem.

One way to overcome multicollinearity is the technique of transformation of the variables. Here, we may examine the term \((P-C)\) as an independent variable in the economic model. \(P-C\) can be referred to as a residual of return for profit, fixed costs and stumpage. We would expect it to be positively related to the real bid price. Under this transformation the estimation results are:

\[
p = 20.5475 - 0.000018872Q + 2.45917 \left[ \frac{1}{2} \sum_{i=0}^{1} (P-C)_{t-i} \right]
\]

\[
\begin{array}{cccc}
S.E. & (-0.0000695) & (.3126) \\
t-ratio: & (-2.712)* & (7.868)* \\
\text{unadjusted } R^2 & = .8063 \\
\text{over-all } F & = 41.63* \\
\text{Durbin-Watson statistic} & = 1.2937
\end{array}
\]

The correlation coefficient of \(Q\) and \(\left[ \frac{1}{2} \sum_{i=0}^{1} (P-C)_{t-i} \right]\) is \(-.2273\).

Since the t-ratios of the estimated coefficients of \(Q\)
and P-C are both statistically significant at the .05 level and the inter-correlation between Q and P-C is only -.23, the multicollinearity problem would appear to be minor and may be ignored.

Autocorrelation Problem:

For the estimated equation (5.8) above, the Durbin-Watson statistic 'd' falls in the inconclusive range.1/ For results of this sort, Theil and Nagar (1961) propose a further test statistic, Q.

\[ \alpha = .05 \]

\[ H_0 : \rho = 0 \quad \text{No autocorrelation} \]

\[ H_a : \rho \neq 0 \quad \text{Autocorrelation} \]

where \( \rho \) is the coefficient of autocorrelation.

Theil-Nagar statistic:

\[ Q = \frac{\text{Var}(u_t - u_{t-1})}{\text{Var}(u_t)} = 2 \left( -\frac{n-1}{n-k'} - \frac{1.64485}{\sqrt{n+2}} \right) \]

\[ = 1.4373 \quad (\text{for } n=23, k'=2) \]

Estimated \( \hat{Q} \):

\[ \hat{Q} = \frac{\hat{\text{Var}}(e_t - e_{t-1})}{\hat{\text{Var}}(e_t)} \]

If \( \hat{Q} \geq Q \), we fail to reject the null hypothesis \( H_0 : \rho = 0 \), i.e., no significant autocorrelation.

---

1/ Given \( \alpha=.05 \), number of observations = 23, number of regressors = 2 (excluding the constant), the tabulated values of the Durbin-Watson statistic are \( d_L = 1.17 \), \( d_u = 1.54 \). Since \( d_L < 1.29 < d_u \), the test is inconclusive.
If $\hat{Q} < Q$, we reject the null hypothesis, but this doesn't mean that we are in favor of the alternative hypothesis $H_a: \rho \neq 0$, i.e., whether there is significant autocorrelation still cannot be determined.

In our case, since $\hat{Q} = 185.4131/136.8055 = 1.3553 < Q = 1.4373$, we can still not say whether autocorrelation is or is not significant.

Given this uncertainty we may examine the results of correcting for autocorrelation on the conservative assumption that it does exist. First we estimate the autocorrelation coefficient ($\hat{\rho}$) by several different methods. Second, these $\hat{\rho}$'s are then used to transform both the dependent and independent variables and OLS is applied to the model:

$$P_t = \hat{\rho}P_{t-1} = a_0(1-\hat{\rho}) + a_1(Q_t - \hat{\rho}Q_{t-1}) + a_2(PC_t - \hat{PC}_{t-1}) + u^* \quad (5.9)$$

We then use the Durbin-Watson statistic to test the residuals $e_t^*$ for autocorrelation.

The five different methods employed here for estimating $\rho$'s were: (1) first difference of the original data ($\hat{\rho}=1$), (2) by derivation from the Durbin-Watson statistic, (3) the Cochrane-Orcutt iterative method, (4) regressing $e_t$ on $e_{t-1}$, and (5) Durbin's "two-step" method. Each was employed in (5.9) with no change in the inconclusive Durbin-Watson results (Appendix V). Also, the estimated coefficients did not change much from the results of equation (5.8). We
conclude that the autocorrelation problem is not serious and retain equation (5.8) as the final model.

Heteroskedasticity Test:

For testing the homoskedasticity of the estimated equation (5.8), the Spearman rank correlation test and the Goldfeld and Quandt test were employed. Neither of these tests (Appendix VI) suggested the existence of heteroskedasticity in the estimated equation (5.8).

B. Private Stumpage Supply Price Elastic

Numerous theories on the supply of private stumpage have been proposed. All assume the timber owner's objective is to maximize profit or present worth, and in this respect are no different from classical, static product supply theory.

Theoretical stumpage supply responses can be divided into stock supply responses and short-run supply responses. An argument can be made (Duerr, 1960) that the predominant response is a stock response and that under the assumption of private land-owner present net worth maximization the price response will be zero (based on no rotation change) or weakly positive (based on increased merchantability or accessability). The short-run price response would consist of silvicultural intensification and would be expected to be positive but lagged over a considerable response period
measured in decades. If the owner had surplus inventory the lag might be reduced based on the allowable cut effect. For the above reasons the structure of the various supply responses may be confused in empirical analysis and require several price and inventory variables for explanation. A hypothesis of positive, but possibly weak, price response seems reasonable but is not necessarily guaranteed.

There are three distinct econometric studies of timber supply on private forest lands that are worth mentioning. These studies are tabulated below:

<table>
<thead>
<tr>
<th>Study</th>
<th>Form of stumpage supply equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>McKillop (1967)</td>
<td>$S_t = a_0 + a_1 p_t + a_2 t$</td>
</tr>
<tr>
<td>Robinson (1974)</td>
<td>$S_t = a_0 + a_1 p_t + a_3 r_t$</td>
</tr>
<tr>
<td>Adams and Haynes (1979)</td>
<td>$S_t = a_0 + a_1 p_t + a_4 V_{t-1}$</td>
</tr>
</tbody>
</table>

where:

- $S_t =$ supply of stumpage in year $t$,
- $p_t =$ price of stumpage in year $t$,
- $r_t =$ alternative rate of return (interest rate as an indicator of opportunity costs), and
- $V_{t-1} =$ growing stock inventory in year $t-1$.

These models all assume that an increase in price would result in an increased supply of timber. McKillop assumed a decrease in supply over time due to reduced availability of timber, employing a time trend as a proxy measure for
declining inventory. Robinson included the interest rate to take account of the cost of holding timber resources. Adams and Haynes also assume that timber supply is positively related to the opportunity costs of timber holding but employ growing stock inventory explicitly.

1. Stumpage Supply Model

In this study, Adams and Haynes' model will be followed, so the functional form of the private timber supply model may be written as:

$$S_p = S_p (p, V_{-1})$$

(5.10)

where:

- $S_p =$ supply of all private stumpage, i.e., $S_p = S_I + S_N$
- $p =$ price of stumpage
- $V_{-1} =$ timber inventory on all private forest lands within the marketing area at the end of year $t-1$.

Several mathematical forms of the private stumpage supply model were fitted, which included the general linear form, intrinsically linear forms (Appendix VII), and intrinsically nonlinear forms (Appendix VIII). Among all of the equations estimated, the general linear model provided the most satisfactory fit while meeting a priori expectations regarding the signs of the coefficients:

$$S_p = -711969 + 2054.23 \, p + 216.75 \, V_{-1}$$

(5.10) unadjusted $R^2 = .5051$
over-all $F = 10.21*$
2. **Private Timber Inventory**

Since private cut varies with private inventory in equation (5.10), private inventory can not be taken as exogenous. A method must be derived to project inventory over time.

A simple biomass growth model can be written as:

\[ V_t = V_{t-1} + G_t (V_{t-1}) - S_t \]

where:

- \( V_t \) = timber inventory at the end of year \( t \),
- \( V_{t-1} \) = timber inventory at the end of year \( t-1 \),
- \( G_t (V_{t-1}) \) = is growth assumed to be a function of inventory volume, and
- \( S_t \) = timber cut (harvest) during year \( t \).

If we set

\[ \alpha_t = \frac{G_t (V_{t-1})}{V_{t-1}} = \text{Gross Growth Rate} \]

then

\[ V_t = V_{t-1} + \alpha_t V_{t-1} - S_t = (1 + \alpha_t) V_{t-1} - S_t \]

The gross growth rate \( \alpha_t \) can be approximated from \( G_t(V_{t-1})/V_{t-1} \) by using the limited available data. In general, there are three possible forms for the gross growth rate \( \alpha_t \) as shown in Figure 5-1. Within the Siuslaw marketing area the regional gross growth rate \( \alpha_t \) on private forest lands calculated from inventory year 1973 and 1976 appears to be slightly increasing ( Appendix IX ).
Figure 5-1. Three possible forms for the gross growth rate $\alpha_t$.

3. Simultaneous Equations Model

Under the assumption of price elastic private stumpage supply, the demand-supply relations for stumpage within the Siuslaw marketing area may be written as a structural model as:

$$D = D(p, PC)$$
$$S_p = S_p(p, V_{-1})$$
$$D = Sp + Ss + SOG + I - E = Q$$

The first equation is the total stumpage demand function, the second is the private stumpage supply function, and the third is a definitional equation which indicates that the market is in short-term equilibrium. All the variables are as previously defined. Assuming linear functional forms, we obtain:
The system is complete in that it contains three equations in three endogenous variables, \( p \), \( S_p \), and \( Q \). The model contains six predetermined variables, \( PC \), \( V_{-1} \), \( S \), \( S_{OG} \), \( I \), and \( \bar{E} \). Since the first two equations are both over-identified (Appendix X), the two-stage least squares (2SLS) method will be employed to estimate the coefficients.

Estimates of the above system were developed using annual data for the period 1954-1976. All unit prices expressed in dollars were deflated by the all commodity producer price index (1967=100.00). First, we find the reduced-form model, in which the endogenous variables are expressed as a function of the exogenous variables only. Using the conventional notation of \( \pi \)'s for the reduced-form coefficients, we have:

\[
\begin{align*}
p &= \pi_{10} + \pi_{11} V_{-1} + \pi_{12} PC + \pi_{13} \left( S + S_{OG} + I - \bar{E} \right) + w_1 \\
S_p &= \pi_{20} + \pi_{21} V_{-1} + \pi_{22} PC + \pi_{23} \left( S + S_{OG} + I - \bar{E} \right) + w_2 \\
Q &= \pi_{30} + \pi_{31} V_{-1} + \pi_{32} PC + \pi_{33} \left( S + S_{OG} + I - \bar{E} \right) + w_2
\end{align*}
\]
Where:
Then, applying OLS to estimate the reduced-form in order to calculate the $\hat{p}$, $\hat{S}_p$, and $\hat{Q}$, we obtain:

$$\hat{p} = 120.58 - .01216 V_1 + 2.078 PC - .0000067 (\bar{S}_s + \bar{S}_{0G} + \bar{I} - \bar{E})$$

$$\hat{S}_p = 145035 + 186.89 V_1 + 1384.13 PC - .20705 (\bar{S}_s + \bar{S}_{0G} + \bar{I} - \bar{E})$$

$$\hat{Q} = 145035 + 186.89 V_1 + 1384.13 PC - .79294 (\bar{S}_s + \bar{S}_{0G} + \bar{I} - \bar{E})$$

The second stage uses OLS once again to estimate the structural-form equations in which the explanatory endogenous variables $p$, $S_p$, and $Q$ are replaced by the calculated values $\hat{p}$, $\hat{S}_p$, and $\hat{Q}$ from the reduced-form:

$$p = 55.7110 - .00002640 \hat{p} + 2.3823 PC$$

unadjusted $R^2 = .8430$

over-all $F = 53.68^*$

D-W statistic = 1.6167

$$S_p = -578487 + 1566.83 \hat{p} + 207.71 V_{-1}$$

unadjusted $R^2 = .4958$

over-all $F = 9.83^*$

D-W statistic = 1.4471

$$Q = \hat{S}_p + \bar{S}_s + \bar{S}_{0G} + \bar{I} - \bar{E}$$
CHAPTER VI
EMPIRICAL RESULTS, IMPLICATIONS
AND
HISTORICAL SIMULATION

I. QUANTITATIVE ANALYSIS OF MARKET STRUCTURE

The estimated coefficients of the stumpage demand function (price-dependent) within the marketing area by OLS and 2SLS in Chapter V are summarized in Table 6-1.


<table>
<thead>
<tr>
<th>Estimation method</th>
<th>Dependent variable</th>
<th>Independent variables</th>
<th>R²</th>
<th>D-W</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>constant Q PC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OLS</td>
<td>p</td>
<td>20.5475 -.00001887 2.4592</td>
<td>.8063</td>
<td>1.29</td>
</tr>
<tr>
<td>2SLS</td>
<td>p</td>
<td>55.7110 -.00002640 2.3823</td>
<td>.8430</td>
<td>1.62</td>
</tr>
</tbody>
</table>

The estimated elasticities of the price-dependent demand equation (p with respect to Q and PC) by OLS and 2SLS are summarized in Table 6-2.

Table 6-2. Estimated elasticities of p with respect to Q and PC.

<table>
<thead>
<tr>
<th>Estimation method</th>
<th>E_p,Q</th>
<th>E_p,PC</th>
</tr>
</thead>
<tbody>
<tr>
<td>OLS</td>
<td>-1.6767</td>
<td>2.2449</td>
</tr>
<tr>
<td>2SLS</td>
<td>-2.3455</td>
<td>2.1747</td>
</tr>
</tbody>
</table>
The interpretation of the above results is straightforward. For example, if we adopt the 2SLS estimates, then

(1) A one percent change in the total quantity of stumpage supplied in the marketing area leads to a 2.35 percent change in price, with an algebraic sign opposite that of the quantity change (an increased quantity leads to a price decline as expected). This implies that total stumpage demand in the marketing area is price inelastic since the elasticity of \( Q \) with respect to \( p \) is

\[
E_{Q,p} = \frac{\partial Q}{\partial p} \left( \frac{-P}{Q} \right) = \left( \frac{1}{\partial P/\partial Q} \right) \left( \frac{-P}{Q} \right) = 0.4263
\]

(2) The unit final product prices less the unit production costs, \( PC \), referred to as a residual of return for profit, fixed costs and stumpage per MBF, lumber tally, in this case has a very strong influence on bid price. A one percent change in \( PC \) leads to a 2.17 percent change in stumpage price. The importance of \( PC \) as an explanatory variable is to be expected as is the result that the percentage fluctuation in stumpage price will be larger than that in \( PC \).

(3) Timber sales from the Siuslaw are imbedded in the \( Q \) term which includes sales from the Willamette and Mt. Hood National Forest, all other public lands, and private forest lands (forest industry and non-industry). Let \( S = S_S + S_{CG} + S_I + S_N \) and \( Q = S_S + S_{CG} + S_p + I - E \), where all the variables are as previously defined. Then the elasticity of bid price with respect to a change in the volume of Siuslaw
sales can be shown to equal:

\[-2.3455 \left( \frac{S_S}{S_S + S_{OG} + S_p + \bar{I} - \bar{E}} \right)\]

Thus, the response of bid price to changes in Siuslaw sales depends on the fraction of Siuslaw sales in total marketing area supply. If this fraction is small, the impact is small - if large the impact is large.

Over the 1954 - 1976 period, Siuslaw sales have averaged 7.84 percent of the annual market area supply. Based on the above expression, then, a one percent increase in Siuslaw sales would be expected to reduce bid prices in the market area by only -.18 percent.

(4) Based on the following procedure, we may compute the demand elasticity of Siuslaw sales volume with respect to bid price, \( E_{S_S, p} \).

Since \( p = f \left( Q, FC \right) \)
\( S_p = g \left( p, V_{-1} \right) \)
\( Q = S_p + S_S + S_{OG} + \bar{I} - \bar{E} \)

We obtain
\( S_S = Q - S_p - S_{OG} - \bar{I} + \bar{E} \)

Then
\( E_{S_S, p} = \frac{\partial S_S}{\partial p} \left( \frac{p}{S_S} \right) \)

\[ = \left[ \frac{\partial f^{-1}(p, PC)}{\partial p} - \frac{\partial g(p, V_{-1})}{\partial p} \right] \left( \frac{-p}{S_S} \right) \]

\[ = (-37879.65 - 1566.83)(47.586/331589) \]
\[ = -5.66 \]
The demand for Siuslaw timber is seen to be highly elastic, i.e., changes in the quantity of timber offered for sale under various harvest alternatives on the Siuslaw will have no appreciable effect on bid price.

(5) From the discussion in (3) and (4) it follows that as the share of public sales in total supply grows - as is the likely case in the future with declining private cut - the demand for public stumpage will become less and less elastic and the price impact of shifts in public stumpage sales will become larger.

(6) If we transform the estimated price-dependent demand function to quantity-dependent form as below

\[ Q = 2110255.2 - 37878.79 \ p + 90238.64 \ PC \]

and calculate the demand elasticities of \( Q \) with respect to \( p \) and \( PC \) we obtain \( E_{Q,p} = -0.4263 \) and \( E_{Q,PC} = 0.9272 \). The function is obviously not homogeneous of degree zero since the sum of the elasticities \((-0.4263 + 0.9272)\) is 0.5009 and not zero. This means, when stumpage price \( p \) and unit net profit per MBF \( PC \) change in the same proportion \( k \), that there will be some change in demand \( Q \). Thus we cannot say there is no "money illusion" in the demand for stumpage.

\[ Q = f ( x_1, x_2 ) \] is homogeneous function of degree \( T \) if \[ f ( kx_1, kx_2 ) = k^T f ( x_1, x_2 ) \]
(7) The market demand function shows for each specific price the quantity of stumpage that buyers will take. From the standpoint of sellers, price times sales \( p \cdot Q \) is the total revenue \( (TR) \) within the market area, and the marginal revenue \( (MR) \) is

\[
MR = \frac{\partial (TR)}{\partial Q} = \frac{\partial (p \cdot Q)}{\partial Q} = p + Q \left( \frac{dp}{dq} \right) = p \left( 1 + \frac{Q}{p} \frac{dp}{dq} \right)
\]

\[= p \left( 1 + \frac{1}{\eta} \right) = p \left( -1.3455 \right) \]

where \( \eta = \left( -\frac{dp}{dq} \right) \left( \frac{p}{Q} \right) = -0.4263 \)

Since the total stumpage demand in the market area is price inelastic, the marginal revenue would be negative.

II. HISTORICAL SIMULATION

To examine the predictive ability of the full model, a simulation was run for the period of common data 1954 - 1976. This was a dynamic simulation using actual values of all the exogenous variables and calculated values of the endogenous and lagged endogenous variables. Solution procedures are straightforward because all the equations in the model are linear functional forms.

A. Model Solution Procedure

For the estimated simultaneous system

\[
p = \hat{\alpha}_0 + \hat{\alpha}_1 Q + \hat{\alpha}_2 PC
\]

\[
S_p = \hat{\beta}_0 + \hat{\beta}_1 p + \hat{\beta}_2 V_{-1}
\]

\[
Q = S_p + S_S + S_{CG} + I - \bar{E}
\]
If we set \( A_0 = \hat{\alpha}_0 + \hat{\alpha}_2 \beta_{-1} \), \( B_0 = \hat{\beta}_0 + \hat{\beta}_2 \beta_{-1} \), and \( C_0 = \hat{\beta}_0 + \hat{\beta}_2 \beta_{-1} \), then

\[
p = A_0 + \hat{\alpha}_1 \beta \\
S_p = B_0 + \hat{\beta}_1 \beta \\
Q = C_0 + S_p
\]

In matrix form, it is

\[
\begin{bmatrix}
1 & 0 & -\hat{\alpha}_1 \\
-\hat{\beta}_1 & 1 & 0 \\
0 & -1 & 1
\end{bmatrix}
\begin{bmatrix}
p \\
S_p \\
Q
\end{bmatrix}
= \begin{bmatrix}
A_0 \\
B_0 \\
C_0
\end{bmatrix}
\]

The solutions of \( p \), \( S_p \), and \( Q \) are

\[
\begin{bmatrix}
p \\
S_p \\
Q
\end{bmatrix}
= \begin{bmatrix}
1 & 0 & -\hat{\alpha}_1 \\
-\hat{\beta}_1 & 1 & 0 \\
0 & -1 & 1
\end{bmatrix}
\begin{bmatrix}
A_0 \\
B_0 \\
C_0
\end{bmatrix}
= \begin{bmatrix}
(A_0 + \hat{\alpha}_1 B_0 + \hat{\alpha}_1 C_0) / (1 - \hat{\alpha}_1 \hat{\beta}_1) \\
(\hat{\beta}_1 A_0 + B_0 + \hat{\alpha}_1 \hat{\beta}_1 C_0) / (1 - \hat{\alpha}_1 \hat{\beta}_1) \\
(\hat{\beta}_1 A_0 + B_0 + \hat{\beta}_1 C_0) / (1 - \hat{\alpha}_1 \hat{\beta}_1)
\end{bmatrix}
\]

The simulation traces actual movements for the bid price of stumpage \( p \), private stumpage supply \( S_p \), and total volume of stumpage demanded in the market area over 1954-1976 period with considerable accuracy for both OLS and 2SLS methods. These are apparent in Figure 6.1-3 which show the actual and simulated values by OLS and 2SLS of endogenous variables \( p \), \( S_p \), and \( Q \) within the market area.
Figure 6-1. Historical simulation of the bid price of stumpage (p) over the sample period 1954-1976 by OLS (private stumpage supply exogenous) and 2SLS (private stumpage supply price elastic).
Figure 6-2. Historical simulation of the private stumpage supply ($S_p$) over the sample period 1954-1976 by OLS (single-equation model) and 2SLS simultaneous equations system.
Figure 6-3. Historical simulation of the total volume of stumpage demanded (Q) within the market area over the sample period 1954-1976 by 2SLS (private stumpage supply price elastic).
B. Testing the Foreosting Power of a Model

Prediction-Realization Diagrams:

The forecasting performance of the econometric model is judged on the basis of the differences between predictions and realizations. The smaller the differences between prediction \( P_1 \) and actual \( A_1 \) values of the dependent variable the better the forecasting performance of the model.

We may examine the forecasting performance by means of a "prediction-realization diagram". This is a diagram in which we plot the predictions against the realizations. In this plot, a \( 45^\circ \) line with a positive slope through the origin is called the "line of perfect forecast". The closer the points to the \( 45^\circ \) line the better the forecasting performance of the model. Figure 6-4 and 6-5 show the diagram for bid price (p) by OLS and 2SLS.

Other Measurements of Forecasting Errors:

Additional validity checks of the forecasting performance of a econometric model are expressed by some forecasting performance measures, average absolute percentage forecast errors, Theil's inequality coefficient, and root mean square errors. The average absolute percentage forecast error, AAPE, provides an index of the average matching of the estimated and actual values over the time period. It is defined as:
Figure 6-4. Prediction-realization diagram of bid price (p) by OLS, 1954-1976.

Figure 6-5. Prediction-realization diagram of bid price (p) by 2SLS, 1954-1976.
\[ \text{AAPE} = \left[ \sum_{i=1}^{N} \left| P_i - A_i \right| / \sum_{i=1}^{N} A_i \right] \times 100 \]

where \( A_i \) = the observed value of the endogenous variable for \( i \)-th time period.

\( P_i \) = the estimated value of the endogenous variable for the \( i \)-th time period.

Theil's inequality coefficient, \( U \), is defined as:

\[ U = \left[ \frac{1}{N} \sum_{i=1}^{N} (P_i - A_i)^2 \right]^{\frac{1}{2}} / \left[ \left( \frac{1}{N} \sum_{i=1}^{N} P_i^2 \right)^{\frac{1}{2}} + \left( \frac{1}{N} \sum_{i=1}^{N} A_i^2 \right)^{\frac{1}{2}} \right] \]

where \( A_i, P_i \) are the same as above, \( N \) is sample size.

Values near zero imply perfect predictions, values near one imply predictions no better than a model of form

\( Y_{t+1} = Y_t \).

The root mean square error, \( \text{RMSE} \), is defined as:

\[ \text{RMSE} = \left[ \frac{1}{N} \sum_{i=1}^{N} (P_i - A_i)^2 \right]^{\frac{1}{2}} \]

where \( A_i, P_i \) are defined as before.

These performance measures of the estimated equations by OLS and 2SLS are shown in Table 6-3.

Table 6-3 provides a comparison of the OLS and 2SLS test statistics. For comparable estimates (p) 2SLS gives slightly lower values of error, in addition to the previously stated advantage of consistency.

<table>
<thead>
<tr>
<th>Estimation method</th>
<th>Endogenous variable</th>
<th>MEAN</th>
<th>RMSE</th>
<th>AAPE</th>
<th>U</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>OLS</td>
<td>p</td>
<td>47.5861</td>
<td>11.44</td>
<td>19.80</td>
<td>0.1067</td>
<td>12.27</td>
</tr>
<tr>
<td>2SLS</td>
<td>p</td>
<td>47.5861</td>
<td>10.84</td>
<td>18.59</td>
<td>0.1007</td>
<td>11.05</td>
</tr>
<tr>
<td>2SLS</td>
<td>sp</td>
<td>2030060</td>
<td>184217</td>
<td>6.57</td>
<td>0.0451</td>
<td>197800</td>
</tr>
<tr>
<td>2SLS</td>
<td>q</td>
<td>4227800</td>
<td>184217</td>
<td>3.16</td>
<td>0.0217</td>
<td>--</td>
</tr>
</tbody>
</table>
CHAPTER VII
POLICY SIMULATION

The final objective of this study, and perhaps one of its most important potential uses, is that of policy analysis. This objective refers to a situation in which a decision-maker must choose one policy, called a 'plan' from a given set of alternative policies.

In the econometric approach to policy analysis an estimated econometric model is combined with explicit or implicit information on objectives of policy to evaluate policy alternatives. One approach to policy analysis using an econometric model is 'simulation'. This approach avoids the necessity of assuming the existence of desired levels of endogenous variables. In general, simulation refers to the determination of the behavior of a system via the calculation of values from an estimated model of the system. The model is assumed to be sufficiently explicit so that it can be programmed for numerical study. The system's numerical behavior is then determined (simulated) under different assumptions in order to analyze its response to a variety of alternative inputs. Each simulation run is an experiment performed on the model, determining values of endogenous variables for alternative assumptions regarding the policy variables, other exogenous variables, and values of parameters.
The simulation run can take two forms. A historical simulation refers to the computation of estimated values of endogenous variables for the sample actually observed, using historical values of exogenous variables (as in ex post forecasts) and estimated parameters. These simulated values can then be compared to actual values in order to determine whether the model accurately "tracks" the historical period. This was the approach employed in Chapter VI. Policy simulation determines values of the endogenous variables corresponding to the alternative policies that are under consideration.

The basic policy simulation approach can be described as follows:

$$Y_t = \Pi_1 X_t + \Pi_2 Z_t + V_t$$

where $Y_t$ is a vector of current endogenous variables, $X_t$ a vector of exogenous variables, $Z_t$ a vector of exogenously specified policy controllable variables, and $V_t$ a vector of stochastic disturbance terms. Given $X_t$ and $Z_t$, simulation methods enable the analyst to solve for a vector of endogenous variables $Y_t$ in terms of $X_t$, $Z_t$, and $V_t$ over a large number of future periods. By manipulating the values of the policy controllable variables, $Z_t$, the time paths of the endogenous variables are determined for each alternative policy. The policy maker then selects the alternative which is most compatible with his preferences.
In this study the endogenous variables are average bid price of stumpage, \( p \), private stumpage supply, \( S_p \), and total quantities of stumpage demanded, \( Q \). The exogenous variables are lumber price, \( P \), non-stumpage lumber production cost, \( C \), growing stock on private forest lands, \( V_{-1} \), log imports and exports from the marketing area, \( I \) and \( E \), and volume of timber harvested by public agencies other than the Forest Service. We take the volumes of stumpage supply on National Forests (Siuslaw, Willamette, and Mt. Hood) as policy controllable variables.

I. PROJECTIONS OF EXOGENOUS VARIABLES

The basis for simulations of the specified Siuslaw market behavior under alternative timber harvest schedules is a set of projections of the time paths of all exogenous variables in the model (except Forest Service supplies) for the period 1977-2030. For the present model, this requires the projection of six different variables. General approaches to projections of these variables are described below.

(1) An estimate of the producer price index (1967=100.0) of all Douglas-fir lumber (BLS code # 0811-01). This estimate was derived from projections by Adams and Haynes (1979) (see Table 7-1).

(2) Estimates of non-stumpage lumber production costs. For the Douglas-fir region, this series of non-stumpage lumber production costs has also been derived from Adams and
Haynes (1979) (see Table 7-1).

Table 7-1. Predicted schedules for lumber price and non-stumpage production cost (1967 $/MBF, lumber tally)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>P</td>
<td>122.02</td>
<td>123.53</td>
<td>166.73</td>
<td>181.20</td>
<td>201.57</td>
<td>220.88</td>
<td>241.50</td>
</tr>
<tr>
<td>C</td>
<td>66.47</td>
<td>72.51</td>
<td>91.80</td>
<td>109.36</td>
<td>110.15</td>
<td>110.43</td>
<td>110.69</td>
</tr>
</tbody>
</table>

(3) Projections of timber inventory on private forest lands. As a result of the continuing high levels of timber supply, inventory from these ownerships declined from 1954 to 1976. A continuation of the declining trend starting in the early 1954's is projected for the future with the harvest on these lands trending downward to 2030.

(4) Projections of total timber imports (flows into) and exports (flows out) of the Siuslaw marketing area. Since the available data on these variables are limited and they constitute only a small part of the total volume in the marketing area, we assume the values of these two variables for the period 1977-2030 remain constant at average levels for 1972-1976.

(5) Prospective future harvest levels on public lands other than those managed by the Forest Service within the marketing area are derived from projections in Gedney and others (1975). Harvest from these ownerships in western
Oregon is projected to increase due to many factors, principally the high intensity of forest management practices incorporated in allowable cut calculations.

The predicted values of these four variables are listed in Table 7-2.

Table 7-2. Predicted schedules for $V_1$, $I$, $E$, and other public stumpage supply within the market area

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<td>7831</td>
<td>7262</td>
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<td>128034</td>
<td>128034</td>
<td>128034</td>
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<td>$E$ (MBF)</td>
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<td>35416</td>
<td>35416</td>
<td>35416</td>
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<td>other public (MBF)</td>
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<td>526670</td>
<td>553340</td>
<td>580010</td>
<td>606680</td>
<td>633350</td>
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II. PROJECTIONS OF POLICY VARIABLES AND BASELINE SIMULATIONS

For the projections of policy variables, the levels of National Forest (Siuslaw, Willamette, and Mt. Hood) advertised timber sales offerings, three possible projections were prepared in which Forest Service supply follows what
may be termed likely trends, given current management and policy directions (see Figure 7-1). The first of these, termed INCREASE, was derived from projections in the Timber Outlook (1974) and from work by Gedney and others (1975). In INCREASE, Forest Service timber supply within the marketing area rises slowly from 1977 to slightly above 1970-1976 averages by 2030 (approximately 20%). The second projection, CONSTANT, is developed under current policy which assumes Forest Service harvest remains constant at average levels for 1970-1976. The third projection, DECREASE, assumes that Forest Service timber supply will slightly decrease by 20% of 1970-1976 averages by 2030.

Figure 7-1 illustrates these three projected harvest schedules. The Mt. Hood and Willamette Forests are assumed to follow the same respective assumptions as the Siuslaw.

Table 7-3 gives numerical values by decade for endogenous variables $p$, $S_p$, and $Q$. The results will be discussed in the following section.
Figure 7-1. Predicted schedules for national forest harvest under INCREASE, CONSTANT, and DECREASE policies.
Table 7-3. Projected baseline bid prices of stumpage (p), private supply (S_p), and total stumpage traded from INCREASE, CONSTANT, and DECREASE policies.

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<td><strong>Q (MMBF)</strong></td>
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<td>3246</td>
<td>3193</td>
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III. **SUMMARY**

The validation in policy simulations of alternative projections will be checked by *a priori* expectation to insure that endogenous variables "move in the right direction" in response to the policy change.

In Table 7-3, stumpage prices increase substantially with some fluctuations under the three policy alternatives, and private cut declines steadily after 1977 as inventories continue to fall as expected. In each projected year, the INCREASE alternative has the lowest stumpage price and DECREASE the highest one, although the differences are small. Under increased supply on National Forests the immediate response of stumpage price to increased offerings was small. This is another evidence of elastic demand for National Forest timber in the Douglas-fir region as previously noted. For private cut, INCREASE has the lowest and DECREASE the highest. This seems reasonable because of the substitution effects between public and private cut resulting from the price responsiveness of private supply. Hence, if private cut declined but demand remained stable, substantial increases in the stumpage supply from National Forests would be required to keep the stumpage price from increasing sharply and reduce the amount cut from depleted private lands.

Total harvest declines because the reductions in private cut are not balanced by increases in public cut.
Therefore, with the anticipated increases in demand, declining cut on private lands, and given the principles of sustained yield and even flow that regulate cutting rates on National Forests, controlling the projected increases in stumpage price may require other policy actions such as encouraging imports of logs and discouraging exports.
CHAPTER VIII

CONCLUSION

Within the Siuslaw marketing area, total demand for stumpage is a function of stumpage price, final product prices, and non-stumpage production costs. Public stumpage supplies are determined by allowable cut or harvest scheduling calculations and are not price responsive. Private cut is assumed to be a function of stumpage price and growing stock inventory. The model estimates of the short-run price elasticities of stumpage demand and private supply were both highly inelastic (Chapter VI). The estimated price elasticity of demand for Siuslaw timber was highly elastic (-5.66), implying that changes in the volume of timber offered for sale under various harvest alternatives on the Siuslaw will have only a limited effect on bid prices.

Analysis of the price effects of different National Forest (Siuslaw associated with Willamette and Mt. Hood) timber harvest schedules necessarily involves projections of the future. The future, to a target year such as 2030, obviously cannot be predicted with certainty. Much depends on demand shifts and technological changes which will be the major determinants of the price effectiveness of different National Forest timber harvest programs.
I. MARKET IMPACTS OF ALTERNATIVE HARVEST SCHEDULES

Under three alternative harvest schedules for National Forests within the Siuslaw marketing area, the baseline projections showed that stumpage price increases substantially and private cut declines in the marketing area faster than public cut increases. The cut from private lands, which provides most of the total harvest in the marketing area, tends to decrease as expected as inventories of merchantable timber on private lands are further exhausted. While the cut from public lands has increased, the increase has not been of a sufficient magnitude to stem the declining supply. Total harvest declines as a result and this is a major factor contributing to the rising stumpage prices.

As mentioned in Chapter VI and shown in the projections, it follows that as the share of public cut in total supply grows with declining private cut, the demand for public stumpage will become less and less elastic and the price impact of shifts in public stumpage sales will become larger. The estimated demand elasticities for public stumpage are shown in Table 8-1.

II. PROBLEMS AND EXTENSIONS

The present study was concerned with assessing impacts of alternative schedules for the Siuslaw National Forest timber harvest on the stumpage market. The model developed
Table 8-1. The estimated demand elasticities for national forests under INCREASE, CONSTANT, and DECREASE policies within the Siuslaw marketing area.

<table>
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</table>
for this purpose appears to offer some promise as a tool for policy analysis but clearly is not without problems:

(1) A prime concern is that the model was not tested for predictive ability with data other than those used in the estimation process. Such a test is particularly valuable as a check on the stability of structural coefficients. Unfortunately, reserving sufficient observations from available time series would have worsened the already critical, small-sample problems in estimation. Also, parameter estimates from the several equations could prove inconsistent when brought together in a complete structure.

(2) In making projections we assumed that the structure of the market as given in the model

\[ D = D (p, PC) \]
\[ S = S_p + S_s + S_{DG} \]
\[ D = S + \bar{I} - \bar{E} = Q \]

and the final estimated equations will not change in the future. This means that the coefficients of the estimated equations will remain the same and that the marketing area for the Siuslaw will remain unchanged. For long projection periods these assumptions of fixity become less and less tenable, particularly in view of the long-term trend toward longer haul distance for logs in the Willamette Valley (Adams and Kao, 1977).

(3) In the stumpage demand function developed here, only lumber price was employed as a measure of final product
price. Since the demand for stumpage is a derived demand for the secondary products such as lumber, plywood, and pulp products, these products prices might be included in the demand function as explanatory variables in a further extension of study.
BIBLIOGRAPHY


APPENDICES
APPENDIX I

Base Data: Sources and Definitions

<table>
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<th>Variable</th>
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<tbody>
<tr>
<td>p</td>
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**Units, definition and source**

(1967 $/MBF, log scale, Scribner) Average real bid price for all timber sold from the Siuslaw National Forest. **SOURCE:** Individual timber sale reports on file at the Siuslaw National Forest; National Forest Advertised Timber Sales, Region 6; and summary sales data on file in the Regional office, USFS, Portland, OR. Deflated by the all commodity producer price index (1967=100.0).

**P**

(1967 $/MBF, lumber tally) The wholesale price of all Douglas-fir lumber in 1967 dollars. Computed as the all Douglas-fir lumber wholesale price index (1967=100.0, BLS code # 0811-01) times the average price in dollars per MBF for 1967. The average price for 1967 was derived by taking the arithmetic average of monthly reported dollar prices for all grades of Douglas-fir lumber, then weighting these annual averages using BLS weights to form a single composite average for the Douglas-fir group.
($85.76/MBF). The series is deflated by the all commodity producer price index.


I (MBF, Scribner) Sum of uncut volume under contract at the beginning of each year on the Siuslaw, Willamette, and Mt. Hood National Forests. Computed as: start under contract = under contract end of year + cut during the year - sold during the year.

**SOURCE:** Region 6 Progress of Timber Management, and special listings maintained at the Regional Office, Portland, OR.

Northwest Region, Portland, OR.

(MBF, Scribner) Volume of timber sold from the Siuslaw National Forest. SOURCE: Individual timber sale reports on file at the Siuslaw National Forest Advertised Timber Sales, Region 6; and summary sales data on file in the Regional Office, USFS, Portland, OR.

(MBF, Scribner) Sum of (1) all National Forest timber sold in the Siuslaw marketing area (excluding Siuslaw), primarily from the Willamette and Mt. Hood National Forest, and (2) timber harvest on all other public ownerships in the Siuslaw marketing area, including State, BLM, BIA, and all other public agency lands (as other Federal, other public). SOURCE: (1) Wall, Brian R. 1972. Log Production in Washington and Oregon: an historical perspective. USDA Forest Service Resource Bulletin PNW-42 (1972). (2) Lloyd, J. D., 1972-1976 Oregon Timber Harvest. USDA Forest Service Resource Bulletin PNW-43, 49, 55, 63 (revised ), 69, and 78. PNW Forest and Range Experiment Station, Portland, OR.
(MBF, Scribner) Volume of timber harvested from integrated private or "forest industry" lands in the Siuslaw marketing area.


(MBF, Scribner) Volume of timber harvested from non-integrated, farm and miscellaneous private ownerships in the Siuslaw marketing area. **SOURCE:** as in \( S_I \) above.

(MBF, Scribner) Volume of timber harvested from all private lands in Siuslaw marketing area, i.e., \( S_p = S_I + S_N \). Actual data prior to 1962 is not available to be divided into \( S_I \) and \( S_N \).

(MBF, Scribner) Total log exports (flows out) from the Siuslaw marketing area.

\[ I \] (MBF, Scribner) Total log imports (flows into) from outside of the marketing area. SOURCE: as for \( E \).

Resources of Northwest Oregon (1979), USDA Forest Service Resource Bulletin PMW-82, PNW Forest and Range Management Station.
## APPENDIX II

### Base Data Listings

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<th>Deflated bid price (p)</th>
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## APPENDIX II

### Base Data Listings—Continued

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<th>Siuslaw volume sold (S_s)</th>
<th>Willamette volume sold</th>
<th>Mt. Hood volume sold</th>
<th>Other public volume cut</th>
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### APPENDIX II

**Baes Data Listings--Continued**

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APPENDIX III

Linear Models for Different Combinations of Variable P

(1) \( p = -6.062 - .000011 Q + 1.46 \text{PLUM} + .000010 I - 1.22 C \)
\((-1.49) \quad (5.22)^* \quad (1.90) \quad (-1.54)\)
unadjusted \( R^2 = .8491 \)
overall \( F = 25.32^* \)

(2) \( p = -32.32 - .00008 Q + 1.01 \text{PLUM} + .757 \text{PLUM}_{-1} + .00001 I - 1.51 C \)
\((-1.57) \quad (4.38)^* \quad (4.11)^* \quad (2.89)^*(-2.62)^* \)
unadjusted \( R^2 = .9243 \)
overall \( F = 41.52^* \)

(3) \( p = -36.25 - .000079 Q + 1.728(\frac{1}{2} \sum_{i=0}^{1} \text{PLUM}_{t-i}) + .000012 I - 1.26 C \)
\((-1.501) \quad (8.346)^* \quad (3.04)^* \quad (-2.56)^* \)
unadjusted \( R^2 = .9221 \)
overall \( F = 53.24^* \)

(4) \( p = 17.21 - .000012 Q + 2.03 \text{PLUM} - .68 \text{PLY} - .00002 I - .87 C \)
\((-1.70) \quad (4.19)^* \quad (-1.43) \quad (-2.00) \quad (-1.08) \)
unadjusted \( R^2 = .8652 \)
overall \( F = 21.85^* \)

(5) \( p = -25.60 - .000085 Q + 1.913(\frac{1}{2} \sum_{i=0}^{1} \text{PLUM}_{t-i}) - .262(\frac{1}{2} \sum_{i=0}^{1} \text{PLY}_{t-i}) \)
\((-1.57) \quad (5.71)^* \quad (-.71) \quad (-.005) \quad (.864) \quad (-2.005)^* \)
unadjusted \( R^2 = .9243 \)
overall \( F = 41.62^* \)

(6) \( p = -25.36 - .000094 Q + 1.377 \text{PLUMP} + .00020 I - 1.23 O2 C \)
\((-1.14) \quad (4.22)^* \quad (3.29)^* \quad (-1.34) \)
unadjusted \( R^2 = .8094 \)
overall \( F = 19.11^* \)
(7) \( p = -63.27 - 0.0000062q + 1.7953PLUM + 0.000249 I - 1.716C \)

\[
\text{unadjusted } R^2 = 0.8903 \\
\text{over-all } F = 36.72^* 
\]

where:

- PLUM = lumber price (1967 $/MBF, lumber tally)
- PPLY = plywood price (1967 $/MSF)
- C = lumber production costs (1967 $/MBF, lumber tally)
- PLUM\(_{-1}\) = lumber price lagged one year
- PPLY\(_{-1}\) = plywood price lagged one year

\[
\frac{1}{\frac{1}{2}} \sum_{i=0}^{t} PLUM_{t-i} = \text{moving average of lumber price of PLUM}_t \text{ and } PLUM_{t-1}
\]

\[
\frac{1}{\frac{1}{2}} \sum_{i=0}^{t} PPLY_{t-i} = \text{moving average of plywood price of PPLY}_t \text{ and } PPLY_{t-1}
\]

PLUMPLY = \(0.6 \times PLUM + 0.4 \times PPLY\)

PLUMPLY2 = \(0.6 \times (\frac{1}{\frac{1}{2}} \sum_{i=0}^{t} PLUM_{t-i}) + 0.4 \times (\frac{1}{\frac{1}{2}} \sum_{i=0}^{t} PPLY_{t-i})\)
APPENDIX IV

Different Functional Forms Fitted for Stumpage Demand

(1) General Linear Model:
\[ p = 20.54 + 0.0001887 Q + 2.4592 \left( \frac{1}{i=0} (P-C)_{t-i} \right) \]
\[ (2.712)* \quad (7.868)* \]
unadjusted \( R^2 = .8063 \)
over-all \( F = 41.63* \)
\( D-W \) statistic = 1.2937

(2) Logarithmic Linear Model (Cobb-Douglas Production Function)
\[ \log_e p = 17.80 - 1.4556 \log_e Q + 2.1657 \log_e \left( \frac{1}{i=0} (P-C)_{t-i} \right) \]
\[ (-2.103)* \quad (6.235)* \]
unadjusted \( R^2 = .7193 \)
over-all \( F = 25.63* \)
\( D-W \) statistic = 1.2043

(3) Exponential Model:
\[ \log_e p = 3.08 -.00000031 Q + .0447 \left( \frac{1}{i=0} (P-C)_{t-i} \right) \]
\[ (-1.806) \quad (5.887)* \]
unadjusted \( R^2 = .6927 \)
over-all \( F = 22.55* \)
\( D-W \) statistic = 1.2355

(4) Semilogarithmic Model:
\[ p = 990.29 - 90.7249 \log_e Q + 117.483 \log_e \left( \frac{1}{i=0} (P-C)_{t-i} \right) \]
\[ (-3.178)* \quad (8.201)* \]
unadjusted \( R^2 = .8226 \)
over-all \( F = 46.38* \)
\( D-W \) statistic = 1.3404
APPENDIX V

Correlating for Autocorrelation Problem

**METHOD I. First Difference of the Original Data (ρ=1)**

Assuming that the autocorrelation coefficient ρ=1. Under this assumption the appropriate transformation is to take the first differences of the original data and apply OLS to the transformed model. For our sampled period, we got

\[
p^* = 0.00000007938 Q^* + 1.7876 PC^*
\]

(unadjusted) \[R^2 = .6230\]

over-all F = 16.53*

D-W statistic = 1.98 (No autocorrelation)

where:

\[
P^* = P_t - P_{t-1}
\]

\[
Q^* = Q_t - Q_{t-1}
\]

\[
PC^* = PC_t - PC_{t-1}
\]

\[
PC' = \frac{1}{i=0} \sum (P-C)_{t-i}
\]

**METHOD II. Estimation of ρ from the d Statistic:**

Since d = 2(1-ρ), from the application of the Durbin-Watson test we obtain d* which we may substitute in the above expression and get

\[
\hat{\rho} = 1 - \frac{1}{2} d^* = 1 - \frac{1}{2} (1.2937) = .35315
\]

and

\[
p^* = -1.21496 - .000011056 Q^* + 2.26656 PC^*
\]

(-1.687) \[6.567)^*\]
over-all F = 24.56*
D-W statistic = 1.4692 (inconclusive)

where:

\[ p^* = p_t - .35315 \ p_{t-1} \]
\[ Q^* = Q_t - .35315 \ p_{t-1} \]
\[ PC^* = PC_{t-1} - .35315 \ PC_{t-1} \]

METHOD III. The Cochrane-Orcutt Iterative Method:

STEP 1: Apply OLS to the original data, compute the "first round" residual \( e_t = Y_t - \hat{Y}_t \), and from these estimate the first round estimate of \( \rho \) by

\[ \hat{\rho}_1 = \frac{e_t e_{t-1}}{e_{t-1}^2} = \frac{514.0403}{226.2806} = 0.2309 \]

STEP 2: Use \( \hat{\rho}_1 \) to transform the original data and apply OLS, we obtain:

\[ p^* = 4.2584 - .00001378 \ Q^* + 2.3454 \ PC^* \]
\[ (-2.060)* \quad (7.063)* \]

unadjusted \( R^2 = .7598 \)

over-all F = 30.05*
D-W statistic = 1.4514 (inconclusive)

where:

\[ p^* = p_t - .2309 \ p_{t-1} \]
\[ Q^* = Q_t - .2309 \ Q_{t-1} \]
\[ PC^* = PC_{t-1} - .2309 \ PC_{t-1} \]

then compute the "second round" residuals \( \hat{e}_t = Y_t - \hat{Y}_t \) and from these we obtain the second round estimate of \( \rho \)
\[ \hat{\rho}_2 = \frac{\hat{e}_t - \hat{e}_{t-1}}{\hat{e}_{t-1}^2} = \frac{226.2290}{1616.8694} = 0.1399 \]

**STEP 3:** Use \( \hat{\rho}_2 = 0.1399 \) to transform the original data and apply OLS, we obtain:

\[ p^* = 9.6950 - 0.00001564 \quad Q^* + 2.3861 \quad PC^* \]

\[ (\text{-2.321})^* \quad (\text{7.440})^* \]

unadjusted \( R^2 = .7852 \)

over-all \( F = 34.72^* \)

D-W statistic = 1.4295 (inconclusive)

we obtain the "third round" estimates, which yield the third round residuals

\[ \hat{\rho}_3 = \frac{\hat{e}_t - \hat{e}_{t-1}}{\hat{e}_{t-1}^2} = \frac{276.7994}{1718.7457} = 0.1610 \]

then

\[ p^* = 8.3451 - 0.000015226 \quad Q^* + 2.3778 \quad PC^* \]

\[ (\text{-2.262})^* \quad (\text{7.353})^* \]

unadjusted \( R^2 = .7796 \)

over-all \( F = 33.60^* \)

D-W statistic = 1.4356

where:

\[ p^* = p_t - .1610 \quad p_{t-1} \]

\[ Q^* = Q_t - .1610 \quad Q_{t-1} \]

\[ PC^* = PC_t - .1610 \quad PC_{t-1} \]

Continuing, the "fourth round" residuals

\[ \hat{\rho}_4 = \frac{\hat{e}_t - \hat{e}_{t-1}}{\hat{e}_{t-1}^2} = \frac{263.4334}{1694.2297} = 0.1555 \]
then
\[ p^* = 8.6956 - .000015336 Q^* + 2.38009 PC^* \]
\[ (-2.277)^* \quad (7.376)^* \]

unadjusted \( R^2 = .7811 \)
over-all \( F = 33.89 \)
D-W statistic = 1.4340 (still inconclusive, stop)

where:
\[ p^* = p_t - .1555 p_{t-1} \]
\[ Q^* = Q_t - .1555 Q_{t-1} \]
\[ PC^* = PC_t - .1555 PC_{t-1} \]

**METHOD IV.** Regressing \( e_t \) on \( e_{t-1} \) for estimating \( \rho \):

Assuming the first order autocorrelation \( e_t = \rho e_{t-1} + v_t \),
we got:
\[ e_t = 0.2309 e_{t-1} \]

i.e.,
\[ \hat{\rho} = 0.2309 \]

then
\[ p^* = 4.25947 - .00001378 Q^* + 2.34537 PC^* \]
\[ (-2.060)^* \quad (7.063)^* \]

unadjusted \( R^2 = .7598 \)
over-all \( F = 30.05^* \)
D-W statistic = 1.4514 (inconclusive)

**METHOD V.** Durbin's "two-step" Method of Estimation \( \rho \):

**STAGE 1:** Set \( p_t = a_0 + \rho p_{t-1} + a_1 Q_t + a_2 Q_{t-1} + a_3 PC_t + a_4 PC_{t-1} + v_t \), and applying OLS to this equation, we obtain
an estimate of \( \rho, \hat{\rho} \), which is the coefficient of the lagged variable \( p_{t-1} \):
\[
\begin{align*}
  p_t &= 50.69 + .6865 p_{t-1} - .0000067 Q_t - .0000085 Q_{t-1} \\
  &\quad + 2.00105 PC_t - 1.2863 PC_{t-1}
\end{align*}
\]

we obtain \( \hat{\rho} = .6865 \)

**STAGE 2:** We use the estimate \( \hat{\rho} = .6865 \) to obtain the transformed variables:

\[
\begin{align*}
  p^* &= p_t - .6865 p_{t-1} \\
  Q^* &= Q_t - .6865 Q_{t-1} \\
  PC^* &= PC_t - .6865 PC_{t-1}
\end{align*}
\]

and then applying OLS to these transformed variables:

\[
\begin{align*}
  p^* &= -4.47027 -.000003611 Q^* + 1.9454 PC^* \\
  &\quad (-.629) \quad (5.631)^* \\
  \text{unadjusted } R^2 &= .6283 \\
  \text{over-all } F &= 16.05^* \\
  \text{D-W statistic} &= 1.6582 \quad \text{(No autocorrelation)}
\end{align*}
\]

Among all the methods we employed above, the solutions for the case of autocorrelation are all still inconclusive except for the method I (first difference \( \rho=1 \)) and method V (Durbin two-step method); but for method I we got a 'wrong sign' of the variable \( Q^* \), and for the method V although we got the expected sign for each transformed variable, the \( R^2 \) reduced too much from 0.8063 to 0.6865. Consequently, we retain the estimated equation (ix) as the final model at this step.
APPENDIX VI

Heteroskedasticity Test

METHOD I. Spearman's Rank Correlation Test:

To apply this test we rank the explanatory variable PC's ($\frac{1}{i} \sum_{i=1}^{n} (P-C)_{t-i}$) and residual $e_t$'s (ignoring their sign) in ascending order. The rankings are shown below:

<table>
<thead>
<tr>
<th>Year</th>
<th>Rank of PC</th>
<th>Rank of $e_t$</th>
<th>D</th>
<th>$D^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1954</td>
<td>11</td>
<td>21</td>
<td>-10</td>
<td>100</td>
</tr>
<tr>
<td>1955</td>
<td>16</td>
<td>14</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>1956</td>
<td>17</td>
<td>20</td>
<td>-3</td>
<td>9</td>
</tr>
<tr>
<td>1957</td>
<td>14</td>
<td>10</td>
<td>-4</td>
<td>16</td>
</tr>
<tr>
<td>1958</td>
<td>3</td>
<td>17</td>
<td>-14</td>
<td>196</td>
</tr>
<tr>
<td>1959</td>
<td>10</td>
<td>15</td>
<td>-5</td>
<td>25</td>
</tr>
<tr>
<td>1960</td>
<td>12</td>
<td>16</td>
<td>-4</td>
<td>16</td>
</tr>
<tr>
<td>1961</td>
<td>2</td>
<td>7</td>
<td>-1</td>
<td>1</td>
</tr>
<tr>
<td>1962</td>
<td>1</td>
<td>2</td>
<td>-1</td>
<td>1</td>
</tr>
<tr>
<td>1963</td>
<td>5</td>
<td>5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1964</td>
<td>9</td>
<td>6</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>1965</td>
<td>7</td>
<td>7</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1966</td>
<td>8</td>
<td>12</td>
<td>-4</td>
<td>16</td>
</tr>
<tr>
<td>1967</td>
<td>6</td>
<td>4</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>1968</td>
<td>13</td>
<td>22</td>
<td>-9</td>
<td>81</td>
</tr>
<tr>
<td>1969</td>
<td>21</td>
<td>1</td>
<td>20</td>
<td>400</td>
</tr>
<tr>
<td>1970</td>
<td>15</td>
<td>19</td>
<td>-4</td>
<td>16</td>
</tr>
<tr>
<td>1971</td>
<td>4</td>
<td>13</td>
<td>-9</td>
<td>81</td>
</tr>
<tr>
<td>1972</td>
<td>19</td>
<td>13</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1973</td>
<td>22</td>
<td>9</td>
<td>13</td>
<td>169</td>
</tr>
<tr>
<td>1974</td>
<td>23</td>
<td>8</td>
<td>15</td>
<td>225</td>
</tr>
<tr>
<td>1975</td>
<td>20</td>
<td>11</td>
<td>9</td>
<td>81</td>
</tr>
<tr>
<td>1976</td>
<td>18</td>
<td>23</td>
<td>-5</td>
<td>25</td>
</tr>
</tbody>
</table>

$\sum D^2 = 1476$

The rank correlation coefficient estimated from the data above is
\[ r' = 1 - \frac{6 \sum D^2}{n(n^2-1)} = 1 - \frac{6(1476)}{23(23^2-1)} = 0.2707 \]

where \( D \) = difference between the ranks of corresponding pairs of \( PC' \) and \( e_t \), and \( n \) = observations in the sample. The standard error of \( r' \) is \( 1/\sqrt{n-1} = 1/\sqrt{22} = 0.2132. \) Since the calculated \( r' \)
\[-1.96/\sqrt{n-1} < r' < 1.96/\sqrt{n-1} \qquad \alpha = 0.05\]
i.e., \(-0.4178 < r' < 0.4178\) showing that the rank correlation is statistically insignificant.

**METHOD II. The Goldfelt and Quandt Test:**

We order the observation in ascending order of the \( PC' \)'s and omitting the five central observations, we are left with two subsets of data, one with the lower values of \( PC' \) and one with the higher values of \( PC' \). These two subsets of data are shown on the next page.

Applying OLS to each subset we obtain

(a) For subset 1
\[ \hat{p} = -83.4774 - .00001296 Q + 4.6339 PC' \]
\[ (-1.536) \quad (3.274)* \]
with \( R^2 = 0.6414 \) and \( \sum e_1^2 = 202.633 \)

(b) For subset 2
\[ \hat{p} = 145.703 - .00004403 Q + 2.0355 PC' \]
\[ (-3.736)* \quad (3.875)* \]
with \( R^2 = 0.8768 \) and \( \sum e_2^2 = 852.634 \)

We form the ratio of the two unexplained variations
The theoretical value of $F$ at the 5 per cent of significance with $v_1 = v_2 = \frac{(n-c)/2}{K} = 6$ degrees of freedom, where $n =$ total number of observations, $c =$ central observation omitted, $K =$ number of parameters estimated from each regression, is $F_{6,6,0.05} = 4.28$. Given that $F^* < F_{0.05}$ we fail to reject the assumption of homoskedasticity.

<table>
<thead>
<tr>
<th>$n_1$</th>
<th>$p$</th>
<th>$Q$</th>
<th>$PC'$</th>
<th>$n_2$</th>
<th>$p$</th>
<th>$Q$</th>
<th>$PC'$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>26.16</td>
<td>4,095,567</td>
<td>34.64</td>
<td>1</td>
<td>33.28</td>
<td>4,095,929</td>
<td>41.88</td>
</tr>
<tr>
<td>2</td>
<td>30.33</td>
<td>3,920,755</td>
<td>35.21</td>
<td>2</td>
<td>35.72</td>
<td>4,488,599</td>
<td>44.56</td>
</tr>
<tr>
<td>3</td>
<td>17.85</td>
<td>4,128,074</td>
<td>35.53</td>
<td>3</td>
<td>35.58</td>
<td>4,632,538</td>
<td>47.23</td>
</tr>
<tr>
<td>4</td>
<td>40.20</td>
<td>4,128,978</td>
<td>36.32</td>
<td>4</td>
<td>101.14</td>
<td>3,461,574</td>
<td>47.96</td>
</tr>
<tr>
<td>5</td>
<td>26.12</td>
<td>4,808,974</td>
<td>37.23</td>
<td>5</td>
<td>69.75</td>
<td>4,437,969</td>
<td>49.01</td>
</tr>
<tr>
<td>6</td>
<td>35.52</td>
<td>3,927,555</td>
<td>37.41</td>
<td>6</td>
<td>82.48</td>
<td>3,806,999</td>
<td>51.45</td>
</tr>
<tr>
<td>7</td>
<td>40.52</td>
<td>4,205,682</td>
<td>38.17</td>
<td>7</td>
<td>66.49</td>
<td>4,180,697</td>
<td>51.46</td>
</tr>
<tr>
<td>8</td>
<td>41.86</td>
<td>4,363,655</td>
<td>38.94</td>
<td>8</td>
<td>93.96</td>
<td>4,107,607</td>
<td>63.65</td>
</tr>
<tr>
<td>9</td>
<td>39.41</td>
<td>4,343,596</td>
<td>39.06</td>
<td>9</td>
<td>108.84</td>
<td>3,795,120</td>
<td>67.29</td>
</tr>
</tbody>
</table>
APPENDIX VII

Different Functional Form Estimates for Private Stumpage Supply Equations

(1) General linear form:
\[ S_p = -711969 + 2054.23 p + 216.75 V_{-1} \]
\[ R^2 = .5051^1/ \]
over-all F = 10.21*
D-W statistic = 1.49

(2) Logarithmic linear form:
\[ \log_e S_p = 2.1867 + .06865 \log_e p + 1.2836 \log_e V_{-1} \]
\[ R^2 = .5008 \]
over-all F = 10.03*
D-W statistic = 1.51

(3) Exponential form:
\[ \log_e S_p = 13.3531 + .0006138 p + .0000929 V_{-1} \]
\[ R^2 = .5007 \]
over-all F = 10.03*
D-W statistic = 1.49

(4) Semi-logarithmic form:
\[ S_p = -26647800 + 186759 \log_e p + 2974930 \log_e V_{-1} \]
\[ R^2 = .5104 \]
over-all F = 10.42*
D-W statistic = 1.51

\[ 1/ R^2 \text{ is unadjusted for degrees of freedom, } r^2 \text{ is square of simple correlation between actual and predicted cut.} \]
(5) \( S_p = A(t)p^{a_1} V^{-1} \)

where \( A(t) = ae^{\epsilon t}, \epsilon = 2.71828, t = \text{time (year)} \)

i.e., \( S_p = ae^{\epsilon t} p^{a_1} V^{-1} \)

Estimated equation:

\( S_p = 1.0563 \times 10^9 e^{-0.0097t} p^{0.0992} V^{0.6908} \)

i.e., \( \log S_p = 20.78 - 0.0097t + 0.0992 \log p + 0.6908 \log V \)

\( R^2 = 0.5176 \)

over-all \( F = 6.79* \)

D-W statistic = 1.48

(6) \( S_p = \sigma_0 \alpha_1^{-1} p^{a_2} V^{-1} \)

Estimated equation:

\( S_p = 416649 \times (1.000107)^{-1} p^{0.07047} \)

i.e., \( \log S_p = 12.94 + 0.000107 V^{-1} + 0.07047 \log p \)

\( R^2 = 0.5290 \)

over-all \( F = 11.23* \)

D-W statistic = 1.57

(7) \( S_p = \alpha_0 (\alpha_1 p)^{a_2} V^{-1} \)

Estimated equation:

\( S_p = 540365 (2704276 p)^{0.00000584} V^{-1} \)

i.e., \( S_p = 13.20 + 0.000086 V^{-1} + 0.0000058 V^{-1} \log p \)

\( R^2 = 0.5280 \)

over-all \( F = 11.19* \)

D-W statistic = 1.56
(8) $S_p = (\alpha + \beta p) V_{-1}^r$

(i) $r = 1$, then $S_p = (\alpha + \beta p) V_{-1}$

i.e., $S_p / V_{-1} = \alpha + \beta p$

Estimated equation:

$S_p / V_{-1} = 163.603 + .0584 p$

$r^2 = .4971$

(ii) $r = 2$, then $S_p = (\alpha + \beta p) V_{-1}^2$

i.e., $S_p / V_{-1}^2 = \alpha + \beta p$

Estimated equation:

$S_p / V_{-1}^2 = .01184 + .00003984 p$

$r^2 = .5083$

(iii) $r$ is an unknown parameter: By using a non-linear programming to estimate $\alpha$, $\beta$, and $r$:

Objective function: $\min_{\alpha, \beta, r > 0} \sum_{i=1}^{23} [S_p - (\alpha + \beta p_i) V_{i-1}^r]$

The non-linear computer programming are presented in Appendix VIII (provided by Chiang Kao).

Estimated equation:

$S_p = (.004240 + .000003802 p) V_{-1}^{1.2966}$

$r^2 = .5162$

1/ $\hat{S}_p = \left( \frac{S_p}{V_{-1}} \right) * V_{-1}$

Correlation ($S_p, \hat{S}_p$) = .7050, then $r^2 = .4971$

2/ $\hat{S}_p = \left( \frac{S_p}{V_{-1}^2} \right) * V_{-1}^2$

Correlation ($S_p, \hat{S}_p$) = .7129, then $r^2 = .5083$
APPENDIX VIII

Non-linear Computer Program Used to Estimate
Non-linear Functional Form in Appendix VII

PROGRAM FLEX(INPUT, OUTPUT)
C THIS PROGRAM USES MODIFIED FLEXIBLE POLYHEDRON METHOD
C TO FIND THE OPTIMAL SOLUTIONS OF A CONSTRAINED
C NONLINEAR PROGRAMMING PROBLEM
REAL II, JJ, KK, LL, MM, NH
DIMENSION X(10, 10), FVAL(10), XIN(10), XHI(10), XC(10)
DIMENSION XNEW(10), XTMP(10), TMP(10)
T=0.5
ITERA=0
WRITE *, "READ IN VARIABLES, EPSILON, AND ITERATIONS"
READ *, N, EPSILON, ICOUNT
M1=N+1
WRITE *, "READ IN INITIAL POINT"
READ *, (XIN(I)), I=1, N)
IF (TEST(XIN).EQ.0.) GO TO 3
WRITE *, "INITIAL POINT IS INFEASIBLE"
STOP
C DETERMINE THE INITIAL SIMPLEX
3 D1=T*(SORT(FLOAT(N1))+(N-1.)/(N*SORT(2.))
D2=T*(SORT(FLOAT(N1))-1.)/(N*SORT(2.))
DO 5 I=1, N1
DO 5 J=1, N
X(I,J)=XIN(J)+D2
IF (I.EQ.J+1) X(I,J)=XIN(J)+D1
5 IF (I.EQ.1) X(I,J)=XIN(J)
DO 7 I=2, N1
DO 6 J=1, N
6 TMP(J)=X(I,J)
IF (TEST(TMP).EQ.0.) GO TO 7
T=T/2.
GO TO 3
7 CONTINUE
DO 9 I=1, N1
DO 8 J=1, N
8 TMP(J)=X(I,J)
9 FVAL(I)=F(TMP)
C FIND THE HIGHEST AND LOWEST POINT
10 FHI=FLOV=FVAL(1)
LHI=LOW=1
DO 12 I=2, N1
IF (FVAL(I).GE.FLOW) GO TO 11
FLOW=FVAL(I)
LOV=I
11 IF (FVAL(I).LE.FHI) GO TO 12
FHI=FVAL(I)
LHI=I
$\text{12 CONTINUE}$

C FIND THE SECOND LOWEST POINT
F2LOW=FVAL(LHI)
NDL=LHI
DO 13 I=1,N1
IF(I.EQ.LOU) GO TO 13
IF(FVAL(I).GE.F2LOW) GO TO 13
F2LOW=FVAL(I)
NDL=I

$\text{13 CONTINUE}$

ALPHA=GAMMA=1.
BETA=0.5
C FIND THE CENTROID
DO 15 I=1,N
SUM=0.
DO 14 J=1,N1
14 SUM=SUM+X(J,I)
15 XC(I)=(SUM-X(LOU,I))/N
IF(TEST(XC).EQ.1.) STOP
FC=F(XC)
C REFLECTION
DO 17 I=1,N
17 XNEW(I)=XC(I)+ALPHA*(XC(I)-X(LOU,I))
ALPHA=ALPHA/2.
IF(TEST(XNEW).EQ.1.) GO TO 16
FNEW=F(XNEW)
IF(FNEW.LE.FVAL(LHI)) GO TO 28
C EXPANSION
DO 19 I=1,N
19 XTMP(I)=XNEW(I)+GAMMA*(XNEW(I)-XC(I))
GAMMA=GAMMA/2.
IF(TEST(XTMP).EQ.1.) GO TO 19
FTMP=F(XTMP)
IF(FTMP.LE.FVAL(LHI)) GO TO 30
DO 20 I=1,N
20 X(LOU,I)=XTMP(I)
FVAL(LOU)=FTMP
GO TO 40
28 IF(FNEW.LT.FVAL(NDL)) GO TO 50
30 DO 32 I=1,N1
32 X(LOU,I)=XNEW(I)
FVAL(LOU)=FNEW
C TERMINATION CHECK
40 SUMSQR=0.
DO 42 I=1,N1
42 SUMSQR=SUMSQR+(FVAL(I)-FC)**2
ITERA=ITERA+1
IF(SORT(SUMSQR/N).GT.EPSILON.AND.ITERA.LT.ICOUNT) GO TO 10
WRITE *,ITERA,(X(LHI,I),I=1,N),FVAL(LHI)
STOP
50 IF (FNEW.LT.FVAL(LOW)) GO TO 60
DO 52 I=1,N
52 X(LOW,I)=XNEW(I)
FVAL(LOW)=FNEW
C CONTRACTION
60 DO 62 I=1,N
62 XTMP(I)=XC(I)+BETA*(X(LOW,I)-XC(I))
BETA=BETA/2.
IF (TEST(XTMP).EQ.1.) GO TO 60
FTMP=F(XTMP)
IF (FTMP.LT.FVAL(LOW)) GO TO 70
DO 64 I=1,N
64 X(LOW,I)=XTMP(I)
FVAL(LOW)=FTMP
GO TO 40
C REDUCTION
70 DO 72 I=1,N
72 XHI(I)=X(LHI,I)
DO 74 I=1,N
74 THP(I)=X(J,I)-X(LHI,I)
IF (TEST(TMP).EQ.1.) STOP
76 FVAL(J)=F(TMP)
GO TO 40
END
FUNCTION TEST(A)
DIMENSION A(10)
TEST=0.
IF (A(1).LT.0..OR.A(2).LT.0..OR.A(3).LT.0.) TEST=1.
RETURN
END
FUNCTION F(A)
DIMENSION A(10)
B=(24.2679-(A(1)+17.85*A(2))*789.8**A(3))*2
C=(26.39400-(A(1)+35.72*A(2))*774.0**A(3))*2
D=(28.08554-(A(1)+35.58*A(2))*753.0**A(3))*2
E=(20.60113-(A(1)+28.63*A(2))*732.7**A(3))*2
G=(19.09759-(A(1)+17.85*A(2))*721.2**A(3))*2
H=(18.09222-(A(1)+34.00*A(2))*710.1**A(3))*2
I=(20.77653-(A(1)+31.91*A(2))*698.7**A(3))*2
J=(19.46931-(A(1)+30.33*A(2))*685.9**A(3))*2
K=(19.86973-(A(1)+26.16*A(2))*679.3**A(3))*2
L=(19.53697-(A(1)+26.12*A(2))*671.3**A(3))*2
M=(20.06749-(A(1)+39.41*A(2))*666.9**A(3))*2
N=(19.95969-(A(1)+40.52*A(2))*663.0**A(3))*2
O=(20.30904-(A(1)+41.86*A(2))*659.0**A(3))*2
P=(19.81627-(A(1)+35.52*A(2))*654.2**A(3))*2
Q=(22.64456-(A(1)+56.89*A(2))*649.8**A(3))*2
R=(19.26790-(A(1)+66.49*A(2))*643.3**A(3))*2
S=(18.58674-(A(1)+33.23*A(2))*638.1**A(3))*2
\[ T = (20.08380 - (A(1) + 40.20 * A(2)) \times 631.8 * A(3)) \times 2 \]
\[ U = (18.08965 - (A(1) + 69.75 * A(2)) \times 624.4 * A(3)) \times 2 \]
\[ V = (18.84923 - (A(1) + 93.96 * A(2)) \times 623.6 * A(3)) \times 2 \]
\[ W = (16.72132 - (A(1) + 108.84 * A(2)) \times 630.1 * A(3)) \times 2 \]
\[ X = (18.24334 - (A(1) + 82.48 * A(2)) \times 588.6 * A(3)) \times 2 \]
\[ Y = (18.45221 - (A(1) + 101.14 * A(2)) \times 545.2 * A(3)) \times 2 \]
\[ F = -(B + C + D + E + G + H + I + J + K + L + M + N + O + P + Q + R + S + T + U + V + W + X + Y) \]

RETURN

END
APPENDIX IX

Regional Gross Growth Rate $\alpha_t$ on Private Forest Lands within the Siuslaw Marketing Area

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>NW</td>
<td>2181</td>
<td>3306</td>
<td>3421</td>
<td>1707</td>
</tr>
<tr>
<td>WC</td>
<td>3312</td>
<td>2538</td>
<td>3046</td>
<td>1663</td>
</tr>
<tr>
<td>total</td>
<td>11,337</td>
<td></td>
<td>9,837</td>
<td></td>
</tr>
</tbody>
</table>

| Annual Growth              |         |         |         |         |
| NW                        | 71.1    | 126.5   | 154.3   | 66.6    |
| WC                        | 75.5    | 72.8    | 106.3   | 62.2    |
| total                     | 345.9   |         | 389.3   |         |

| Gross Growth Rate $\alpha_t$ | 0.030511 | 0.039577 |

Sources: see Appendix I.
APPENDIX X

Identification in a Simultaneous Equation System

Consider the simultaneous equation system

\[ p = a_0 + a_1 q + a_2 pc + u \]
\[ \sum_p = \beta_0 + \beta_1 p + \beta_2 v_{-1} + v \]
\[ q = \sum_p + \sum_s + \sum_{OG} + \overline{1} - \overline{E} \]

It is mathematically complete in the sense that it contains three equations in three endogenous variables. To establish the identifiability of the demand function (the first equation) two conditions must be satisfied.

(1) Order Condition: \((K - M) \geq (G - 1)\)

where:

- \(G =\) total number of equations = total number of endogenous variables
- \(K =\) total number of variables in the model (endogenous and predetermined)
- \(M =\) number of variables, endogenous and exogenous, included in a particular equation

In the above model we have \(K = 9\), \(M = 3\), \(G = 3\)

therefore \((K - M) > (G - 1)\)

or \((9 - 3) > (3 - 1)\)

Consequently the first equation satisfies the order condition for identification.

(2) Rank Condition:

The rank condition states that, in a system of \(G\) equations any particular equation is identified if and only if it is
possible to construct at least one non-zero determinant of order \((G-1)\) from the coefficients of the variables excluded from that particular equation but contained in the other equations in the model.

The table of the coefficients of the structural model is:

<table>
<thead>
<tr>
<th>Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equations</td>
</tr>
<tr>
<td>1st equation</td>
</tr>
<tr>
<td>2nd equation</td>
</tr>
<tr>
<td>3rd equation</td>
</tr>
</tbody>
</table>

Now we strike out the first row and the first, second, and fourth columns. Thus we are left with the table of the coefficients of excluded variables:

<table>
<thead>
<tr>
<th>Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>(S_p)</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>-1</td>
</tr>
</tbody>
</table>

Obviously from this table we can form at least one non-zero determinant of order \((G-1)\)=\((3-1)\)=2. We see that both the order and rank conditions are satisfied. Hence the first equation of the model is identified. Furthermore, we see that in the order condition the inequality holds: \((9-3)>(3-1)\), i.e., \((K-M)>(G-1)\). Consequently the first equation is over-identified. For the second equation, we have the same result.