ESSAYS OF FORESTRY INVESTMENTS IN THE US

AND STUMPAGE MARKET IN THE US SOUTH

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VITA

Xianchun Liao, son of Mingjing Liao and Qiaozhi Han, was born on April 5, 1964 in Hubei, China. I graduated from Huazhong Agricultural University with Bachelor degree of Science in 1985. Then I obtained Master's degree of Forest Management in Beijing Forestry University in 1987. After graduation, I went to Huazhong Agricultural University as a teaching assistant and research fellow of Forest Economics and Management. In 1991, I was promoted to an assistant professor at Huazhong Agricultural University. In 1998, I was chosen to be a visiting scientist by China's government for research in Germany. In August 2001, as a PhD student, I entered graduate school at Michigan State University and became PhD candidate in December, 2004. In January 2006, I entered graduate school at Auburn University and became PhD candidate in December, 2006. I am married to Yunxing Cheng and we have daughter Jing, sons George and Ethan.

DISSERTATION ABSTRACT

ESSAYS OF FORESTRY INVESTMENTS IN THE US

AND STUMPAGE MARKET IN THE US SOUTH

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In 2005, nearly $30 billion of American forest land in the hands of institutional investors may suggest that timberland is a good portfolio diversifier. However, this statement may be overstated because forestry investments may have correlations with non-forestry assets in the long run. In addition, timberland investment is largely determined by stumpage market. Moreover, the differentiated ownerships make the analysis of the stumpage market more complicated. This study investigates the relationships between forestry and non-forestry instruments in the US while examining pulpwood market and stumpage supply by differentiated ownerships in the US South.

Chapter 1 the introduction identifies research problems and presents research objectives. Chapter 2 presents a literature review focusing on the major empirical analyses of timberland investment and stumpage market.

Chapter 3 investigates the short-run and long-run correlations between forestry and non-forestry assets in the US using quarterly data from January 1992 to July 2006. The results of capital asset pricing model (CAPM) show that the eight investment vehicles (timberland, timber, farmland, national property index, treasury bill for 3-month, deposit, government bond for 30 years, and gold) have lower risk and lower relationship with S&P 500 in the short run. The results of cointegration analysis show that cointegrated relationships exist between timberland, timber price, and the financial assets.

Chapter 4 examines the determinants of pine pulpwood supply and demand in the southern US using annual data from 1950 to 2002 with three-stage least squares (3SLS) regression techniques. The results of SSE model show that price elasticities of supply of and demand for pine pulpwood are relatively small, which is consistent with previous studies for the US South. In addition, the significant substitution between pulpwood stumpage and energy use was found with an elasticity of -0.35.

Chapter 5 focuses on the short run price elasticities for stumpage market by comparing forest industry (FI) and non-industrial private forest (NIPF) using a two-stage least squares (2SLS) techniques with time series data from 1953 to 2002. The estimated results show that supply price elasticities of 0.70 for sawtimber and 0.90 for pulpwood for FI owners are larger than those of 0.29 for sawtimber and 0.32 for pulpwood for NIPF owners, which, in general, are within the price elasticity range from previous studies.

Finally, chapter 6 summarizes the major findings of this study and some policy implications. Recommendations for further research are also addressed in this chapter.

Key words: Timberland return, capital asset pricing model, co-integration, simultaneous system of equations, profit maximization model, price elasticity

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 Problems

Currently, there are an estimated 620 million acres of forestland in the United States (Smith et al. 2004). In 2005, nearly $30 billion of American forest land was in the hands of institutional investors (Browning 2005) and a recent US Forest Service study made a forecast that more than 44 million acres of private forest land would be sold over the next 25 years (Washington Post, March 24, 2006). This suggests that timberland is a good portfolio diversifier because it is widely believed that timberland carries low risk and has low correlation with other financial instruments, such as the stock market. However, the diversified benefits might be overstated because forestry-related investments may be highly correlated with other financial assets in the long run. If timberland investment is related to other financial vehicles such as farmland, stock market, policy changes in one market will potentially spillover onto the other markets and have welfare implications (e.g. Uri and Boyd 1990, Murray and Wear 1998). So far, no study on the long-run relationship between forestry-related investments and financial instruments has been conducted in the US.

In addition, timberland investment is largely determined by stumpage market. If the fundamentals of investment do not change, for example, the supply of and demand for stumpage do not change, the over-frequent transactions or involvement of too many institutional investors in timberland investment may cause an investment bubble. Thus, there is a need to examine the stumpage market.

In this study, pulpwood market in the US South is chosen because more than 83% of softwood pulpwood production in the United States comes from the South (Howard 2003, p.6) and pulping capacity of 125 thousand tons per day in the US South accounts for more than 70% of the Nation's total pulping capacity (Johnson and Steppleton 2004, p.7). Although timber market models are extensively used to estimate short-run elasticity for pulpwood (e.g., Brännlund et al. 1985, Newman 1987, Carter 1992), these studies have small samples covering only 20-30 annual observations. The small observations with time series data might cause the coefficients of a simultaneous system of equations (SSE) to be sensitive to its specification and even inconsistent (Wooldridge 2000). Moreover, previous studies have paid little attention to energy use and recycled paper in production of paper and allied products. Energy use among US pulp, paper, and paperboard mills accounts for about 12% of all energy used in the domestic manufacturing sector and shares production cost by 13% within the paper mills (NAF 2002, Brown and Zhang 2005a). The wastepaper utilization accounts for 42% for newsprint, 10% for printing/writing paper, 60% for tissue paper, and 15% for packaging paper, respectively (Brown and Zhang 2005a).

The differentiated ownerships make the analysis of the stumpage market more complicated. For example, in the US South, a large share of the regional softwood production came from the small share of forested area owned by forest industry (FI), while a relatively small share of the production from a much large share of forestlands held by nonindustrial private forest (NIPF). Understanding the difference in production behavior between FI and NIPF has been a concern in the forestry literature and an important aspect in public policy and management plan. For example, price elasticities of stumpage play significant roles in measuring market and economic impacts of Sustainable Forestry Initiative by American Forest and Paper Association on stumpage market in the U.S. South in 1994 (Brown and Zhang 2005b). While many studies estimated short-run supply price elasticities for stumpage market (e.g., Brännlund et al. 1985, Newman 1987, Carter 1992, Polyakov et al. 2004), few studies conduct research on supply elasticities for industry and NIPF timberlands separately (e.g. Adams and Haynes 1980, Haynes and Adams 1985, and Newman and Wear 1993). For example, Adams and Haynes (1980) estimated a combined pulpwood/sawtimber supply elasticity for FI and NIPF. It is clear that different species have different biological characteristics, which influence timber growing stock. Although Newman and Wear (1993) gave the most recent supply elasticities for FI and NIPF, the study used cross-sectional data, which might not pick up all the past dynamic variability between stumpage supply and price.

1.2 Objectives

This study is intended to examine long-run and short-run relationships between forestry-related investments and non-forestry financial instruments in the US, while investigating pine pulpwood stumpage supply and demand in the US South and stumpage supply in the US South by the differentiated ownerships. The dissertation consists of three essays: Forestry-related Investments as Part of Portfolio Selection in the US, Modeling Pine Pulpwood Stumpage Market and Estimating Stumpage Supply by the Different Ownerships (FI and NIPF) in the US South.

1.3 Organization

To accomplish the above objectives appropriately, the dissertation is divided into five major chapters in addition to the first chapter of introduction.

Chapter 2 presents a literature review dealing with the subject of timberland investment, pulpwood demand and supply, and stumpage supply by different ownerships in forest sectors. Since it is unrealistic and unnecessary to cover all previous studies, the review focuses on the major empirical analyses of timber investment and stumpage market. The important thing is that the chapter provides the conceptual framework for this study.

Chapter 3 investigates the short-run and long-run correlations among timberland return, timber market and financial assets in the United States using quarterly data from January 1992 to July 2006. Capital asset pricing model (CAPM) and cointegration analysis are used in this study. The non-forestry financial instruments include farmland return, real estate, S&P500, treasury bill, deposit, and gold. Four hypotheses are tested in this study: (1). There might exist cointegration between timberland, timber, and the non-forestry financial assets; (2). Some financial instruments might not be excluded from the investment model; (3). Some variables might play leading roles in the model system; (4). There might not exist perfect integration for timberland model. Moreover, the empirical analyses are presented and a discussion of the results is provided.

Chapter 4 examines the determinants of pine pulpwood supply and demand in the southern US using annual data from 1950 to 2002. A structural simultaneous system of equations (SSE) model is used to estimate short-run price elasticities with three-stage least squares (3SLS) regression techniques. In the process of the model development, two hypotheses will be tested. They include: (1). Energy use might have impact on the pulpwood demand; (2). There might exist substitution or complementation between pulpwood and sawtimber stumpage. Then, the data sources are presented and the empirical estimation using 3SLS follows. Next, the regression results are interpreted. The study ends with summary and conclusion.

Chapter 5 focuses on the short run price elasticities for stumpage market by comparing forest industry (FI) and nonindustrial private forest (NIPF). The main task is to estimate stumpage supply in the US by different ownerships (FI and NIPF). This study hypothesizes that price elasticities for the two ownerships might be different. An econometric model is derived under the framework of profit maximization. A two-stage least squares (2SLS) techniques with time series data from 1953 to 2002 are employed in this study. Then, the regression results are presented and interpreted. This study is closed with summary and conclusion.

Chapter 6 summarizes the major findings of this study and some policy implications. Also, recommendations for further research are addressed in this chapter.

CHAPTER 2

LITERATURE REVIEW

This chapter presents a literature review dealing with the subject of timberland investment and stumpage market. Many scholars have developed timberland investment and timber market models and extensively used these models to assess forest policy effects (Adams and Haynes 1980, Brännlund et al. 1985, Newmann 1987, Kallio et al. 1987, Hetemäki and Kuuluvainen 1992, Lindsey et al. 2000, Zhang 2001, Jennings et al. 1991, Sarker 1996, and Hetemäki et al. 2004). The review focuses on the major empirical analyses of timberland investment and stumpage market. Table 2.1 lists the selected studies, which are divided into three groups: investment model, structural simultaneous system of equations model, and stumpage supply model by two ownerships (FI and NIPF). This chapter provides a conceptual framework for this study.

2.1 Forestry investments

Capital asset pricing model (CAPM) has been the most widely used method for asset valuation during the last two decades. For example, Hotveldt and Tedder (1978) use CAPM to evaluate the performance of five forestry industry firms. Redmond and Cubbage (1988) examine the risk and returns from timber investments. Thomson (1989) evaluated some financial uncertainties of a west coast Douglas-fir tree improvement program using CAPM. Biophysical uncertainties such as amount of genetic gain or uncertainty of site quality are determined by *apriori* assumption to be nonmarket; thus, use of expected value adjusts for these risks. The market uncertainties of tree improvement are found to be reasonable and the financial risks were small. The author conclude that the tree improvement investment is worthwhile, considering its risk as well as return. Washburn and Binkley (1993) estimate the relationship between forestry returns and inflation. Sun and Zhang (2001) assess the financial performance of forestry-related investment vehicles by comparing CAPM with arbitrage pricing theory (APT). Although APT findings are more robust, the results from APT support previous findings from CAPM. The authors conclude that institutional timberland investments have a low risk and excess returns and stumpage price does not resemble the return generation process of timberland investments.

These previous studies using CAPM conclude that return for timberland was weakly correlated with financial instruments such as stock market and timberland carries a relatively low risk (Sun and Zhang 2001). Thus, timberland provides an opportunity for portfolio selection. The statement may coincide with the recent trends that a large portion of the most productive timberlands are sold to Timber Investment Management Organization (TIMO). This might be true in the short run. However, in the long run, the diversified benefits might be overstated because these assets might be cointegrated, which means policy changes in one asset market will potentially spill over onto the other asset markets and have welfare implications (Uri and Boyd 1990, Murray and Wear 1998).

While many studies have examined the long-run relationship between timber market and financial market instruments in Scandinavian countries (Heikkinen and Kanto

2000, Heikkinen 2002), few studies on the long-run relationships between timberland and financial instruments have been conducted in the United States. For example, Heikkinen and Kanto (2000) reformulate conventional market model by considering also long-run characteristics of forestry returns. The authors suggest that the Finnish stumpage prices are cointegrated with stock market index.

Instead, Heikkinen (2002) examine the short-run and long-run correlations between Finish forestry returns and financial market instruments. The results show that the Finnish stumpage prices, and bond and deposit rates are co-integrated in the long run.

The first part of this study is to examine short-run and long-run relationships among nine financial investments using CAPM and multivariate cointegration method (Johansen 1988, 1991) because both approaches have their own advantages. A CAPM enables us to obtain the short run relationships between investment vehicles and market portfolio proxy S&P 500. A vector autoregressive model (VAR) is developed as a complementary analysis because the VAR model does not impose an a *priori* theoretical structure, while allowing both short-run and long-run dynamical impacts of an endogenous variable and leading to vector error correction model (VECM). The dual-track approach should draw more accurate and robust conclusions.

2.2 Structural simultaneous system of equations

Long-range projections of forest products markets and the condition of the forest resource base are essential tools for resource development planning. Among these partial equilibrium models, a structural econometric model (SEM) has been used to quantify both demand and supply factors. The SEM is based on the economic theory of demand

and supply. In general, supply is specified as a function of price, inventory, and other variables. Likewise, demand is specified as a function of price, income, and other variables. The demand must be equal to supply on the market.

Brännlund et al. (1985) use an econometric analysis of the sawtimber and pulpwood market in the northern part of Sweden. The sawtimber market is modeled as a competitive market. A simultaneous system of supply and demand equations (SSE) for sawtimber was estimated. The supply of sawtimber is a function of the sawtimber price, pulpwood price, the harvest cost, and dummy variable to indicate that subsidies are paid. On the other hand, the demand for sawtimber is a function of the sawtimber price, the ability to pay for sawtimber (as the difference between the world market prices of sawn products and the wage rate in the sawmill industry), and the lagged sawtimber supply. They use ordinary least squares (OLS), two stage least squares (2SLS), and three stage least squares (3SLS) to estimate the simultaneous system. The results imply that if the policy maker wishes to increase the supply of sawtimber and/or pulpwood in a particular period, a direct unit subsidy per cubic meter will work well.

Newman (1987) presents an econometric analysis of the Southern softwood stumpage market in the US. Aggregate stumpage supply, for both pulpwood and solidwood products, is specified as a function of the received price for both of these goods, and the amount of standing softwood inventory as a proxy for harvesting costs. Stumpage demand for both pulpwood and solidwood is regressed as a function of their own stumpage prices, the respective prices of solidwood and pulpwood, labor and capital inputs, and respective one-period lagged production. 3SLS techniques are used for the simultaneous parameter estimation. The results show that solidwood stumpage is a complement with pulpwood in pulpwood production while pulpwood is a substitute good for solidwood in solidwood production.

Hetemäki and Kuuluvainen (1992) examine the aggregate pulpwood market in Finland using simultaneous-equations models. The supply of pulpwood is a function of pulpwood price, disposable income, allowable drain, bank lending rate, lagged pulpwood price, and lagged supply quantity. On the other hand, the demand for pulpwood is a function of pulpwood price, export price, wage rate, user cost, lagged pulpwood price, and lagged demand quantity.

Carter (1992) investigate Texas pine pulpwood stumpage market using time series data from 1964-1986. The paper combine profit maximization for the demand side with utility maximization for the supply side. The aggregated demand is determined by output price of wood pulp, input price of pulpwood, input price of ships and residues, capital, input ratio of softwood to hardwood, and level of net pulpwood exports. The supply is a function of inventory, time preference, nontimber income, price of pine pulpwood stumpage, price of pine sawtimber stumpage, and intensity of southern pine beetle activity. A ridge regression form of three-stage least squares is used to deal with collinearity.

Instead, many scholars have used a reduced-form equation (RFE) to assess policy impacts. Lindsey et al. (2000) employ an RFE to assess the effects of the trade restrictions between Canada and US on the lumber market. Housing starts, Japanese gross domestic product (GDP), lagged housing starts, and previous year's lumber price determine the lumber price. Zhang (2001) combines an RFE with equilibrium displacement model to estimate the effects of the trade restrictions on lumber prices.

Although the econometric approach has been the most widely employed and played an important role in examining policy issues in the forest sector, most of the previous studies have paid little attention to energy use in the production of paper and allied products when they derived pulpwood demand. Energy use among US pulp, paper, and paperboard mills accounts for about 12% of all energy used in the domestic manufacturing sector and energy's share of production cost is 13% in the paper mills (NAF 2002, Brown and Zhang 2005a). In addition, previous studies often ignore recycled paper, an increasingly significant input for environmental reasons. The wastepaper utilization accounts for 42% for newsprint, 10% for printing/writing paper, 60% for tissue paper, and 15% for packaging paper (Brown and Zhang 2005a). Moreover, most previous studies have small samples covering only 20-30 annual observations. The small observations with time series data might cause the coefficients of a simultaneous system of equations (SSE) to be sensitive to specification and even inconsistency (Wooldridge 2000).

Therefore, the second part of this study is to estimate pine pulpwood supply and demand using structural SSE approach in the Southern US because this approach has its own advantages. First, a structural SSE is a partial equilibrium model based on economic theory and variable choices make economic sense. Second, an advantage of a structural SSE over non structural vector autoregression (VAR) model is that it estimates multiple equations simultaneously and enables us to obtain the price elasticities in the short run. It is important to fully understand how different factors have influenced timber production and consumption.

2.3 Profit maximization model

Profit maximization model is widely used for forest industry (FI) (e.g., Adams and Haynes 1980, Brännlund et al. 1985, Newman 1987). For nonindustrial private forest (NIPF), there is some evidence to support profit maximization model (e.g., Adams and Haynes 1980, Brännlund et al. 1985, Newman 1987). By the definition of NIPF in the US, land owners of NIPF just do not operate wood-processing plants regardless of sizes of land tracts they own (Zhai and Harrison 2000). At the aggregated level, profit maximization is appropriate because many large-scale NIPF owners who mainly pursue profit from timber production make significant contribution to stumpage supply, although the number of these large-scale family forest owners is less than that of small-scale family forest owners in the US South.

While many studies estimate short-run supply price elasticities for stumpage market (e.g., Brännlund et al. 1985, Newman 1987, Carter 1992, Polyakov et al. 2004), few studies conduct research on supply elasticities for industry and NIPF timberlands separately (e.g. Adams and Haynes 1980, Haynes and Adams 1985, and Newman and Wear 1993).

Adams and Haynes (1980) estimate a combined pulpwood/sawtimber supply elasticity for FI and NIPF using an econometric analysis for the US Southeast and Southcentral respectively. The stumpage supply is determined by output price and inventory. It is clear that different species have different biological characteristics, which influence timber growing stock. In addition, the study has small samples covering only 20-30 annual observations. The small observations with time series data might cause the coefficients of a simultaneous system of equations (SSE) to be sensitive to its specification and even inconsistent (Wooldridge 2000).

Newman and Wear (1993) compare the production behavior of industrial and nonindustrial private forestland in the US Southeast using survey data. Profit maximization model is applied to the study as a restricted function of sawtimber and pulpwood, regeneration cost in the short run. The results indicate that both ownerships have the same behavior, which is consistent with profit-maximizing motivations. However, the study uses cross-sectional data, which might not pick up all the past dynamical variability between stumpage supply and price. Moreover, the study treats stumpage prices as exogenous variables, which might not have economic justification because prices would be endogenous at the forest sector in general.

The third part of this study is to estimate stumpage supply in the US South by comparing the production behavior between FI and NIPF. This study hypothesizes that NIPF owners' behavior is the same as industrial owners who pursue profit maximization. A two stage least squares (2SLS) method with time series data from 1953 to 2002 is developed to estimate the model.

Table 2.1 The selected empirical studies using econometric models

Authors	Variables	Data	Model	Scope of research
Sun and Zhang (2001)	NCREIF-T, TPI, TLP, L-FICP, M-FICP, SSPA, PNWSP, LUMBER, S&P500	1987-1997 (quarterly, 44 observations)	CAPM and APT	U.S.A.
Heikkinen and Kanto (2000)	TIMBER, HEX	1985-1995 (monthly, 123 obs)	CAPM and cointegration analysis	Finland
Heikkinen (2002)	TIMBER, HEX, BOND, DEPO	1988-1999 (monthly, 141 obs)	Cointegration analysis	Finland
Adams and Haynes (1980)	Stumpage: S=Ps, I D=Sl+Sp+Mp+F+LE	1966-1976 (annual, 11 observations)	Spatial equilibrium	U.S.A.
Brännlund et al. (1985)	S=Ps, Pm, W, Dummy D=Ps, Psw-w	1958-1979 (annual, 22 observations)	Structural econometrical	The northern Sweden
Newman (1987)	S= Psw, Ppp, I D= Psw, Fpp, Ppp, wsw, rsw, Ssw-1	1950-1980 (annual, 31 observations)	Structural econometrical	The US South
Hetemaeki and Kuuluvainen (1992)	S= P, Pt-1, I, V, R, Qt-1 D= P, Pt-1, W, C, Qt-1	1960-1988 (annual, 29 observations)	Structural econometrical	Finland
Carter (1992)	S=PP, PS, I, R, M, SPB, Qt-1 D=PP, T, PWP, PCR, C, NEXP	1964-1986 (annual, 23 obs.)	Structural econometrical	Texas
Newman and Wear (1993)	S=Psw, Ppp, RC	Cross sectional data in 1988 (132 Obs.)	Structural econometrical	The US Southeast

Note:
Variables are defined as follows:
CAPM: capital asset pricing model; APT: Arbitrage pricing theory.

NCREIF-T: timberland index; TPI: timberland performance index; TLP: timberland limited partnership; L-FICP: large forest industry company portfolio; M-FICP: medium forest industry company portfolio; SSPA: southern stumpage price average; PNWSP:

Pacific Northwest stumpage price average; LUMBER: lumber futures; S&P500: standard and poor 500 index.

TIMBER: six assortment timber price; HEX: Helsinki stock market index. BOND: a five years government bond; DEPO: one month Helibor to describe the deposit rate.

S: supply equation; D: demand equation; P: stumpage price; I: inventory; Stumpage demand is the sum of lumber, plywood, pulp products, miscellaneous products, fuelwood, and log exports; P1: lumber or plywood price; W: overrun factor; C: stump to car production cost; Ps: stumpage price; Y: per capita personal income.

Ps: sawtimber price; Pm: the price of pulpwood; W; the cutting cost; Dummy equals 0 if the total real subsidy is less than 30 million SEK or 1 otherwise; w: the wage rate in the sawmill industry; Psw: the world market price of sawn products. Psw-w is the ability to pay for sawtimber.

Psw: solidwood price; Ppp: pulpwood price; I: standing timber inventory; Fsw: producer price indexes for lumber; wsw: wages; rsw: user cost of capital.

P: pulpwood price; Pt-1:lagged pulpwood price; I: disposable income; V: allowable drain; R: bank lending rate; and Qt-1: lagged supply quantity. On the demand side, P: pulpwood price; Pt-1:lagged pulpwood price; W: wage rate; C: user cost; and Qt-1: lagged demand quantity.

PP: price of pine pulpwood stumpage; I: inventory; R: interest rates on short-term; M: nontimber income; SPB: intensity of southern pine beetle activity; PS: price of pine sawtimber stumpage; C: pulping capacity in Texas; T: time preference; PWP: wood pulp price index; PCR: input price of ships and residues, and NEXP: level of net pulpwood exports. Psw: solidwood price; Ppp: pulpwood price; RC: regeneration cost.

CHAPTER 3

FORESTRY-RELATED INVESTMENTS IN THE US: COINTEGRATION ANALYSIS AND CAPTIAL ASSET PRICING MODEL

3.1 Introduction

Currently, there are an estimated 749 million acres of forestland in the United States (Smith et al. 2004). Forestry-related investments include timberland, timber, and combination of timberland and timber. Timberland alone is defined as an asset because it is generally owned by landowners. Timber alone is purchased by loggers or wood dealers, whereas most of forest industrial firms (processors) own both timberland and timber. Non-forestry financial assets include farmland, real estate, S&P500, treasury bill, deposit, and gold.

It is generally believed that timberland provides an opportunity for portfolio diversification because of its relatively low correlations with other financial assets and low level of financial risk (e.g. Redmond and Cubbage 1988, Thomson 1989, Washburn and Binkley 1993, and Sun and Zhang 2001) (Figure 3.1, 3.2). The statement may coincide with the recent trends that a large portion of the most productive timberlands are sold to Timber Investment Management Organization (TIMO’s). Clutter et al. (2005) indicated that the TIMO’s largely act as fiduciaries for using timberland as an investment instrument. This might be true in the short run. However, in the long run, the diversified benefits might be overstated because forest-related assets may be influenced by other financial selections, whereas investments in the forestry-related assets may affect other financial instruments as well.

While many studies have examined the short-run relationships between timberland and other financial market instruments using capital asset pricing model (CAPM) (e.g. Redmond and Cubbage 1988, Thomson 1989, Washburn and Binkley 1993, and Sun and Zhang 2001), few studies on the long-run relationships among forestry-related investments and financial instruments have been conducted (Heikkinen and Kanto 2000, Heikkinen 2002). Recent developments in time series provide a tool to study the long-run relationships, i.e., cointegration between timberland and other financial assets and incorporate this information in a short-run market model. For example, Heikkinen and Kanto (2000) suggest that Finnish stumpage prices are cointegrated with stock prices. Further, Heikkinen (2002) shows that Finnish stumpage prices, bond, and deposit rates are co-integrated.

In order to gain a clearer understanding of the short and long run relationships among timberland return, timber and financial assets in the US, our empirical work employs both multivariate cointegration method (Johansen 1988, 1991) and CAPM, because both approaches have their own advantages. A vector autoregressive model (VAR) is developed as a complementary analysis because the VAR model does not impose an a *priori* theoretical structure, while allowing both short-run and long-run dynamical impacts of an endogenous variable and leading to vector error correction model (VECM). In contrast, a CAPM enables us to obtain the short run relationships between investment vehicles and market portfolio proxy S&P 500. The dual-track approach should draw more accurate and robust conclusions.

This study is intended to examine the short-run and long-run correlations among timberland return, timber market and financial market instruments in the United States. We begin with our data source, followed by models and empirical results. The chapter concludes with a discussion of the results at the end.

3.2 Data

Data sources are described and summarized in Table 3.1 — 3.2. Eight investment instruments or price indexes were selected for this study, in which two are forestry-related. Timberland index from the National Council of Real Estate Investment Fiduciaries (NCREIF-T) is chosen to represent institutional timberland investment. NCREIF-T is an index based on actual property performance and separates the total return into income and capital components. It is published quarterly by NCREIF-T Timberland Index and is available on the NCREIF website. It currently covers more than 75% of all institutionally managed timberlands (Binkley et al. 2003). The average volume-weighted stumpage price of southern pine pulpwood and sawtimber is chosen to represent timber market because 68% of the NCREIF-T index value is in the South. The data is available from Timber Mart-South. The deflator is the Producer Price Index used for the average price from the US Department of Commerce (1982=100).

The third portfolio is the total leased farmland index (Webb and Vendl 2006) because the returns in the index just reflect the return on the land and not the operation of that land. Since timberland and farmland are closely related, they may be influenced by each other. The fourth portfolio is National Property Index from NCREIF. The Index is accepted as a real estate measure. The fifth portfolio is the representative of the stock market index, reflecting returns of major financial assets. S&P500 is a composite indicator of the broad market, which is computed as quarterly averages from the monthly closing values of the S&P500 stock market index. The sixth portfolio is the U.S. 3-month Treasury bill rates. The seventh portfolio is the 3-month certificate of deposit rate. The last portfolio is gold price, which represents precious metals and may have an impact on the timber or timberland market (Sun and Zhang 2001). All data are quarterly and the time series covers the period from January 1992 to June 2006. Due to the data constraint of the leased farmland index from NCREIF, each series has only 58 observations.

3.3 Cointegration Analysis

3.3.1 Theoretical Framework

Following the Johansen multivariate co-integration method (Johansen 1988, 1991, Johansen and Juselius 1990), a VAR model for asset returns was as follows:

$$X_t = \Gamma_1 X_{t-1} + \ldots + \Gamma_k X_{t-k} + \varepsilon_t \tag{3.1}$$

where *X* is a vector of variables, *t* is time index, *k* is number of lags in the model, Γ is a matrix of parameter coefficients, and ε_t is a vector of error terms. If all variables are stationary, an unrestricted VAR system in level form could be employed, or if all variables are non-stationary, an unrestricted VAR system in first difference could be used. However, if all variables are nonstationary and cointegrated, the estimates obtained by the standard VAR model will be misspecified (Engle and Granger, 1987). To circumvent this problem, a VECM has been suggested (Harris 1995). Thus, it can be further reformulated into a vector error correction model as follows:

$$\Delta X_t = \Gamma_1 \Delta X_{t-1} + \ldots + \Gamma_k \Delta X_{t-k} + \Pi X_{t-1} + \varepsilon_t \quad (3.2)$$

where Γ is a matrix of parameter coefficients for short-term dynamics and Π is a matrix of parameter coefficients. $\Pi = \alpha\beta'$, where α can be interpreted as the speed of adjustment to equilibrium and β is a matrix of long-run coefficients. It is clear that all variables in first difference are stationary because all variables are unit root, or I(1). The series $\beta' X_t$ is required to be stationary. Although X_t is nonstationary, the existence of co-integrating relationships indicates that the linear combinations of $\beta' X_t$ are indeed stationary and thus the columns of β form r distinct cointegrating vectors. The rank of Π is equal to the number of co-integration vectors. Thus, cointegration tests are to find the number of r linearly independent columns in Π (Harris 1995, p.79). The concept of cointegration indicates the existence of a long-run equilibrium to which an economic system converges over time (Harris 1995). It can be seen that the VECM model restricts the long-run behavior of the endogenous variables to revert to their equilibrium through the error correction term to adjust disequilibrium, while allowing a change of short-run dynamics.

The modeling procedures are as follows: First, the stationarity property of individual series is examined by the Augmented Dickey-Fuller (ADF) test (Enders 1995, p.433) because the data used in this study are time-series and may not be stationary. In addition, the number of lags should be determined because the VAR model is sensitive to lag selection. Furthermore, the trace and maximum Eigenvalue tests are used to detect the number of cointegration vectors. After determining the cointegration rank, the restriction tests are applied to long-run exclusion and weak exogeneity. If there exist perfect integration among the variables, a multivariate test will be conducted by imposing restrictions on the cointegration vectors. Lastly, diagnostic tests are conducted to examine the statistical adequacy of the models. The tests include the tests of the normality, serial correction, and homoskedasticity for the residuals. Keep in mind, the minimum requirement for an appropriate VAR model is the selected model is free of serial correlation in diagnostic tests (Doornik and Hendry 1994). In the empirical estimation, EViews 5.1 is used.

3.3.2 Empirical Results

Before the implementation of cointegration analysis, we need to examine if individual variables are nonstationary and integrated to the same order. The Augmented Dickey-Fuller (ADF) test was employed and the lag length for the test was determined by the Akaike Information Criterion (AIC). The results of the ADF test are reported in Table 3.3. Stumpage price, S&P500, long-term government bond, and gold price are stationary. All other investment instruments are nonstationary and integrated of order one.

Another requirement is to determine the optimum lag length for the model. Three VAR systems were estimated; the first included timber alone (loggers or wood dealers) and other non-forestry financial instruments that consist of farmland return, real estate, stock index, treasury bill rates, certificate of deposit rate, and gold price. The second model consisted of timberland alone (forest landowners) and the same non-forestry financial instruments. The third included both timber and timberland (forest industry processors) and the same non-forestry financial instruments. A number of VAR lag selection criteria were employed in the estimation. They are Log Likelihood Ratio (LR), Final Prediction Error (FPE), Akaike Information Criterion (AIC), Schwarz Information Criterion (SC), and Hannan-Quinn information Criterion (HQ) (EViews 2004). For timber, LR, FPE, AIC, and HQ suggest two lags, but SC indicates one lag. For timberland, LR, FPE, and AIC conclude two lags, but SC and HQ suggest one lag. For both timber and timberland, LR, FPE, AIC, and HQ conclude two lags, but SC suggests one lag. The diagnostic tests were then conducted and lag lengths were set to two for timber, timberland, and both timber and timberland because the VAR satisfied the minimum requirement of no serial correlation. The results of diagnostic tests for three VAR systems are available by request from the authors. The tests indicate that the residuals were not normally distributed due to excess kurtosis. This result is similar to the findings in Finland (Heikkinen 2002). Gonzalo (1994) suggests that cointegration results appear robust to excess kurtosis. Therefore, the models are acceptable, although they have this minor problem.

Johansen's multivariate cointegration analyses are explored for each of the three forestry-related investments. Two types of tests, the trace statistic and maximum Eigenvalue statistic, were used to detect the number of cointegrating vectors, *r,* which is an indictor of the extent of integration among variables. The results of the analyses are presented in Table 3.4. Trace and maximum Eigenvalue tests show that the number of cointegration vectors is three for all three categories (timber, timberland, and both timber and timberland).

After determining the cointegration rank, the long-run exclusion tests are conducted for each financial instrument for three models. The null hypothesis states that an individual instrument can be excluded from the cointegration space. The tests are conducted by imposing restrictions on $\beta_{r,k}$ of the r-th cointegrating relation, i.e., H_0: $\beta_{r,k} = 0$, r=1, 2, 3 for timber, timberland, and for both timber and timberland models; k=1, …, 7 for timber and for timberland, but k=1, ..., 8 for both timber and timberland, representing the corresponding variable equation in the cointegrating space. The test results are presented in Table 3.5. The null hypotheses are rejected in all cases. Therefore, none of these variables can be left out from the cointegration space and each variable has a long-run relationship with other variables in the system.

Moreover, we need to examine if there are some leading or driving forces in the systems in the long-run. This can be tested by examining the weak exogeneity of each variable (Sanjuan and Gil 2001, Heikkinen 2002, Sun and Zhang 2006). Weak exogeneity means that a variable drives the system away from the long-run equilibrium errors, however, can not be affected by the other variables. In other word, the variable is dominant and plays a leading role in the system. The null hypothesis states that there is a weak exogenous variable. The weak exogeneity for each portfolio in each model was examined by placing restrictions on the adjustment coefficient, $\alpha_{k,r}$ of the r-th cointegrating relation in the k-th VEC equation. That is, H_0: $\alpha_{k,r}$=0, k=1, …, 7 for timber and for timberland, but k=1, ..., 8 for timber and timberland; r=1, 2, 3 for timber, timberland, and both timber and timberland models. The likelihood ratio statistics have a Chi-Square distribution and the degree of freedom is equal to the number of cointegrating vectors. The test results are presented in Table 3.6. For timber model, S&P500, government bond for 30 years, and gold price are weakly exogenous variables, which play leading roles in the model. For timberland, only S&P500 is weakly exogenous, whereas timberland, and SP500 are weakly exogenous for both timber and timberland model. The result for government bond is similar to the finding in Finland (Heikkinen 2002), although in most of the cases, no variable is weakly exogenous.

3.4 CAPM Model

3.4.1 Theoretical Framework

The capital asset pricing model is chosen in this study because it is a simple and robust method to estimate financial risk and market-wide effects, although it is not without critiques (Roll 1977, Ross 1978). Following the framework of Zhang and Hussain (2004), a CAPM model was specified as the following:

$$R_i = \alpha_i + \beta_i R_m + \varepsilon_i \tag{3.4}$$

where R_i is the rate of return for investment i(i=1, …, 8), R_m represents the rate of return on the market portfolio. Here the S&P 500 index was used as the market return index for U.S. and it is weak exogenous based on the weak exogeneity test in the previous section.

Note that five out of nine variables are found to be nonstationary, but they are cointegrated series in the VECM model. Therefore, all estimates with ordinary least squares (OLS) regression are consistent (Stock 1987).

Empirically, a seemingly unrelated regression equation (SURE) is applied to the CAPM model (Zeller 1962, Theil 1971) because the explanatory variables are the same for each of the eight instruments. Thus:

$$
\begin{aligned}
R_1 &= \alpha_1 + \beta_1 R_m + \varepsilon_1 \\
R_2 &= \alpha_2 + \beta_2 R_m + \varepsilon_2 \\
&\vdots \\
R_8 &= \alpha_8 + \beta_8 R_m + \varepsilon_8
\end{aligned} \tag{3.5}
$$

This system of equations can be used to estimate the CAPM model.

3.4.2 Empirical Results

Table 3.7 presents the regression results based on the equation (3.2) using seemingly unrelated regression equation (SURE). Except for farmland and national property index, all alpha coefficients are significantly different from zero at the 5% level. Only one out of eight beta coefficients are significant at the 5% level. It is deposit interest rate. The betas for all other assets are not significant. Generally, the betas are small in the magnitude, which reveals that these assets have lower risk compared with the market return. The result is consistent with the literature (e.g. Redmond and Cubbage 1988, Thomson 1989, Washburn and Binkley 1993, and Sun and Zhang 2001). The R^2 of the regression is generally low, which means that CAPM does not explain the return variation of those assets well. It also indicates that these assets might not have close relationship with S&P500 in the short run.

Conclusion and Discussion

Using capital asset pricing model and cointegration analysis, we examine the short-run and long-run correlations among timberland, timber market and non-forestry financial instruments in the US. The results of the cointegration analysis reveal that there might exist cointegrated relationships among timberland, timber price, and the non-forestry financial assets in the long run. In terms of the long run relationships, the results show that no financial instrument is excluded from the model systems and no driving variable is identified for timberland and for both timber and timberland models. The results of CAPM indicate that the eight investment vehicles, including timberland index, average softwood price, farmland, national property index, treasury bill rates, deposit interest rate, government bond, and gold price have lower risk and might not have close relationship with market portfolio proxy S&P 500 in the short run.

These findings contribute to the literature gap in three major aspects. First, a seemingly unrelated regression equation (SURE) is applied to the CAPM model so that the heteroscedasticity across equations and contemporaneous dependence of the disturbances are explicitly incorporated in the statistical tests (Collins and Dent 1984, Binder 1985). Second, the short and long run relationships among timberland return, timber, and financial assets are examined using both CAPM and multivariate cointegration method. The dual-track approach should draw more accurate and comprehensive conclusions. Third, diversified financial instruments provide risk-reducing benefits for the portfolio investors. This study uses eight financial instruments whereas previous studies have limited financial selections (e.g. Heikkinen and Kanto 2000, Heikkinen 2002).

The results may have policy and welfare implications. First, timber investors might consider portfolio strategy in both short-run and long run because although forestry-related investments and financial assets have no close relationships in the short run, they might have cointegrated relationships in the long run. Second, timberland investor or landowners might not only think about forestry-related investment markets but also other financial asset markets because any policy change in one market will potentially spill over onto the other markets and have welfare implications in the long run. Further research is needed to examine the long-run relationship among forestry-related assets and other non-forestry financial assets at regional level, considering the large variations in asset investments in the coterminous US.

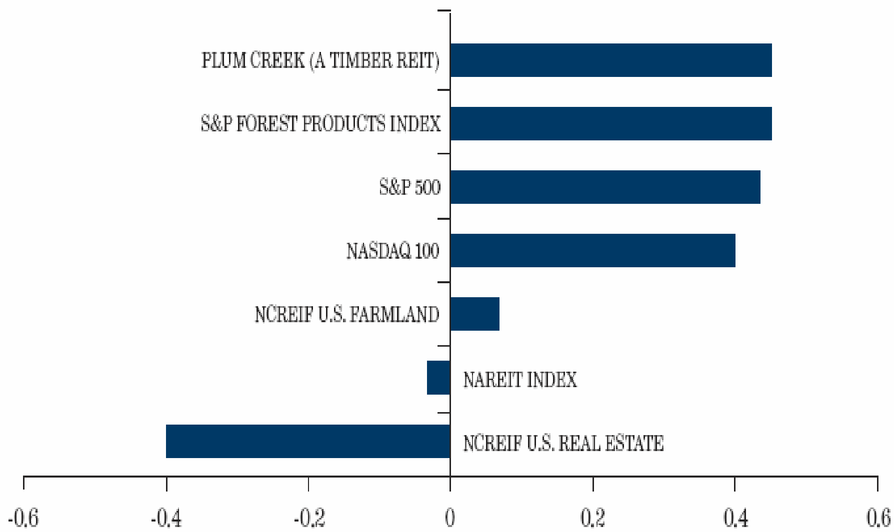

Figure 3.1 The correlations between US timberland and other assets
Source: Bank of America Corporation, 2005.

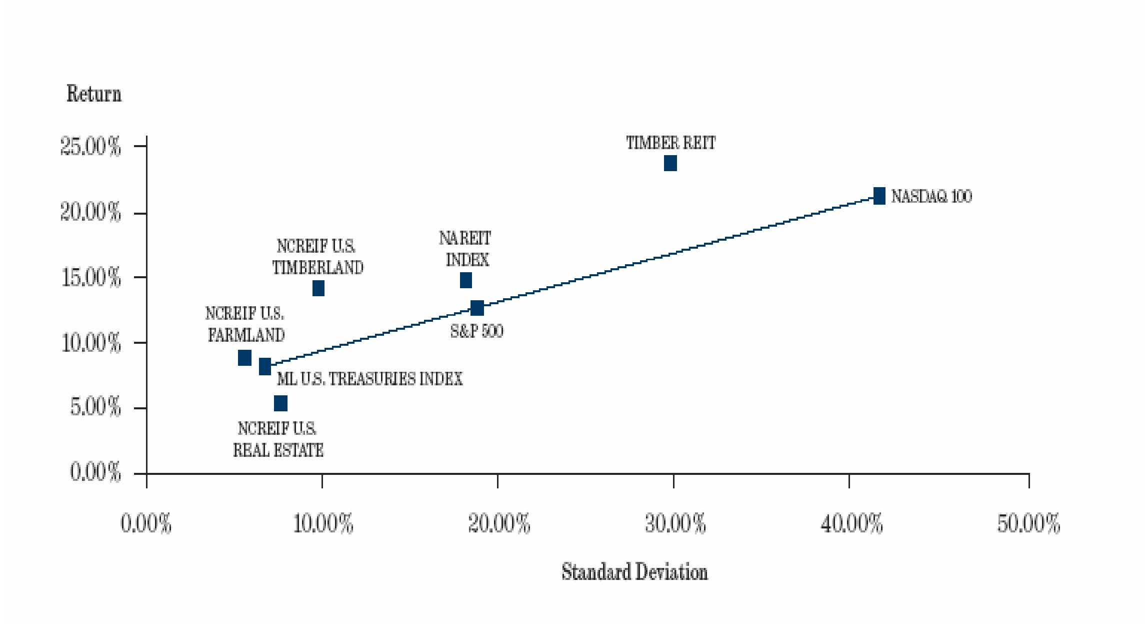

Figure 3.2 The risk profiles of various assets from 1990-2004
Source: Bank of America Corporation, 2005.

Table 3.1. Data description

Data	Abbreviation	Measurement	Source
NCREIF Timberland Index	NTI	%	For 1st quarter,1992-2nd quarter, 2006 from NCREIF
Softwood Price	SWP	%	For 1st quarter,1992-2nd quarter, 2006 from Timber Mart-South
Farmland Return	FR	%	For 1st quarter,1992-2nd quarter, 2006 from Webb and Vendl (2006)
National Property Index	NPI	%	For 1st quarter,1992-2nd quarter, 2006 from NCREIF
Standard & Poor's 500	S&P500	%	For 1st quarter,1992-2nd quarter, 2006 from Financial Forecast Center, LLC
Treasury Bill (3 month)	TB3M	%	For 1st quarter,1992-2nd quarter, 2006 from Financial Forecast Center, LLC
Certificate of Deposit Interest Rate (3 month)	CD3M	%	For 1st quarter,1992-2nd quarter, 2006 from Financial Forecast Center, LLC
Government Bond (30 years)	GB30Y	%	For 1st quarter,1992-2nd quarter, 2006 from Financial Forecast Center, LLC
Gold Price	GP	%	For 1st quarter,1992-2nd quarter, 2006 from Financial Forecast Center, LLC
U.S. Producer Price Index	PPI	1982=100	U.S. Bureau of Labor Statistics

Table 3.2. Data summary

Series	Mean	Std	Min	Max
NTI	2.97	4.24	-6.54	22.34
SWP	0.51	6.42	-11.68	17.13
FR	2.36	1.84	-0.24	11.33
NPI	2.32	1.53	-2.81	5.43
SP500	2.21	5.61	-15.66	12.81
TB3M	3.84	1.61	0.93	6.20
CD3M	4.12	1.72	1.05	6.63
GB30Y	6.00	0.98	4.48	7.96
GP	1.08	4.98	-6.68	14.20

Note: 58 observations from January 1992 to June 2006.

Table 3.3. Results of ADF unit-root tests

Series	Level	First Difference	Number of lags
NTI	-3.05	-7.96**	3
SWP	-4.86**		5
FR	-1.99	-8.79**	5
NPI	-2.41	-4.94**	2
SP500	-5.86**		0
TB3M	-2.76	-3.35*	6
CD3M	-3.02	-3.42*	2
GB30Y	-5.66**		3
GP	-5.53**		0

Note:

1. See Table 3.1 for definitions of the variables
2. ** and * denote rejection of null hypothesis of a unit root at 5% and 10% significant level.
3. The 5% and 10% critical values for the ADF including a constant and a linear trend are -3.50 and –3.18
4. The lag lengths were chosen on the basis of the Akaike information criteria.

Table 3.4. Trace and maximum Eigenvalue tests for cointegration rank

	Timber		Timberland		Timber & Timberland	
H_0	Trace	Max	Trace	Max	Trace	Max
r=0	211.55**	62.27**	203.89**	66.53**	267.45**	68.62**
r=1	149.28**	46.83**	137.36**	41.91	198.83**	58.92**
r=2	102.45**	43.50**	95.45*	39.91*	139.91**	49.65**
r=3	58.96	21.94	55.54	21.55	90.25	35.48
r=4	37.01	17.16	33.98	14.47	54.77	20.96
r=5	19.85	8.93	19.52	9.66	33.81	14.13
r=6	10.92	6.00	9.86	5.59	19.68	8.65
r=7	4.92	4.92	4.27	4.27	11.03	6.11
r=8					4.93	4.93
r	3	3	3	3	3	3

Note:

1. ** and * denote rejection of the hypothesis at the 5% and 10% levels

2. Two lags for timber, timberland, and both timber & timberland.

Table 3.5. Test results for long-run exclusion

Variable	Timber $\chi^2_{(3)}$ =7.81	Timberland $\chi^2_{(3)}$ =7.81	Timber & Timberland $\chi^2_{(3)}$ =7.81
SWP	15.51^{**}		6.58^{*}
NTI		15.78^{**}	11.71^{**}
FR	22.52^{**}	24.34^{**}	15.98^{**}
NPI	23.71^{**}	20.05^{**}	15.70^{**}
SP500	14.48^{**}	13.35^{**}	19.30^{**}
TB3M	32.43^{**}	36.7^{**}	21.82^{**}
CD3M	34.49^{**}	37.51^{**}	22.78^{**}
GB30	23.71^{**}	29.14^{**}	15.24^{**}
GP	27.17^{**}	34.63^{**}	24.71^{**}

Note: The likelihood ratio tests have a Chi-Square distribution and the degree of freedom is equal to the number of cointegrating vectors. ** and * indicate significant at the 5% and 10% levels.

Table 3.6. Likelihood ratio tests of weak exogeneity

Variable	Timber $\chi^2_{(3)}=7.81$	Timberland $\chi^2_{(3)}=7.81$	Timber & Timberland $\chi^2_{(3)}=7.81$
SWP	14.69**		17.06**
NTI		11.10**	5.09
FR	14.58**	11.91**	10.74**
NPI	10.86**	9.80**	14.98**
SP500	1.64	2.27	2.23
TB3M	15.68**	7.43*	21.84**
CD3M	18.49**	6.47*	21.86**
GB30	5.96	13.14**	7.68*
GP	3.14	10.84**	4.00

Note: The likelihood ratio tests have a Chi-Square distribution and the degree of freedom is equal to the number of cointegrating vectors. ** and * indicate significant at the 5% level and 10% level, respectively.

Table 3.7. Estimated results with CAPM using SURE

Asset	α		β (S&P500)		R^2
	Coefficient	t-ratio	Coefficient	t-ratio	
NTI	1.639	1.568	0.055	0.577	0.14
SWP	3.679	2.585**	0.163	1.260	0.30
FR	1.441	3.424**	0.029	0.765	0.26
NPI	2.128	5.275**	0.035	0.958	0.02
TB3M	3.683	8.809**	0.059	1.546	0.04
CD3M	3.873	8.655**	0.066	1.625*	0.04
GB30Y	5.913	23.065**	0.025	1.056	0.02
GP	1.194	0.917	-0.081	-0.680	0.03

Note:

1. See Table 3.1 for definitions of the variables
2. ** and * denote significant at the 5% and 10% levels
3. To save space, the coefficients for quarterly dummies are not list.

CHAPTER 4

MODELING PINE PULPWOOD SUPPLY AND DEMAND IN THE US SOUTH: STRUCTURAL SIMULTANEOUS SYSTEM OF EQUATIONS APPROACH

4.1 Introduction

More than 83% of softwood pulpwood production in the United States came from the South (Howard 2003, p.6) and some 72% of timberland in the South was owned by non-industrial private forest (NIPF) landowners in 2002 (Smith et al. 2004). These landowners supply stumpage to loggers or wood-dealers and paper processors produce final product combining processing inputs (such as capital and labor) with the log materials delivered by the loggers or wood-dealers. In 2004, 89 southern pulpmills were operating and pulping capacity of 125 thousand tons per day accounts for more than 70% of the Nation's total pulping capacity (Johnson and Steppleton 2004, p.7) (Figure 4.1, 4.2).

Understanding the characteristics of the stumpage market has been an important aspect in modeling exercises or forecast efforts, public policy and management plan. For example, Adams and Haynes (1980), Newman (1987), and Carter (1992) emphasize timber supply and demand issues and give insights into the determinants of quantity supplied and demanded, and price. Another example is that supply and demand elasticities of stumpage play significant roles in measuring welfare impacts (e.g., Li and Zhang 2006). Modeling the stumpage market is also useful for assessing the effects of cost-share and technical assistance on reforestation (e.g., Royer 1987, Hyberg and Holthausen 1989, Zhang and Pearse 1996, and Zhang and Flick 2001).

Timber market models are extensively used to estimate short-run elasticity for forest landowners (e.g., Brännlund et al. 1985, Newman 1987, Carter 1992); however, these studies have small samples covering only 20-30 annual observations. The small observations with time series data might cause the coefficients of a simultaneous system of equations (SSE) to be sensitive to its specification and even inconsistent (Wooldridge 2000). In addition, previous studies have paid little attention to energy used in the production of paper and allied products. Energy use among US pulp, paper, and paperboard mills accounts for about 12% of all energy used in the domestic manufacturing sector and shares production cost by 13% within the paper mills (NAF 2002, Brown and Zhang 2005). Moreover, previous studies often ignore recycled paper, which is an increasingly significant input for environment reasons. The wastepaper utilization accounts for 42% for newsprint, 10% for printing/writing paper, 60% for tissue paper, and 15% for packaging paper, respectively (Brown and Zhang 2005). Furthermore, most of previous studies do not examine time series stationarity and may have the problem of spurious residuals.

Therefore, this study is to estimate pine pulpwood supply and demand using structural SSE approach in the Southern US after cointegration analysis because this approach has its own advantages. First, a structural SSE is a partial equilibrium model based on economic theory. Second, an advantage of a structural SSE over non structural vector autoregression (VAR) model is that it estimates multiple equations simultaneously and enables us to obtain the price elasticities in the short run.

The chapter is organized as follows. First, the data sources are presented. Then, the theoretical models of pine pulpwood stumpage supply and demand are presented. Next, the empirical estimation using cointegration analysis and three-stage least squares (3SLS) followed by the regression results with interpretation. This study ends with summary and conclusion.

4.2 Data

Data sources are described in Table 4.1 — 4.2. Softwood stumpage is the total quantity of pine pulpwood of the 13 southern states covered by the Southeastern and Southern Forest Experiment Stations of the USDA Forest Service. The softwood roundwood imports from and exports to the region are ignored because both are relatively small quantities. The average volume-weighted stumpage prices of southern pine pulpwood and sawtimber for 1977-2002 are from Timber Mart-South and for 1950-1976 from Ulrich (1989). The US bank prime loan is used as the opportunity cost of capital (www.federalreserve.gov/releases/h15/data). The producer price index of the paper and allied products is employed as the final product price from the Bureau of Labor and Statistics (BLS). Wage rate is from the BLS. The producer price index of waste or recycled paper is also obtained from BLS, which serves as a proxy for the wastepaper price. Annual data for electricity is also taken from the BLS index for industrial electric power. Standing timber inventory for 1950-1985 is from Adams (1988) and for 1986-2002 from Smith et al (2002). The missing data is found based on the formula from Newman (1987). The formula is specified as the following: $v_t = v_{t-1} + [G^* - (S_t - S^*)$, where G^* is the average annual net growth between survey years and S^* is the average stumpage production between survey years. All data are annual and the time series cover the period from 1950 to 2002 (53 observations). The deflator is the Producer Price Index used for all prices from the US Department of Commerce (1982=100) and the Consumer Price Index is used for wage rate from the US BLS (1982=100).

4.3 Theoretical framework

Pricing and competition based on market forces can be used to characterize the softwood stumpage market. The market concentration is unlikely given that most NIPF and sawmills in the South are small-scale. Thus, the stumpage market is assumed to close to competitive.

Demand for stumpage derives from its use as a raw material in the production of paper and paperboard products. Paper and paperboard firms purchase the stumpage in the market along with other inputs (e.g. labor, capital) to provide their particular output. Following the early authors' frameworks (Newman 1987, Brown and Zhang 2005), the production function for a competitive firm *i* is assumed to be a twice continuously differentiable production function. Thus,

$$\mathrm{Q_{it}} = q_i(L_{it}, K_{it}, E_{it}, W_{it}, D_{it}) \tag{4.1}$$

where $i = 1,..., N$; t = annual observations (1950, …, 2002) for pulpwood; Q_{it} is the quantity of paper and paperboard production by firm *i* in period *t*; and L_{it}, K_{it}, E_{it}, W_{it}, and D_{it} are the quantities of labor, capital, energy, wastepaper, and raw material that firm *i* uses in period *t*.

The paper and paperboard products trade in national markets, and as such, the final good price (*FP*) is exogenous to the region. The profit function for firm *i* in period *t* is:

$$\text{Max}\ \pi_{\text{it}} = FP_{it} q_{it}(L_{it}, K_{it}, E_{it}, D_{it}) - w_{it}L_{it} - i_{it}K_{it} - e_{it}E_{it} - r_{it}W_{it} - PP_{it}D_{it} \qquad (4.2)$$

where w_{it}, i_{it}, e_{it}, r_{it}, and PP_{it} are for the particular industry, the respective prices of labor, capital, energy, recycled paper and pine pulpwood stumpage.

Applying Hotelling's lemma, the firm's derived demand for stumpage in period *t* is a function of market price and the prices of all inputs in production. The demand function for stumpage D_i is found by taking the first derivative of the profit function (Varian 1978, p.31). Thus,

$$\partial\pi_{\text{it}} / \partial PP_{it} = D_{it}(\underset{+}{FP_{it}}, \underset{?}{w_{it}}, \underset{?}{i_{it}}, \underset{?}{e_{it}}, \underset{?}{r_{it}}, \underset{-}{PP_{it}}) \qquad (4.3)$$

where the signs below the variables represent the expected effects on stumpage demand given an increase in output price or stumpage input costs. The signs for the wage, capital, and energy are uncertain because they depend on whether stumpage is a technical complement or substitute with other inputs (Newman 1987).

If all the firms in the southern region have the same production function and face the same input prices, the regional stumpage demand equation can be obtained by aggregating the N individual firm's demand functions. Thus,

$$\text{D}_{\text{t}}(\text{FP}_{\text{t}}, \text{w}_{\text{t}}, \text{i}_{\text{t}}, \text{e}_{\text{t}}, \text{r}_{\text{t}}, \text{PP}_{\text{t}}) = \sum_{i=1}^{N} D_{it}(FP_{it}, w_{it}, i_{it}, e_{it}, r_{it}, PP_{it}) \qquad (4.4)$$

This equation serves as the theoretical model for the analysis and shows that pulpwood demand depends on own price, paper price, wage rate, capital cost, energy use, and recycled paper.

The aggregated roundwood supply is assumed to be a function of the received price for roundwood and the harvesting costs suggested by Newman (1987). There are several reasons for the assumption. First, the diversified ownership and management structure of forestland in the South complicates the aggregation of individual roundwood supply functions as was done by Brännlund et al. (1985) and Kuuluvainen (1986). If owner-specific data is available, a complete production function specification is possible, although still problematic (Brännlund et al. 1985). Second, numerous factors influence the individuals output of roundwood such as multiple potential outputs (sawlog, pulp and paper log, poles). The amount of standing softwood pulpwood inventory serves as an inverse proxy for harvesting costs (Newman 1987). Pine sawtimber stumpage might influence the output of pine pulpwood suggested by Newman (1987). Thus, the supply specification is as the following:

$$\mathrm{S}_{\mathrm{jt}} = S_j(\underset{+}{PP_{jt}}, \underset{?}{SP_{jt}}, \underset{+}{v_{jt}}) \tag{4.5}$$

where *SP* is sawtimber stumpage price; *v* is inventory of pulpwood. The own price for the pulpwood supply function is positive while the sign on sawtimber price is uncertain. Timber inventory has a positive effect on the output because the marginal harvesting costs decrease as inventory increases. If all the forest owners in the region maintain the same production, the regional stumpage supply specification can be found by aggregating the N individual forest owner's production functions. Thus,

$$S_t(PP_t, SP_t, v_t) = \sum_{j=1}^{N} S_{jt}(PP_{jt}, SP_{jt}, v_{jt}) \tag{4.6}$$

The equation serves the theoretic model for this analysis and shows that the stumpage supply of pine pulpwood depends on own price, sawtimber price, and inventory.

Finally, a market clearing assumes that the quantity of supply and demand should be equal. Thus:

$$S_t(PP_t, SP_t, v_t) = D_t(FP_t, w_t, i_t, e_t, r_{it}, PP_t) \tag{4.7}$$

Keep in mind, transportation costs are assumed a relatively constant fraction of the stumpage price and do not affect the short-run supply and demand in the region.

4.4 Empirical Model and Results

Empirical analysis is adapted in two important ways. First, the dataset has to be examined because most of time series are nonstationary in the forest sector. If they are nonstationary, then a cointegration analysis can be conducted. Second, although they are nonstationary but cointegrated, all estimates with ordinary least squares (OLS) are consistent (Stock 1987). Therefore, a three stage least squares (3SLS) can be used to estimate economic structure for pulpwood market in the southern US or an ECM.

4.4.1 Cointegration Analysis

The modeling procedures are as follows: First, the stationarity property of individual series is examined by the Augmented Dickey-Fuller (ADF) test (Enders 1995, p.433) because the data used in this study are time-series and may not be stationary. In addition, the number of lags should be determined because the VAR model is sensitive to lag selection. Furthermore, the trace and maximum Eigenvalue tests are used to detect the number of cointegration vectors. After determining the cointegration rank, the restriction tests are applied to long-run exclusion and weak exogeneity. Finally, diagnostic tests are conducted to examine the statistical adequacy of the models. The tests include the tests of the normality, serial correction, and homoskedasticity for the residuals. Keep in mind, the minimum requirement for an appropriate VAR model is that the selected model is free of serial correlation in diagnostic tests (Doornik and Hendry 1994). In the empirical estimation, EViews 5.1 is used.

4.4.2 Empirical Results

Before the implementation of cointegration analysis, we need to examine if individual variables are nonstationary and integrated on the same order. The Augmented Dickey-Fuller (ADF) test was employed and the lag length for the test was determined by the Akaike Information Criterion (AIC). The results of the ADF test are reported in Table 4.3. All variables except for recycled paper and sawtimber price are nonstationary and integrated of order one.

Another requirement before the cointegration analysis is to determine the optimum lag length for the model. A VAR system was estimated, which includes quantity, pulpwood price, inventory, paper and allied products, wage rate, capital cost, and energy use. A number of VAR lag selection criteria were employed in the estimation. They are Log Likelihood Ratio (LR), Final Prediction Error (FPE), Akaike Information Criterion (AIC), Schwarz Information Criterion (SC), and Hannan-Quinn information Criterion (HQ) (EViews, 2004). Three lag is suggested for the VAR system. The results of diagnostic tests for the VAR system is available by request from the authors. The tests indicate that the residuals were not normally distributed due to excess kurtosis. This result is similar to the findings in Finland (Heikkinen 2002). Gonzalo (1994) suggests that cointegration results appear robust to excess kurtosis. Therefore, the models are acceptable, although they have this minor problem.

Johansen's multivariate cointegration analysis was explored for the system. Two types of tests, the trace statistic and maximum Eigenvalue statistic, were used to detect the number of cointegrating vectors, *r,* which is an indictor of the extent of integration among variables. The results of the analysis are presented in Table 4.4. The trace and maximum Eigenvalue tests show that the number of cointegration vectors is six for the system.

The role of these variables in the system was investigated by using weak exogeneity tests under the rank, r=6. Table 4.5 presents the test results, which clearly rejected the weak exogeneity hypothesis for all variables (pulpwood quantity, pulpwood price, inventory, paper and allied products, wage rate, capital cost, and energy use).

Moreover, the null hypothesis was tested by imposing restrictions on the long-run coefficients. The hypothesis states that an individual variable could be excluded from the system. The results show that the null hypothesis is rejected and all variables are included in the system (Table 4.6). As a result, in terms of the relationships in demand and supply for pulpwood, the economic structure of the model could not be identified in the long run as Toppinen (1998) did for Finnish sawlog market.

4.4.3 Three-stage Least Squares

Note that all the variables except sawtimber price and recycled paper are found to be nonstationary, but they are cointegrated series in the cointegration analysis. Therefore, all estimates with traditional regression are consistent.

The SSE model satisfies the order condition for identification because there are two endogenous variables (Dem and PP) and more than two excluded exogenous variables (PPI, w, i, r, e, t) in the demand equation. Likewise, there are two endogenous variables (SUP and PP) and more than two excluded exogenous variables (V and SP) in the supply equation. The SSE model was estimated with three-stage least squares (3SLS) because it is consistent and asymptotically more efficient than two-stage least squares (2SLS) in overidentified systems (Wooldridge 2000, p516). It is clear that ordinary least squares (OLS) is inconsistent for the SSE model. In the empirical estimation, EViews 5.1 is used.

4.4.4 Empirical Results

Both linear and log-linear forms are explored to estimate the SSE model. The log-log form results are reported here because it outperforms better than linear form in terms of coefficient significance. In addition, the logarithmic transformation can partly overcome exponential trends of these time series and the coefficients have an interpretation as elasticity. The White's tests indicate that no heteroscedasticity is present in the SSE model. Following the procedure from a special case of the White test (Wooldridge 2000, p. 260), we obtain the *F*-values (2.12 for the demand equations and 0.53 for the supply equations). Both of them are less than the value of $F_{2,50}$ distribution at the 5% level ($F_{2,50}$ =3.19), indicating we fail to reject homoskedasticity. The low values for the Durbin Watson (DW) statistic in the SSE model reveal a problem of serial correlation in the system. However, the statistical package in this study cannot correct the serial correlation for the system equations (Newman 1987). One treatment is suggested to calculate serial correlation-robust (SC) standard error, while keeping other results of the SSE model, following the framework of Newey-West (Wooldridge, 2000, p.395). However, the SC-robust standard errors may be poorly behaved when there is substantial serial correction and the sample size is small. In addition, the OLS used in the system can be very inefficient. Moreover, the method is inappropriate for 3SLS regression.

Table 4.6 presents the regression results for pine pulpwood supply and demand. Overall, the explanatory variables significantly explain the dependent variables because the R^2 values are high. All variables have the expected sign and seven out of nine variables are significant.

On the demand side, the own price elasticity is significantly negative at the 5% level, but very inelastic with an estimated value of 0.22. On contrary, the final good price (paper and allied products) is significantly positive with an elasticity of 0.37, unlike previous studies where the final good price is not significantly different from 0. After a careful examination, we find that some degree of complements exists between stumpage and capital, while stumpage and energy are technical substitute. Both of these coefficients are significant at the 5% level. However, neither labor shows significantly positive relationship with stumpage, nor recycled paper shows significantly negative relationship with stumpage.

On the supply side, the own price elasticity is significantly positive at the 1% level, but very inelastic with an estimated value of 0.35. The inventory elasticity is significantly positive at the 1% level and close to 1, which means that a 10% increase in the growing stock tends to increase pulpwood production by 8.9 %. The cross elasticity with pine sawtimber is significantly positive at the 5% level, but very small in magnitude at 0.11.

The estimated elasticities in this study can only be partially compared with previous studies because of difference in data sources, methodology, and regional focus. In this study, the price elasticities of softwood pulpwood demand and supply were found to be relatively small, but similar to those reported for the US South (e.g., Newman 1987, Carter 1992) (Table 4.7). The significant substitution between pulpwood stumpage and energy was found with elasticity of -0.35.

4.5 Concluding Remarks

The primary objective of the paper is to provide an up-to-date econometric analysis of pine pulpwood supply and demand in the South. To that end, a structural SSE model is developed and three-stage least squares regression techniques were used for that model. The results show that price elasticities of supply of and demand for pine pulpwood are relatively small, but similar to those reported for the US South (e.g. Newman 1987, Carter 1992). The results also show that the cross elasticity with pine sawtimber is significantly positive at the 5% level, but very small in magnitude at 0.11, which is consistent with the finding by Newman (1987). Finally, the significantly substitution between pulpwood stumpage and energy was found with elasticity -0.35.

The study makes two contributions to the U.S. timber supply and demand literature. First, a five-factor demand specification for pine pulpwood stumpage is employed, while previous studies often ignore recycled paper and energy uses. Second, on the supply side, the complementary role of sawtimber in pulpwood production for the US South is found to be similar in Sweden (Johansson and Lofgren), while it does not hold for Texas (Carter 1992).

The finding in this study may have implications on paper industry processors, landowners, and public policymakers. Paper industry processors should be aware that any policy change in increasing capital investment may result in demand increase for pulpwood. Landowners who pursue profits from pulpwood production may consider the complementary role of sawtimber because sawtimber generates more revenue than pulpwood. The apparent substitution between wood and energy use produces a possible dilemma for environmental policymakers. If a hypothetical environmental tax is imposed on industrial electricity use, it may increase natural resource consumption.

Further research is needed to examine pine pulpwood production by different ownerships so that a complete production function could be specified. In addition, the long-run relationship among the variables could be examined.

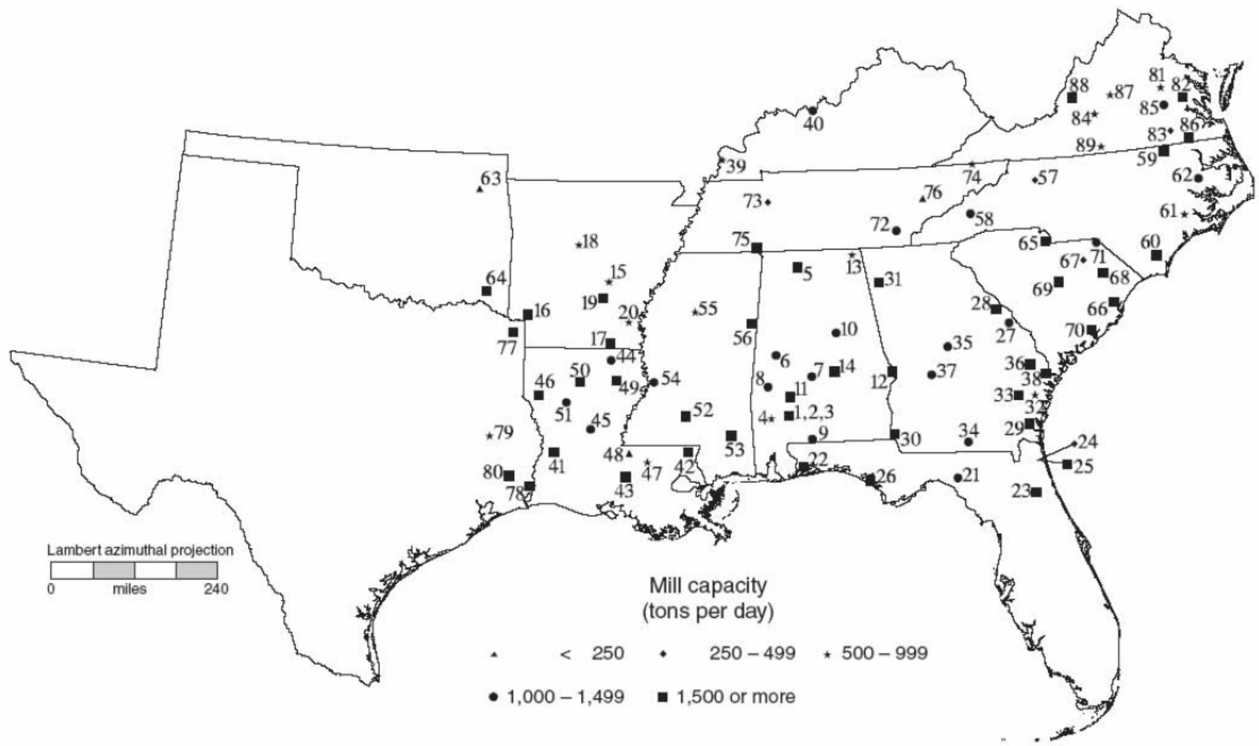

Figure 4.1 Mill capacities for softwood by states in the South, 2004

Source: Johnson and Steppleton 2004, p.7

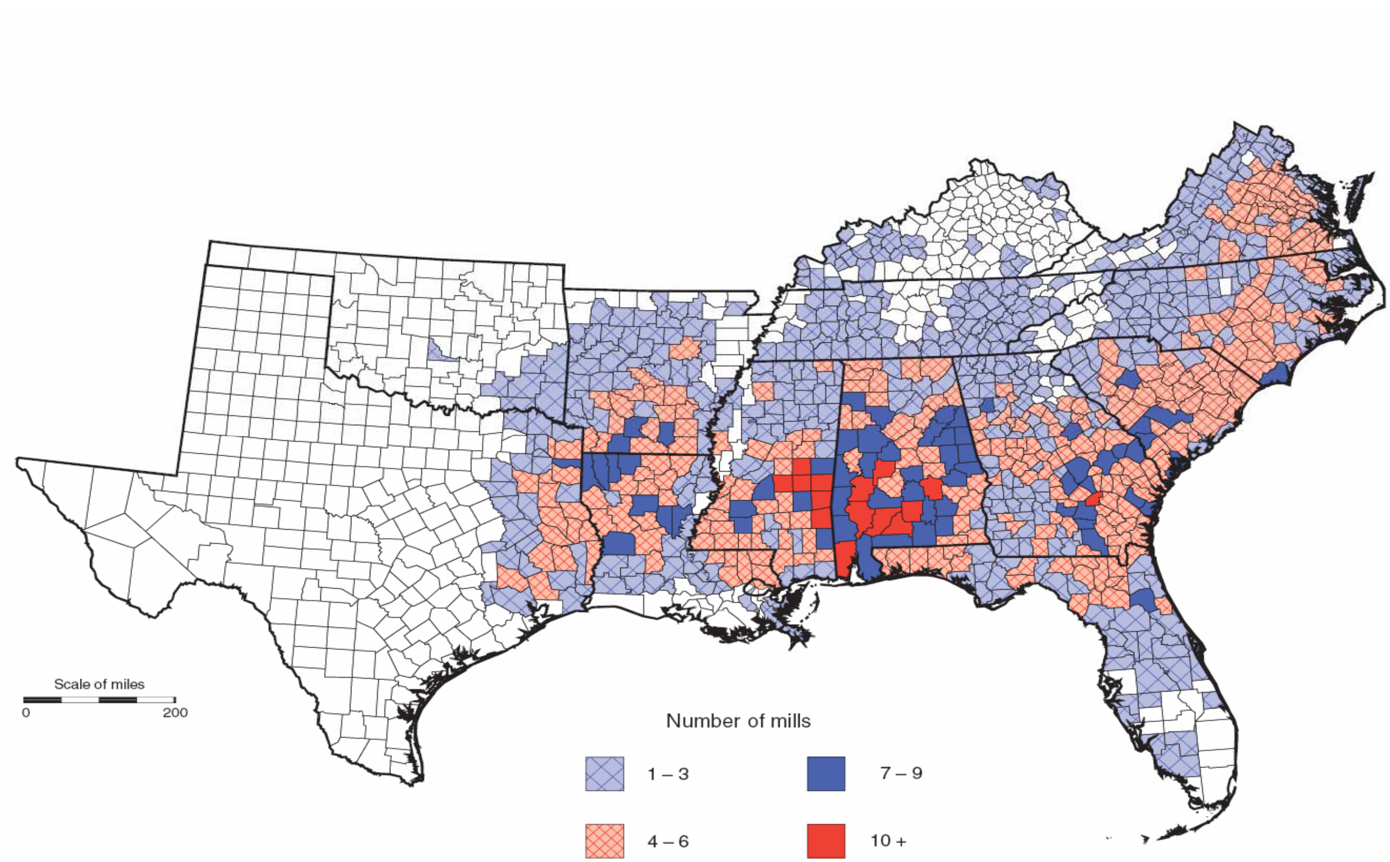

Figure 4.2 Numbers of mills for softwood by county in the South, 2004

Source: Johnson and Steppleton 2004, p.8

Table 4.1 Data description and sources

Variable (Abbreviation)	Measurement	Source
Pine pulpwood demand (DEM)	Thousand cord	Southern Forest Experiment Station
Pine pulpwood supply (SUP)	Thousand cord	Southern Forest Experiment Station
Stumpage price of pine pulpwood (PP)	US$/Standard cord	1977-1999 from Timber Mart-South, 1950-1976 from Ulrich (1989)
Stumpage price of pine sawtimber (SP)	US$/Thousand board feet (Scribner)	1977-1999 from Timber Mart-South, 1950-1976 from Ulrich (1989)
Paper and allied products (FP)	Index (1982=100)	US Bureau of Labor Statistics
Inventory (v)	Million cubic feet	1950-1985 from Adams et al (1988), 1986-2002 from Smith et al. (2002)
Wage rates (w)	U.S.$ per hour	US Bureau of Labor Statistics
Capital cost (i)	%	US Federal Reserve
Recycled paper (r)	Index (1982=100)	US Bureau of Labor Statistics
Energy (e)	Index (1982=100)	US Bureau of Labor Statistics
Technical change (t)	Integer	From 1 for 1950 to 53 for 2002
U.S. Consumer Price Index (CPI)	1982=100	US Bureau of Labor Statistics
U.S. Producer Price Index (PPI)	1982=100	US Bureau of Labor Statistics

Table 4.2. Data summary

Variable	Mean	Std	Min	Max
Pine pulpwood demand /supply	23760.66	6301.45	11190.00	34170.74
Pine pulpwood price	14.05	3.14	3.66	22.95
Inventory	43281.76	9092.48	26041.92	51354.04
Pine sawtimber price	141.00	42.91	85.44	243.97
Paper and allied products	76.72	46.26	23.70	159.00
Wage rate	8.79	1.27	5.79	10.29
Capital	7.29	3.43	2.07	18.87
Recycled paper	141.40	52.69	80.00	371.10
Energy	48.10	34.60	12.60	105.30
Technical change (t)	27.00	15.44	1.00	53.00

Table 4.3. Results of ADF unit-root tests

Series	Level	First Difference	Lags
Pine pulpwood demand (DEM)	-2.06	-7.35**	0
Stumpage price of pine pulpwood (PP)	-1.46	-5.42**	1
Paper and allied products (FP)	-1.46	-5.42**	1
Wage rates (w)	-2.57	-5.75**	2
Capital cost (i)	-0.98	-6.82**	2
Recycled paper (r)	-6.73**		1
Energy (e)	-2.03	-4.14**	3
Pine pulpwood supply (SUP)	-2.06	-7.35**	0
Inventory (v)	-0.76	-5.06**	1
Stumpage price of pine sawtimber (SP)	-4.54**		7

Note:

1. All variables are in log-form.
2. ** denotes rejection of null hypothesis of a unit root at 5% significant level.
3. The 5% and 10% critical values for the ADF including a constant and a linear trend are -3.50 and –3.18
4. The lag lengths were chosen on the basis of the Akaike information criteria.

Table 4.4. Trace and maximum Eigenvalue tests for cointegration rank

	VAR system			
H_0	Trace	5% critical value	Max	5% critical value
r=0	303.34**	125.62	98.47**	46.23
r=1	204.87**	95.75	69.74**	40.08
r=2	135.13**	69.82	45.13**	33.88
r=3	89.99**	47.86	36.17**	27.58
r=4	53.83**	29.80	30.34**	21.13
r=5	23.48**	15.49	23.11**	14.26
r=6	0.37	3.84	0.37	3.84
r	6			6

Note:

1.** denotes rejection of the hypothesis at the 5% level

2. Three lags for the VAR system (quantity, pulpwood price, inventory, paper and allied products, wage rate, capital cost, energy use).

Table 4.5. Test results for weak exogeneity and long-run exclusion

Variable	VAR for weak exogeneity $\chi^2_{(6)}$=12.59	VAR for long-run exclusion $\chi^2_{(6)}$=12.59
Pine pulpwood quantity	37.89**	51.99**
Stumpage price (PP)	43.45**	45.78**
Inventory (v)	21.87**	48.84**
Paper and allied products (FP)	42.49**	65.71**
Wage rates (w)	40.94**	53.06**
Capital cost (i)	44.80**	56.58**
Energy use (e)	38.21**	54.26**

Note:

1. The likelihood ratio tests have a Chi-Square distribution and the degree of freedom is equal to the number of cointegrating vectors.
2. ** indicates significant at the 5% level.

Table 4.6. 3SLS estimates of softwood pulpwood stumpage demand and supply for the US South, 1950-2002

	Demand		Supply	
Variable	Coefficient	Std. Error	Coefficient	Std. Error
Intercept	9.13	0.64**	-0.87	0.56
Pine pulpwood price	-0.22	0.11**	0.35	0.07**
Inventory			0.89	0.07**
Pine sawtimber price			0.11	0.05**
Paper and allied products	0.37	0.20**		
Wage rate	0.21	0.20		
Capital	0.27	0.06**		
Recycled paper	-0.04	0.05		
Energy	-0.35	0.10**		
Technical change	0.02	0.01**		
No. of observations	53		53	
Adjusted-R^2	0.92		0.93	

Note:

1. ** indicates significant at the 5% level
2. All variables are in logarithm form.

Table 4.7. Elasticity estimates from this study and other studies of the stumpage market for the US South

Equations and variables	This study	Newman (1987)	Carter (1992)	Polyakov et al. (2004)
Demand				
PP	-0.22**	-0.43*	-0.42**	-0.77**
FP	0.37**	0.12	0.05	
w	0.21	0.68**		
i	0.27**	-0.15**		
r	-0.04			
e	-0.35**			
t	0.02**			
Supply				
PP	0.35**	0.23**	0.59**	0.35**
v	0.89**	1.20**	3.60**	
SP	0.11**	0.08**	-0.07	

Note: ** and * denote significances at the 5% and 10% levels.

CHAPTER 5

DOES FORESTRY OWNERSHIP MATTER FOR STUMPAGE MARKET IN THE US SOUTH?

5.1 Introduction

Almost 25% of timber removal in the world came from the US (FAO 2005) and more than 62% of softwood roundwood products in the US were from the South in 2002 (Smith et al. 2004). In the US South, a large share of the regional softwood production (34%) came from the small share of forested area (17%) owned by forest industry (FI), while a share of the production (62%) from a much large share of forestlands (71%) held by nonindustrial private forest (NIPF) in 2002 (Smith et al. 2004). Understanding the difference in production behavior between FI and NIPF has been a concern in the forestry literature and an important aspect in public policy and management plan. For example, price elasticities of stumpage play significant roles in measuring market and economic impacts of Sustainable Forestry Initiative by American Forest and Paper Association on stumpage market in the U.S. South in 1994 (Brown and Zhang 2005b). Modeling the stumpage market is also useful for assessing the effects of public intervention attempting to improve NIPF output (e.g. Boyd and Hyde 1989, Hardie and Parks 1996).

While many studies estimated short-run supply price elasticities for stumpage market (e.g., Brännlund et al. 1985, Newman 1987, Carter 1992, Polyakov et al. 2004), few studies conduct research on supply elasticities for industry and NIPF timberlands separately (e.g. Adams and Haynes 1980, Haynes and Adams 1985, and Newman and Wear 1993). For example, Adams and Haynes (1980) estimated a combined pulpwood/sawtimber supply elasticity for FI and NIPF. It is clear that different species have different biological characteristics, which influence timber growing stock. In addition, the study has small samples covering only 20-30 annual observations. The small observations with time series data might cause the coefficients of a simultaneous system of equations (SSE) to be sensitive to its specification and even inconsistent (Wooldridge 2000). Although Newman and Wear (1993) gave the most recent supply elasticities for FI and NIPF, the study used cross-sectional data, which might not pick up all the past dynamical variability between stumpage supply and price. Moreover, the study treated stumpage prices as exogenous variables, which might not have economic justification because prices would be endogenous in the forest sector in general.

This study estimates stumpage supply in the US South by comparing the production behavior between FI and NIPF. This study hypothesizes that NIPF owners' behavior is the same as industrial owners who pursue profit maximization. A two stage least squares (2SLS) method with time series data from 1953 to 2002 is applied to estimate the model. The paper is organized as follows. First, the theoretical model of stumpage supply is presented. Then, the data sources are presented and the empirical estimation using 2SLS follows. Next, the regression results are interpreted. The study ends with summary and conclusion.

5.2 Data

Data sources are described in Table 5.1. Softwood stumpage is the total quantity of softwood timber from the US South. Softwood harvest on FI,and NIPF for 1953-2002 from Adams et al. (2006). The average volume-weighted stumpage price of softwood timber for 1977-2002 is from Howard (2003) and for 1950-1976 from Ulrich (1989). Standing timber inventory for 1953-2002 is from Adams et al. (2006). The data from Adams et al. (2006) combines pulpwood/sawtimber. Therefore, a ratio of sawtimber to pulpwood over time is estimated first, based on the removal and growing stock data from Smith et al. (2004). Then production and growing stock were allocated for sawtimber and pulpwood by the two ownerships, respectively. The missing data is found based on the formula from Newman (1987). The formula is specified as the following: $v_t = v_{t-1} + [G^* - (S_t - S^*)$, where G^* is the average annual net growth between survey years and S^* is the average stumpage production between survey years. All data are annual and the time series cover the period from 1953 to 2002 (50 observations). The deflator is the Producer Price Index used for all prices from the US Bureau of Labor Statistics (BLS) (1982=100).

5.3 Theoretical framework

The stumpage market is assumed to close to competitive because the market concentration is unlikely in the US South. An aggregate stumpage supply is derived from a profit maximization model, following the early authors' framework of Johansson and Löfgren (1985), and Brännlund et al. (1985). The present profit function can be defined as:

$$\pi_o^i(p_o^i, w_o^i, v_o^i) = \underset{Q^i, L^i}{Max}(p_o^i Q_o^i - w_o^i L_o^i \mid v_o^i) \quad (5.1)$$

where i = 1 for sawtimber and 2 for pulpwood, o = 1 for FI and 2 for NIPF, Q is the set of feasible cutting possibilities, *p* is the stumpage price, *w* is per unit harvesting cost, *L* is labor input, *v* is the inventory. Timber production is constrained by inventory. Assuming that the present profit function is convex in *p* and *w* and applying Hotelling's lemma, the firm's supply of the stumpage in period *t* is a function of market price and the prices of all inputs in production. The supply function is found by taking the first derivative of the profit function. Thus,

$$\frac{\partial \pi_o^i}{\partial p_o^i} = Q_o^i(p_o^i, w_o^i, v_o^i) \quad (5.2)$$

$$\frac{\partial \pi_o^i}{\partial w_o^i} = -L_o^i(p_o^i, w_o^i, v_o^i) \quad (5.3)$$

Because the data about harvesting cost is not available, the amount of growing stock serves as an inverse proxy for it, as suggested by Newman (1987). The reasoning behind is that growing stock is viewed as a measure of accumulated forestry capital adjusted through time by forest regeneration costs, forest growth, and timber cutting (Newman and Wear 1993). Thus, the supply specification is as the following:

$$\mathrm{Q}_{\mathrm{ojt}}^{\mathrm{i}} = Q_{ojt}^i(\underset{+}{p_{ojt}^i}, \underset{+}{v_{ojt}^i}) \quad (5.4)$$

The own price for the pulpwood has a positive effect on supply. Timber inventory has a positive effect on the output because the marginal harvesting costs decrease as inventory increases. If all the forest owners in the region maintain the same production, the regional stumpage supply specification can be found by aggregating the N individual forest owner's production functions. Thus,

$$Q_{ot}^{i}(p_{ot}^{i}, v_{ot}^{i}) = \sum_{j=1}^{N} Q_{ojt}^{i}(p_{ojt}^{i}, v_{ojt}^{i}) \tag{5.5}$$

The equation serves as a theoretic model for this analysis and shows that the stumpage supply depends on own price and inventory. Keep in mind, transportation costs are assumed a relatively constant fraction of the stumpage price and do not affect the short-run supply in the region as well.

5.4. Empirical Model and Results

5.4.1. Cointegration Analysis

The modeling procedures are as follows: First, the stationarity property of individual series is examined by the Augmented Dickey-Fuller (ADF) test (Enders 1995, p.433) because the data used in this study are time-series and may not be stationary. In addition, the number of lags should be determined because the VAR model is sensitive to lag selection. Furthermore, the trace and maximum Eigenvalue tests are used to detect the number of cointegration vectors. After determining the cointegration rank, the restriction tests are applied to long-run exclusion and weak exogeneity. Finally, diagnostic tests are conducted to examine statistical adequacy of the models. The tests include the tests of the normality, serial correction, and homoskedasticity for the residuals. Keep in mind, the minimum requirement for an appropriate VAR model is the selected model is free of serial correlation in diagnostic tests (Doornik and Hendry 1994). In the empirical estimation, EViews 5.1 is used.

5.4.2. Empirical Results

Before the implementation of cointegration analysis, we need to examine if individual variables are nonstationary and integrated to the same order. The Augmented Dickey-Fuller (ADF) test was employed and the lag length for the test was determined by the Akaike Information Criterion (AIC). The results of the ADF test are reported in Table 5.3. All inventory variables are nonstationary and integrated of order two, while supply for sawtimber for FI, supply for pulpwood for FI, supply for pulpwood for NIPF, paper and allied products, pulpwood stumpage price are nonstationary and integrated of order one. Other variables (supply for sawtimber for NIPF, sawtimber price, and lumber price) are stationary. Because they are integrated to different order, cointegration analysis could not be used in this study.

5.4.3. Two-stage Least Squares

In the empirical analysis, equation 5.5 is adapted in the following way. A two-stage least squares (2SLS) procedure is used to correct for endogenous bias in the stumpage supply model, because market price and output quantity may be determined jointly. The 2SLS approach includes a first stage regression, estimating how market price changes are influenced by economic variables.

Then predicted price values from this first stage regression are used in place of output price in the second stage. The two-stage empirical model is as follows:

Stage 1

$$\mathrm{p}^{\mathrm{i}}_{\mathrm{ot}} = \alpha^{i}_{o} + \beta^{i}_{o1} v^{i}_{ot} + \varphi Z^{i}_{ot} + \varepsilon^{i}_{ot} \tag{5.6}$$

Stage 2

$$\mathrm{Q}^{\mathrm{i}}_{\mathrm{ot}} = \alpha^{i}_{o} + \beta^{i}_{o1} v^{i}_{ot} + \varphi \hat{p}^{i}_{ot} + \varepsilon^{i}_{ot} \tag{5.7}$$

where Z^{i}_{ot} is an instrumental variable for stumpage price. $\hat{p}^{i}_{ot}$ is predicted values for market price at year t from first stage regression. Instrument choices show reasonable in this study. An instrument should be (a) correlated with the endogenous explanatory variable and (b) uncorrelated with the error term in the equation. We regress pulpwood stumpage price on paper and allied products price index (instrument variable) and other independent variables using a reduced-form. The results show that the instrument variable (IV) is correlated (coefficient =0.09) with pulpwood price at the 5% significant level (p-value=0.011) and R^2 is 0.73. Unfortunately, we cannot test (b) using the data because it is impossible to check the correlation between IV and the error term, which is not observable, but appealing by economic assumption (Wooldridge p463). Based on economic theory, final paper price do not have effect on pulpwood supply, which implicitly assume that there is no correlation between the IV and the error term. Likewise, we regress sawtimber stumpage price on lumber price (instrument variable) and other independent variables using a reduced-form. The results show that the instrument variable is correlated (coefficient =0.64) with pulpwood price at the 1% significant level (p-value=0.0001) and R^2 is 0.82.

5.4.4. Empirical Results

Linear and log-linear forms have been estimated by two stage least squares (2SLS). The linear form results are presented here because it outperforms better than log-linear form in terms of coefficient significant. Table 5.4 presents coefficients of the estimated profit maximization function for FI and NIPF. Overall, the R^2 values for all equations are high, which means the explanatory variables significantly explain the dependent variables. The coefficients have the expected sign and all of them are significant at the 5% or 10% levels for both FI and NIPF ownerships.

Our results show that all own prices are significantly positive at the 5% level, which is consistent with the literature in that an increased own price of sawtimber or pulpwood increases the supply of the assortment (e.g. Brännlund et al. 1985). Timber inventory variables are significantly positive at the 5% or 10% level, which is also consistent with the claims in the literature that the marginal harvesting costs decrease as inventory increases (e.g., Newman 1987). The positive cross-price effects between sawtimber and pulpwood for FI and between pulpwood and sawtimber for NIPF indicate that they are gross complement in the short run. However, the effects between pulpwood and sawtimber for FI and between sawtimber and pulpwood for NIPF are insignificant and excluded from the equations, which demonstrate that there is neither gross substitute nor complement in the short run. A possible explanation is that cross price has both substitute and joint production effects. The substitute effect will lead a shift from pulpwood to sawtimber, while joint effect indicates that an increase in final cuttings will increase both sawtimber and pulpwood supply (Brännlund et al. 1985, Newman 1987). Which effect is larger depends on empirical analysis.

To measure the impacts of the explanatory variables on stumpage supply, the elasticities are calculated at the mean of the variables (see table 5.5). The own price elasticities are generally high: 0.70 for sawtimber and 0.90 for pulpwood for FI owners, while they are low: 0.29 for sawtimber and 0.32 for pulpwood for NIPF owners. The respective elasticities are significantly different between the two ownerships; however, the result is consistent with those reported for the US South (Newman and Wear 1993). The possible explanation is that FI owners manage timberland exclusively for timber production, while NIPF owners who do not own wood processing facilities produce both timber and nontimber benefits. Pulpwood supply shows relatively more elastic responses to own price than sawtimber for both ownerships. The possible explanation is that pulpwood can be produced from growing stocks at almost any age whereas sawtimber can only be produced from larger trees at older stage (Newman and Wear 1993). Inventory elasticities for FI are higher than those for NIPF, which is consistent with the literature in that NIPF owners obtain nontimber benefits from the growing stock remaining in place while FI owners perceive financial profits from the timber.

The estimated elasticities in this study can only be partially compared with existing values in the literature because of difference in methodology, data sources and regional focus. Table 5.5 compares price and inventory elasticities from this study and other studies for the US South. For example, Adams and Haynes (1980) estimated a combined sawtimber/pulpwood supply elasticity for the southeast of 0.47 for FI and 0.39 for NIPF and the south-central of 0.47 for FI and 0.30 for NIPF. Only Newman and Wear (1993) estimated supply price elasticities for sawtimber (0.27 for FI and 0.22 for NIPF) and pulpwood (0.58 for FI and 0.33 for NIPF) in the Southeast separately. Few studies on supply price elasticities in the US South exist in the literature in terms of the two ownerships and the two timber categories.

5.5 Concluding Remarks

Using profit maximization model with time series data from 1953 to 2002, this study estimated stumpage supply for both forest industry and NIPF owners in the US South. The results show that supply price elasticities of 0.70 for sawtimber and 0.90 for pulpwood for FI owners are larger than those of 0.29 for sawtimber and 0.32 for pulpwood for NIPF owners, which in general are relatively larger than previous studies (e.g. Adams and Haynes 1980, Newman and Wear 1993). Pulpwood supply shows relatively more elastic responses to own price than sawtimber regardless of ownership.

This study makes two contributions to the US timber supply literature. First, a separated stumpage supply function for FI and NIPF is estimated, while most previous studies combined the two ownerships together. Second, a separated stumpage category (sawtimber and pulpwood) is employed while most previous studies did combine the two species together.

The finding suggests that profit maximization model is appropriate for NIPF owners at the aggregate level, although they are not able to respond to changing market conditions as strongly as FI owners. In addition, using previous small price elasticities for FI to measure market and economic impacts of Sustainable Forestry Initiative may cause biased welfare implication. Moreover, public efforts to improve NIPF output might not be efficient because NIPF owners have relatively less responses to market signal than FI owners. Further research is needed to examine landowner’s behavior at individual level.

Table 5.1. Data description and sources

Data	Abbreviation	Measurement	Source
Softwood supply (i=1 for sawtimber, i=2 for pulpwood; o=1 for FI and 2 for NIPF)	Q_o^i	MCF	Adams et al. 2006; Smith et al. 2004
Stumpage price of softwood	p_o^i	US$/MBF for sawtimber, US$/cord for pulpwood	For 1977-2002 from Howard (2003), for 1950-1976 from Ulrich (1989).
Lumber prices of southern pine	LP	US$/MBF	For 1977-2002 from Random Lengths, for 1953-1976 from Adams et al. 1988
Inventory	v_o^i	MCF	Adams et al. 2006; Smith et al. 2004
Paper and allied products	FP	Index (1982=100)	US Bureau of Labor Statistics
U.S. Producer Price Index	PPI	1982=100	US Bureau of Labor Statistics

Table 5.2. Data summary

Variables	Mean	Std	Min	Max
Softwood supply for sawtimber for FI	668.61	308.36	226.38	1096.09
Softwood supply for pulpwood for FI	673.27	225.31	341.52	1047.93
Softwood supply for sawtimber for NIPF	1292.82	383.13	736.15	1975.57
Softwood supply for pulpwood for NIPF	1337.01	199.12	926.86	1723.82
Sawtimber stumpage price	168.49	72.03	85.44	326.98
Pulpwood stumpage price	14.47	3.12	10.62	23.50
Lumber prices of southern pine	241.01	47.61	183.86	353.32
Sawtimber inventory for FI	9901.27	888.47	7973.02	10923.05
Pulpwood inventory for FI	12814.45	1786.28	8567.98	14952.19
Sawtimber inventory for NIPF	24629.09	6113.82	13742.42	31796.53
Pulpwood inventory for NIPF	32938.42	5041.95	22617.58	38324.38
Paper and allied products	79.76	45.87	28.00	159.00

Table 5.3. Results of ADF unit-root tests

Series	Level	First difference	Second difference	Lags
Softwood supply for sawtimber for FI	-2.82	-3.25*		1
Softwood supply for pulpwood for FI	-1.04	-6.15**		0
Softwood supply for sawtimber for NIPF	-3.54**			2
Softwood supply for pulpwood for NIPF	-3.06	-7.53**		2
Sawtimber stumpage price	-3.59**			10
Pulpwood stumpage price	-2.39	-5.43**		1
Lumber prices of southern pine	-4.01**			3
Sawtimber inventory for FI	-2.32	-2.71	-5.59**	1
Pulpwood inventory for FI	-2.24	-2.92	-6.99**	1
Sawtimber inventory for NIPF	-2.30	-1.69	-6.78**	7
Pulpwood inventory for NIPF	-2.00	-1.68	-6.70**	1
Paper and allied products	-2.25	-6.73**		0

Note:

1. See Table 5.1 for definitions of the variables
2. ** and * denote rejection of null hypothesis of a unit root at 5% and 10% significant levels.
3. The 5% and 10% critical values for the ADF including a constant and a linear trend are -3.50 and –3.18
4. The lag lengths were chosen on the basis of the Akaike information criteria.

Table 5.4. Estimates of coefficients for both FI and NIPF using profit maximization model

Variable	FI		NIPF	
	Sawtimber	Pulpwood	Sawtimber	Pulpwood
Constant	-745.02** (334.60)	-853.81** (118.98)	98.33 (108.56)	203.23* (111.07)
Inventory	0.05* (0.029)	0.07** (0.02)	0.03** (0.01)	0.02** (0.003)
Pulpwood price	28.60** (12.45)	42.03** (13.01)	a	29.70** (6.72)
Sawtimber price	2.80** (0.66)	a	2.23** (0.87)	0.66** (0.27)
Obs.	50	50	50	50
R-squared	0.70	0.74	0.79	0.85

Note:

1. ** and * indicate significances at 5% and 10% levels.
2. Numbers in parentheses denote standard error.
3. All variables are in level form.
4. a means the variable is not significant and dropped off from the model.

Table 5.5. Elasticities from this study and other studies of the stumpage market for the US South

Source	Region and timber type	Supply	Inventory
This study	Forest industry sawtimber (S)	0.70	0.79
	Forest industry pulpwood (S)	0.90	1.36
	NIPF sawtimber (S)	0.29	0.63
	NIPF pulpwood (S)	0.32	0.44
Adams and Haynes 1980	Forest industry stumpage (SC)	0.47	0.41
	Private stumpage (SC)	0.39	0.66
	Forest industry stumpage (SE)	0.47	0.49
	Private stumpage (SE)	0.30	0.72
Haynes and Adams 1985	Forest industry stumpage (SC)	0.63	1.00
	Private stumpage (SC)	0.17	1.00
	Forest industry stumpage (SE)	1.20	1.01
	Private stumpage (SE)	0.17	1.00
Newman and Wear 1993	Industry sawtimber in SE	0.27	
	Industry pulpwood in SE	0.58	
	NIPF sawtimber in SE	0.22	
	NIPF pulpwood in SE	0.33	

Note: S, the Southern United States; SC, South Central United States; SE, Southeast United States.

CHAPTER 6

CONCLUSIONS

This chapter summarizes the major findings of this study and some policy implications. Also, recommendations for further research are addressed in this chapter.

6.1. Summary of the empirical findings

Based upon the up-to-date data, a capital asset pricing model (CAPM) and cointegration analysis are employed to examine the short-run and long-run correlations between timberland return, timber market and non-forestry financial instruments in the United States. The results indicate that the eight investment vehicles, including timberland index, average softwood price, farmland, national property index, 3-month treasury bill rates, deposit interest rates, 30-year government bond, and gold price have lower risk and might not have close relationship with S&P 500 in the short run. However, the results of cointegration analysis reveal that there might exist cointegrated relationships between timberland return, timber price, and the non-forestry financial assets in the long run. In terms of the long run relationships, the results show that no financial instrument is excluded from the model systems and three driving variables are identified for timberland and for both timber and timberland models, but one for timberland. Therefore, investment should be low risk and low return, or high risk and high return in the long run, but it could be low risk and high return in the short run because short-run dynamics deviates from long-run equilibrium temporarily.

Considering that timberland investment is largely determined by stumpage market in forest sector, a structural simultaneous system of equations (SSE) model is used to examine the determinants of pine pulpwood supply and demand in the southern US using annual data from 1950 to 2002 with three-stage least squares (3SLS) regression techniques. The results show that price elasticities of supply of and demand for pine pulpwood are relatively small, but similar to previous studies for the US South. The results also show that the cross elasticity with pine sawtimber is significantly positive at the 5% level, but very small in magnitude at 0.11, which is consistent with the previous finding. Finally, the significantly substitution between pulpwood stumpage and energy use was found with elasticity -0.35.

The heterogeneous ownerships make the analysis of the stumpage market more complicated. Therefore, an econometric model is derived under the framework of profit maximization to investigate the short run price elasticities for stumpage market by comparing forest industry (FI) and non-industrial private forest (NIPF). A two-stage least squares (2SLS) techniques with time series data from 1953 to 2002 are employed in this study. The estimated results show that supply price elasticities of 0.70 for sawtimber and 0.90 for pulpwood for FI owners are larger than those of 0.29 for sawtimber and 0.32 for pulpwood for NIPF owners, which in general are within the price elasticity range from previous studies.

6.2. Policy implications

Given the current transaction trends, this study may have policy implications. First, timber investors might consider portfolio strategy in both short-run and long run because although forestry-related investments and financial asset have no close relationships in the short run, they might have cointegrated relationships in the long run. second, policy makers should be careful when changing any investment policy because any policy change in one market will potentially spillover the other markets and have welfare implications in the long run.

Furthermore, the finding in this study implicates that paper industry processors should be aware that any policy change in increasing capital investment may result in demand increase for pulpwood. For landowners who pursue profits from pulpwood production, they may consider the complementary role of sawtimber because sawtimber generates more revenue than pulpwood. For environmental policymakers, a possible dilemma could occur due to an apparent substitution between wood and energy use. If a hypothetical environmental tax is imposed on industrial electricity use, it may increase natural resource consumption.

Finally, this study suggests that profit maximization model is appropriate for NIPF owners at the aggregate level, although they are not able to respond to changing market conditions as strongly as FI owners. Keep in mind, using previous small price elasticities for FI to measure market and economic impacts of Sustainable Forestry Initiative may cause biased welfare implication. It should be cautions that public efforts to improve NIPF output might not efficient because NIPF owners have relatively less responses to market signal than FI owners.

6.3. Closing remarks and further research

From an economics perspective, the synthesis approach has created more accurate results and robust conclusions, which can make a valuable contribution to the literature gap in terms of timberland investment and stumpage market.

However, caution should be considered when making applications and implications of these results due to data and technical limitation. First, among the implications of the study for future work is the need for examining the long-run relationship among forestry-related assets and other non-forestry financial assets at regional level, considering the large variations in asset investments in the conterminous United States. In addition, the long-run relationship among the determinants of the softwood pulpwood demand and supply could be examined. Finally, further research is needed to investigate landowner's behavior at individual level.

Nevertheless, the results using the systematic approach provide important and broad insights into the estimation of timberland investment and stumpage market.

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