Economic Analysis of Institutional Timberland Ownership in the United States

by

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Abstract

The rise of institutional timberland ownership has led to a significant change in the structure and conduct of timber industry and forest management in the country. Understanding how industrial timberland sales affect the shareholder values of forest products firms, what factors influence landowners' harvest and reforestation activities, and if different ownerships have an impact on timber supply and silvicultural practices, is critical for developing policies to improve forest sustainability.

In the first study, we use an event study to investigate the impact of industrial timberland sales from 1997 to 2007 on shareholder values of major U.S. forest products firms. Cross-sectional regression analysis and the Capital Asset Pricing Model are used to examine factors influencing changes in market capitalization and systematic risk before and after the sales. The average cumulative abnormal rates of returns associated with timberland sales are found to be positive for all firms, and the resulting change in capitalization is related to these firms' total asset and debt. The systematic risk for these firms changed little or increased slightly after the timberland sales.

The second and third studies use USDA Forest Service Forest Inventory and Analysis (FIA) forest inventory data in nine southern states. In the second study, we use a two-period harvest choice model to explain the determinants of timber harvesting choices and estimate price elasticity of timber supply in response to market signal across different ownerships. We find that timber harvest choices are positively related to current timber value, stand volume, and net

growth volume, and negatively associated with future timber value, and squared terms of stand volume and net growth volume across four ownership categories (i.e., forest industry, TIMOs, REITs, and NIPF landowners). Also, institutional timberland owners have smaller timber supply elasticities for two forest products than forest industry and NIPF landowners.

In the third study, we apply a binomial logit model to investigate the impact of timberland ownership on reforestation effort. We find that the propensity to reforest is different across three ownership categories. The probability of reforestation is 0.83 for institutional owners, 0.80 for forest industry owners, and 0.69 for NIPF landowners. The results suggest that different timberland ownerships have an impact on reforestation activities and that the institutional timberland owners limited investment period of 8-15 years do not hinder their efforts with respect to reforestation and stewardship in forest management.

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List of Abbreviations

U.S.	United States
USDA	United States Department of Agriculture
FS	Forest Service
FIA	Forest Inventory and Analysis
NIPF	Non-industrial Private Forest
TIMOs	Timberland Investment Organizations
REITs	Real Estate Investment Trusts
OLS	Ordinary Least Squares
CAPM	Capital Asset Pricing Model
CRSP	Center for Research in Security Prices
CEDDS	Complete Economic and Demographic Data Source

Chapter 1. Introduction[1]

The United States (U.S.) is the largest producer and consumer of industrial roundwood in the world. Timber production in the southern U.S. has grown both in absolute terms and relative to other regions of the country since the 1970s. Over this period, the U.S. South has demonstrated a strong competitive advantage in producing timber (Wear et al. 2007). Today, the U.S. South produces about 17 percent of global industrial roundwood. Moreover, the South's forest production share of the United States is expected to increase in the coming decades as the Pacific Northwest mills encounter timber scarcity, higher timber costs, and higher wages (Zinkhan et al. 1992). Thus, the forest market in the Southern U.S. is critical in producing forest-based timber manufacture and providing forest-related aesthetic and ecological values. Yet, over the past decades, the U.S. South has experienced a significant change in timberland ownership with over 18 million acres of timberland changing hands (Clutter et al. 2007). Consequently, U.S. timber supply comes from four distinguished sources: (1) publicly-owned forests; (2) non-industrial private forests (NIPF); (3) industrial timberlands; and (4) institutional timberlands.

Institutional timberland investment in the U.S. and particularly the U.S. South has steadily increased while industrial timberland ownership has fallen sharply. Beginning in the mid-1970s, two separate forces have worked in favor of institutional timberland investment. First, some government laws (e.g., the 1974 federal Employee Retirement Income Security Act) encouraged institutional investors to diversify from their traditional investment reliance on fixed-

[1] This dissertation uses the official format required by the journal *Forest Science* (www.safnet.org/publications/forscience/index.cfm).

income securities such as government bonds (Binkley et al. 1996). Secondly, the stock market has undervalued industrial timberland holdings (Binkley et al. 1996). Thus, in the last decade, several large forest industry firms, including Georgia Pacific, International Paper Company, Temple-Inland, and Meadwestvaco, sold most of their timberlands.

As millions of acres of timberland have moved out of forest industrial ownership, a relatively and rapidly growing owner (i.e., institutional investors) is playing an increasingly important role in timberland investment. Whereas institutional investment in 1989 was under $1 billion, the total value and acreage of institutional investment in timberlands, especially through TIMOs (Timberland Investment Organizations) and REITs (Real Estate Investment Trusts), currently amounts to an estimate of $40 billion and 30 more million acres. The rise of institutional holdings in timberland has raised some concerns and questions regarding their impacts on forest management. The dissertation addresses the impact of institutional timberland ownership on timber supply and stewardship forest management.

The objectives in this dissertation are to (1) study the impact of industrial timberland sales on shareholder values of major forest products firms (i.e., the supply side of institutional timberland ownership), (2) examine the impact of timberland ownership on timber harvest in forest stands and estimate elasticity of timber supply associated with timberland ownership, and (3) reveal if ownership type has an impact on reforestation.

Understanding these aspects of institutional investment in timberland can firstly explain the supply side of institutional timberland ownership, that is, why these forest products firms sold their timberlands to institutional investors. Secondly, estimating landowners' harvest behavior and timber supply can increase our understanding of the timber market. Finally, exploring reforestation behaviors of different ownerships can shed some light on issues about forest sustainability. To analyze the impact of institutional timberland ownership on forest sector economy, the second study will employ financial and economic models of event study and capitalization analysis to explore whether or not industry timberland transaction with institutional investors provides benefit to forest products firms' shareholders, the second study will apply a two-period harvest approach to model timber harvest choice, and the third study will use a binomial logit model to investigate if the ownership has impact on silvicultural forest practice.

In Chapter 2, I examine how industrial timberland transactions with institutional entity influence the shareholder values of forest products firms in the short term. The increasing amount of timberland under institutional management is directly correlated with the decreasing amount of timberland under industrial timberland ownership in the U.S. Why were major vertically-integrated forest products firms not willing to hold on to their timberlands? Some researchers suggest that this is because these firms underperformed financially based on the Wall Street standard and had to sell their timberlands to secure better value for their shareholders (Binkley et al. 1996; Clutter et al. 2007). However, many recent studies conclude that industrial timberland ownership enhances forest products firms' financial performance and reduces their levels of risk (Yin et al. 1998; Nagubadi and Zhang 2005; Nagubadi and Zhang 2005; Li and Zhang 2007). Thus, it is unclear whether industrial timberland sales have increased the shareholder value of forest products firms in the short term.

In Chapter 3, I focus on timber supply from all timberland ownerships (i.e., forest industry, TIMOs, REITs, and NIPF landowners) in the U.S. South. A fundamental issue in forest economics is to explore how the supply for stumpage markets reacts to the price of timber. Supply price elasticity plays an important role in calculating the supply effects of policy and economic alternatives. However, it is unclear how institutional timberland owners respond to market signals. Some analysts hypothesize that institutional timberland owners may be apt to be more patient in their timber supply decisions because they do not need to meet hard annual cash flow targets as required by some industrial timberland owners. Thus the timber supply elasticity for institutional investors could be different from industrial and other non-industrial timberland owners. Consequently, estimate of supply elasticity is important to forecast the future timber market. However, no study has documented if, and to what extent, there are differences in timber supply elasticities across the four forest landowners. This study, therefore, is to take a look at the questions of harvest choices and elasticity of timber supply for stumpage markets in response to differential timberland ownership.

The third study in Chapter 4 is focused on the impact of timberland ownership on reforestation. I investigate what factors influence the probability of reforestation, and estimate the impact of timberland ownership on reforestation probability. Replanting following a clearcut harvest is the fundamental process of re-establishment of the forest to healthy and sustainable productivity which prospectively provides financial returns from timber revenues, potential carbon sequestration, and/or other scenic values and ecosystem services. Moreover, silvicultural management treatments can enhance the productivity and marketability of the lands. Given that reforestation is fundamental to sound forest management, it is critical to understand how the change of timberland ownership affects the behavior of replanting. Regarding the emerging class of timberland ownership, Rogers and Munn (2002) point out that consistent and intensive forest management may be more likely to be performed on institutional investment timberland. However, there have been few studies which explore the relationship between ownership types with respect to silvicultural activities and investigate the influence of differential ownerships on reforestation. The results would reveal the role of differential timberland ownerships in silvicultural practices and thus provide some insights on how to expand forest land area.

Chapter 2. An Event Analysis of Industrial Timberland Sales on Shareholder Values of Major U.S. Forest Products Firms [2]

Abstract

We used an event study to investigate the impact of industrial timberland sales from 1997 to 2007 on shareholder values of major U.S. forest products firms. Cross-sectional regression analysis and Capital Asset Pricing Model were used to examine factors influencing changes in market capitalization and systematic risk before and afterward. The average cumulative abnormal rates of returns associated the timberland sales were found to be positive for all firms, and the resulting change in capitalization was related to these firms' total asset and debt. The systematic risk for these firms changed little or increased slightly after the timberland sales.

[2] This chapter has been published in *Forest Policy and Economics*; the citation is: Sun, X. and D. Zhang. 2011. An event analysis of industrial timberland sales on shareholder values of major U.S. forest products firms. *Forest Policy and Economics* 13(5): 396-401.

1. Introduction

Forest products firms collectively owned some 70 million acres or 14 percent of timberland in the United States in the 1980s that contributed nearly 30 percent of timber supply in the country (Waddell et al. 1989). This industrial timberland ties large amounts of capital (Jones and Ohlmann 2008). As timberland became an established class of investment asset in the last decades, these firms have gradually divested their timberland. Most of the industrial timberland was sold to institutional investors who either hire Timberland Investment Management Organizations (TIMOs) to manage their lands or directly put their lands in Real Estate Investment Trusts (REITs). Between 1996 and 2009, some $28 billion of industrial timberland was sold, and $25.8 billion of them went to institutional investors (Figure1).

This change of industrial timberland ownership may be related to forest products firms' need to raise capital to pay off their debt incurred from mergers and acquisitions, the institutional investors' desire for portfolio diversification, and the tax advantage of institutional timberland ownership over industrial timberland ownership (Binkley 2007). Originally, forest products firms acquired timberland to control the supply of raw materials for their manufacturing plants. As focus of these firms was on manufacturing, it is argued that they might not be able to capture the true value of their timberlands for shareholders. Further, these firms as a group was underperform the market. For example, stockholder returns over the 10-year period from 1995 to 2005 averaged 6.2% for the "Forestry and Paper Group" as compared to 12.1% for the S&P 500 (Clutter et al. 2007). To enhance returns, these firms started to merge and acquire each other, which resulted in significant debt. To pay off debt, they began restructuring timberlands into separate holdings or divesting timberlands. This perhaps explains the supply side of industrial timberland sales in the last two decades. However, it is unclear, empirically, if industrial timberland sales indeed increased shareholder values and if industrial timberland sales have any long-term impacts on these firms' ability to raise capital.

The purpose of this paper is to investigate whether industrial timberland sales have increased the shareholder values in the short term and potentially changed the systematic risk of forest products firms in the long run. A few studies have looked at the impact of industrial timberland ownership restructuring (Zinkhan 1988) and public policy changes (Zhang and Binkley 1995; Boardman et al. 1997; Binkley and Zhang 1998). Other forestry studies use event analysis to examine mergers and acquisitions (Mei and Sun 2008), and forest products trade dispute (Zhang and Hussain 2004). This study differs from other investigations insofar as it looks into the short-term benefits (an increase in shareholder value) as well as possible long-term costs (an increase in the systematic risk) for U.S. forest products firms which have conducted major industrial timberland sales in the last decade. Our results show that industrial timberland sales bring short-term benefits, but do not increase the long-term costs for forest products firms.

2. Methodology

Event analysis provides evidence of market efficiency following an event in capital market research (Brown and Warner 1980; Fama 1991). It is based on the assumption that an abnormal return will occur if new information (an event) communicated to the market is useful. The methodology implicitly assumes that the event is exogenous with respect to the change in a firm's market rate of return (Rucker et al. 2005). By assuming that capital markets are sufficiently efficient to evaluate the impact of the event on expected future profits of forest products firms, we measure an abnormal rate of return to evaluate the impact of industrial timberland sale events, both announcements and actual sales, on shareholder values.

2.1. Event analysis

In this study, we use the market model that relates the rate of return of a given forest products firm to the overall market rate of return. Figure 2 shows the time line associated with an event. Rate of return is indexed in event time as τ. Defining τ =0 as the event date, $\tau = T_0$ to $\tau = T_1 - 1$ constitutes the estimation window that generally ends before the event, $\tau = T_1$ to $\tau = T_2$ represents the event window, and $\tau = T_2 + 1$ to $\tau = T_3$ represents the post-event window. Correspondingly, $L_1 = T_1 - T_0$, $L_2 = T_2 - T_1 + 1$, and $L_3 = T_3 - T_2$ define the length of the estimation window, the event window, and the post-event window respectively. Often, an event study is conducted using the five steps (MacKinlay 1997) described below.

2.1.1. Identifying events and defining event window

A few methods have been developed to identify specific width of event window. Here, a Chow test is used to determine the presence of structural break, where the estimated coefficient shows if there are different impacts between event days and nonevent days (Greene 2003). When this structural break corresponds to a discrete event, the Chow test is useful to investigate the variability of the rate of return surrounding an event. Unlike regulatory changes, there are no firm-to-firm correlations among industrial timberland sale events. Therefore, we could simultaneously conduct a Chow test along the time line for all timber sale events. The Chow test is a common application of *F* test mathematically expressed as follows:

[1] $$F = \frac{SSE_{all} - \left(SSE_{event} + SSE_{nonevent}\right)}{df(n)} \Bigg/ \frac{SSE_{event} + SSE_{nonevent}}{df(d)}$$

where SSE_{all}, SSE_{event}, and $SSE_{nonevent}$ are the estimated sum of squared errors on pooled nonevent and event days, event days, and nonevent days, respectively; $df(n)$and $df(d)$ are the numerator and denominator degrees of freedom, respectively. Consequently, alternative event windows are selected based on Chow test in this study: $[T_1, T_2]$.

To obtain efficient estimates, the estimation window (L_1) should be sufficiently long so that it is free from any effects related to the event of interest (MacKinlay 1997). We chose L_1 to be approximately 80 trading days prior to L_2 to reduce the impact of announcement events on parameter estimates of the sale events for specific forest products firms[3]. Finally, the post-event window (L_3) covering 100 and 150 days after L_2 is only used in risk analysis.

2.1.2. Estimating the parameters of the market model

A linear relationship is specified between the return rate of an individual firm (R_{it}) and the return rate of market portfolio each day (R_{mt}) (Campbell et al. 1997). It is assumed that asset rates of return are jointly normal and independently and identically distributed through time. Mathematically, this is expressed as follows:

[2] $$R_{it} = \alpha_i + \beta_i R_{mt} + \mu_{it}$$

where R_{it} is the rate of return for firm *i* on date *t*, calculated as $\ln\left[(P_{it} + DIV_{it}) / P_{i\,t-1}\right]$ with P_{it} equal to the *i*th firm close price on date *t*, $P_{i\,t-1}$ to *i*th firm close price on date *t*-1, and DIV_{it} to *i*th firm dividend on date *t*; R_{mt} is the rate of return on a value-weighted portfolio of all firms; μ_{it} is a random disturbance term, assumed to be normally distributed as $N(0,1)$; α_i and β_i are parameters to be estimated.

[3] There is little agreement in the literature regarding when the event window should start and how long the estimation period should last. Therefore, four trial estimation periods were used in preliminary test: 100 days, 150 days, 200 days, and 250 days before event window. Although the results from these four trial periods did not significantly differ from the result from 80 days, the magnitude of t value increases a little for cumulative abnormal rate of return of sale event when estimation period increases.

Generally, consistent estimators for the market-model parameters are obtained using ordinary least squares (OLS) procedures (Campbell et al. 1997). Given $E[\mu_i] = 0$ and $Var[\mu_i] = \sigma_i^2$, OLS is efficient (Greene 2003).

2.1.3. Predicting a normal return rate in the event window

Once the parameters in equation [2] are estimated, a normal return rate over L_2 can be predicted using

[3] $\hat{R}_i = \mathrm{X}^*{}_i \hat{\theta}_i$

where $\mathrm{X}^*{}_i$ is a matrix with a vector of ones in the first column and the vector of market rates of return $R^*{}_m$ over the event window in the second column and $\hat{\theta}_i = [\hat{\alpha}_i \ \hat{\beta}_i]'$ is the (2×1) parameter estimate vector.

2.1.4. Calculating the abnormal return rate over the event window

Using measured normal rate of return from Equation [3], the abnormal rate of return defined as the difference between the actual and normal rate of return can be measured as:

[4] $\hat{\mu}^*{}_i = R^*{}_i - \hat{R}_i = R^*{}_i - \mathrm{X}^*{}_i \hat{\theta}_i$

where $R^*{}_i$ is a vector of actual rates of return over L_2 for firm *i*. Conditional on the market rate of return over L_2, the abnormal rate of return is jointly distributed with a zero conditional mean and conditional variance with two parts. The first part is the variance due to the disturbances and the second part is the additional variance due to the sampling error in $\hat{\theta}_i$. As L_1 increases, the second term will approach zero. Hence, the expectation value of abnormal return rate across time is unbiased and asymptotically independent (Campbell et al. 1997).

2.1.5. Aggregating the abnormal rate of return and testing for statistical significance

As the abnormal rate of return is the actual return rate of an individual firm minus the rate of return that would be expected if the event did not take place, a nonzero significant abnormal security return rate would suggest that an event influenced the financial performance of individual firm over L_2. The sum of abnormal rates of return (CAR_i) is used to estimate the performance of $\overline{AR}_{L_2}$ (aggregated abnormal rate of return across all events) over a given L_2 (the length of the event window). The CAR_i starting at time T_1 through time T_2 for an individual firm i can be defined as:

[5a] $$CAR_i(T_1, T_2) = \sum_{T_1}^{T_2} \hat{\mu}^*{}_i \ ;$$

[5b] $$Var[CAR_i(T_1, T_2)] = \sigma^2(T_1, T_2) = L_2 \sigma^2_{\mu_i}$$

where CAR_i is normally distributed with mean 0 and variance $\sigma^2(T_1, T_2)$,

[5c] $$CAR_i \sim N(0, \sigma^2(T_1, T_2)).$$

If the event did not influence the rate of return for an individual firm, the expected value of CAR_i (Equation [5a]) should be zero, which implies $H_0\!: CAR_i = 0$ (MacKinlay 1997). Equation [5b] suggests that the longer L_2, the higher the variance of CAR_i.

An individual firm's abnormal rates of return can be aggregated using Equation [5a] for each L_2. Aggregating all abnormal rates of return over L_2 across all relevant events allows us to test if the aggregated abnormal rate of return $\overline{AR}_{L_2}$ over L_2 is equal to zero. Assuming there are no firm-to-firm correlations among all N individual events, the aggregated abnormal rate of return for L_2 is given by:

[5d] $$\overline{AR}_{L2} = \frac{\sum_{i=1}^{N} CAR_i}{N}.$$

Its variance can be expressed as:

[5e] $$Var(\overline{AR}_{L2}) = \frac{\sum_{i=1}^{N} Var[CAR_i(T_1, T_2)]}{N^2}.$$

Since CAR_i is normally distributed with mean 0, it follows that $\overline{AR}_{L_2}$ is normally distributed and we can test the null hypothesis H_0: $\overline{AR}_{L2} = 0$. A standard *t*-test can be used to detect the presence of abnormal performance:

[5f] $$t = \frac{\overline{AR}_{L2}}{\sqrt{Var\left(\overline{AR}_{L2}\right)}}.$$

The *t*- statistic tests the effect of major industrial timberland sales on shareholder wealth of forest products firms.

2.2. Capitalization analysis

The change in a firm's shareholder wealth due to industrial timberland sales is often associated with its financial characteristics (Mei and Sun 2008). We used a cross-sectional regression to analyze the market impact of abnormal rate of return and the characteristics of forest products firms. Our regression equation is

[6] $$AC_{iL_2} = \kappa_0 + \kappa_1 TIME_i + \kappa_2 TA_i + \kappa_3 TD_i + \varepsilon_i$$

where AC_{iL_2} is the average change in market capitalization per acre of timber sale in dollar for firm *i* over event window L_2, calculated as $\frac{CAR_{iL2} \times SHARE_{iL_2} \times P_{i0}}{SIZE_i}$ where CAR_{iL_2} is the sum of abnormal rates of return for firm *i* over event window L_2, $SHARE_{iL_2}$ is firm *i*'s number of outstanding shares over event window L_2, P_{i0} is the average closing firm price for 10 days prior to firm *i*'s event window, and $SIZE_i$ is firm *i*'s total acreage of transaction land for sale; ε_i is a disturbance term with mean zero; κ's are parameters to be estimated. *TIME* is the interval length in years between the event year and 1996 (e.g., *TIME*=1 for 1997 and 11 for 2007). TA_i is firm *i*'s total asset, a measure of firm size and TD_i is total debt, both in million dollars.

2.3. Risk Analysis

In this study we use the Capital Asset Pricing Model (CAPM) to study the possible long-term cost associated with industrial timberland sales. The application of CAPM implies that the expected rates of return of an event must be linearly related to the covariance of return rates of market portfolio (Jensen 1969). The mathematic expression of CAPM can be represented as:

[7a] $$R_{it} - R_{ft} = \alpha_i + \beta_i \left(R_{mt} - R_{ft}\right) + \mu_{it}$$

where R_{it} and R_{mt} are the realized rates of return on date *t* for firm *i* and the market portfolio *m*; R_{ft} is the rate of return on a risk-free asset on date *t*; μ_{it} is an error term that is normally and independently distributed with mean zero and constant variance; β_i is firm *i*'s beta representing systematic risk. β_i is a well-known measure of systematic risk for form i, whose rise and fall often influence the long-term cost of capital for firm i. Should the systematic risk of a forest products firm rise after it sells its timberlands, the cost of capital for the firm is likely to rise in the future. Thus, an increase in β_i indicates a likely increase in the long-term cost for the firm.

In this study, it is useful to compare the statistical estimates of systematic risk before and after industrial timberland sales for any given forest products firm. Thus, a dummy variable is introduced into Equation [7a]:

[7b] $$R_{it} - R_{ft} = \alpha_i + \beta_i\left(R_{mt} - R_{ft}\right) + \gamma_i D_i\left(R_{mt} - R_{ft}\right) + \mu_{it}$$

where D_i is set equal to 0 for the days before the sale events and 1 otherwise; γ_i is the parameter for the interaction term, capturing the difference for a firm *i* after industrial timberland sale events.

3. Data

In this study, the events of interest were major industrial timberland sales of more than $100 million from 1997 to 2007. Industrial timberland sales were collected from online newspaper databases (e.g., LexisNexis Academic), major daily news outlets (e.g., New York Times, Wall Street Journal), and news releases from major forest products firms. For each event, there were six items collected: seller, buyer, event date, sale price in billion dollars, transaction land size in million acres, and a brief event description. The date of each event was based on the date of announcement by forest products firms, i.e., the first day the announcement appeared in the newspapers or company homepages.

For the event and risk regression analysis, daily historical closing prices on a firm were obtained from *Center for Research in Security Prices* (CRSP) and dividends were obtained from CRSP Distribution Array, indicating ordinary cash dividends, splits, and exchanges. Dividends were based on the record date, on which shareholders must register as holders of records on the firm transfer record of the firm in order to receive a particular distribution directly from the firm (Center for Research in Security Prices 2007). A value-weighted market portfolio index (NYSE + NASDAQ + AMEX) including dividend distribution was collected from CRSP database.

For the capitalization regression, the numbers of shares outstanding for each firm were obtained from CRSP. Total asset (*TA*) and total debt (*TD*) of each firm at fiscal year-end preceding industrial timberland sales were collected from the financial database COMPUSTAT.

Finally, for the risk analysis, the risk-free rate of return was measured by the secondary market rate of 3 month U.S. T-bills (Federal Reserve Bank 2006).

4. Results

We found 32 large (more than $100 million) industrial timberland sale events (Table 1). Eleven firms (i.e., Boise Cascade Corp., Georgia Pacific Corp., International Paper Co., Kimberly Clark Corp., Louisiana Pacific Corp., Meadwestvaco Corp., Potlatch Corp., Smurfit Stone Container Corp., Temple Inland Inc., Weyerhaeuser Co., and Willamette Industries Inc.) were included in eleven announcement events of industrial timberland sales and twenty-one sale events. Sale prices varied from $101 million to $5 billion and transaction land size ranged from 0.1 million acres to 6.8 million acres. The average time elapsed between the announcement and actual sale was 8.5 month. The publicly-traded shares of all firms included in this study were highly liquid.

The Chow test statistics for different event widths are presented in Table 2. For all the announcement and sale events as a group, the variation of abnormal rates of return was largest for the event period that covered the day of the event and one day after the event ($F = 6.42$, $p = 0.002$). The Chow tests show that all event windows that included the event day and up to 4 days after the day of the event (i.e., a 5-day event window) are significant. However, as the event window widened, the F value gradually decreased. The Chow test statistic was insignificant in other windows. For sale events, the Chow test statistics for testing the structural break was largest for event day plus one day after the event day (i.e., a 2-day event window) and also significant in a 3-day window (0, 2). Similarly, for the announcement events, the Chow test statistics was largest and significant at the 10% significance level only for a 2-day (0, 1) event window.

Therefore, a 2-day (0, 1) event window was selected for all three groups of events. Nonetheless, we report, in Table 3, the aggregated abnormal rates of return for each event group in three windows, (0, 1), (0, 2), and (0, 3). For all the 32 events as a group, the aggregated abnormal rate of return are significant at the 1% and range from 1.46% to 1.78%, with an average of 1.59%. For the 21 sale event group, the average cumulative abnormal rates of return are positive and significant at the 5% significance level or better, with an average of 1.3%. For the 11 announcement event group, the aggregated abnormal rates of return are statistically significant at the 10% significance level with an average value of 2.14%.

For the capitalization change analysis, we focused on all the 32 events and the 21 sale events only. We omitted the 11 announcement event group because none of the explanatory variables is significant. Our results are presented in Table 4. Since the regression was cross-sectional, White's heteroscedastic consistent standard errors were used in the evaluation. The model had a relatively good fit, given that the values of R^2 are 0.23 and 0.37, compared to values around 0.10 in previous studies (Mei and Sun 2008).

The parameter estimates for all 32 events and 21 sale events were comparable. *TIME, TA*, and *TD* contributed most to the variations of market impact of abnormal rates of return. Specifically, *TD* had a negative impact on capitalization change per transaction land acreage while *TA* had a positive contribution towards capitalization change. The coefficients for these variables were significant at 10% level or better. These results imply that firms with high levels of debt may not benefit much from timberland sales and large firms may benefit more from timberland sales.

For risk analysis, the systematic (beta) and unsystematic (gamma) risk of a firm before and after the announcement and sale events are reported in Table 5. The systematic risk for forest product firms that sold timberlands did not change much or increased slightly, indicating that the long-term cost associated with these sales are minimal.

5. Discussion

We found that industrial timberland sales have positive impacts on shareholder values of major U.S. forest products firms. In addition, the change in market capitalization per unit of land sale of these firms is positively related to their size and negatively to their total debt as well as the time of sales. Finally, the systematic risk of firms that sold their timberlands did not change much or only increased slightly.

The economic and policy implications of this study are three fold. First, since industrial timberland sales increase shareholder values and do not impose long-term cost of capital financing, it is logic that forest products firms have sold their timberlands in the first place. These results explain industrial timberland sales or the supply side of the institutional timberland ownership as we know of today. This indicates that the recent structural change in industrial timberland ownership is perhaps going to stay for a while.

Second, just because industrial timberland sales have all the benefits and little costs, a possible change in U.S. tax code that attempts to level the playing field in timber sales tax treatment between industrial and institutional timberland owners may not bring back large scale industrial timberland ownership in the United States. In the 2008 Farm Bill, U.S. Congress temporally changed the corporate tax code and given industrial timberland owners the same treatment as REITs and TIMOs. It was speculated that, this change, if made permanent, could help stabilize and possibly bring back the industrial timberland owners in the U.S. This study shows that changing tax code alone is unlikely to reshape the current mixture of industrial and institutional timberland ownership in the country. Weyerhaeuser Company, the last large industrial timberland owner in the U.S., announced in February of 2010 to convert itself to a REIT. Perhaps it does not see a permanent change in the corporate tax code coming any time soon. More likely, these vertically integrated forest products as an industrial organization is less efficient that two separate organizations (timberland owners and forest products manufacturers) that transact through markets.

Finally, as institutional timberland ownership has now reached a high level, it is time for researchers to study this class of timberland owners. Do institutional timberland owners behave similarly as forest products firms with respect to supplying timber and environmental goods? In most cases forest products firms that sold their timberland have retained a long-term timber supply agreement with buyers based on some kind of price index. Will these agreements distort timber markets or the supply of non-timber products? Further research in forest economics could look into these issues.

Table 1. Major industrial timberland sale events from 1997 to 2007.

N	CUSIP	Date	Seller	Event	Payment[1]	Size[2]
1	67622P10	2004-07-26	Boise Cascade Corp.	Sale	3700	2.3
2	37329810	1999-06-17	Georgia Pacific Corp.	Announcement	--	0.196
3	37329810	1999-12-16	Georgia Pacific Corp.	Sale	397	0.194
4	37329810	2000-07-20	Georgia Pacific Corp.	Sale	4000[3]	4.7
5	46014610	2001-02-15	International Paper Co.	Sale	500	0.265
6	46014610	2002-01-03	International Paper Co.	Sale	101	0.145
7	46014610	2003-03-28	International Paper Co.	Announcement	--	1.5
8	46014610	2004-11-09	International Paper Co.	Sale	250	1.1
9	46014610	2005-07-19	International Paper Co.	Announcement	--	6.8
10	46014610	2006-03-28	International Paper Co.	Sale	300	0.218
11	46014610	2006-04-04	International Paper Co.	Sale	1130	0.9
12	46014610	2006-04-04	International Paper Co.	Sale	5000	4.64
13	46014610	2006-04-11	International Paper Co.	Sale	137	0.275
14	49436810	1998-05-05	Kimberly Clark Corp.	Announcement	--	0.5
15	49436810	1999-10-01	Kimberly Clark Corp.	Sale	400	0.46
16	54634710	2002-05-09	Louisiana Pacific Corp.	Announcement	--	0.935
17	54634710	2003-07-10	Louisiana Pacific Corp.	Sale	285	0.465
18	58333410	2003-05-15	Meadwestvaco Corp.	Announcement	--	0.636
19	58333410	2003-10-01	Meadwestvaco Corp.	Sale	125.8	0.629
20	58333410	2007-01-31	Meadwestvaco Corp.	Announcement	--	0.3
21	58333410	2007-08-06	Meadwestvaco Corp.	Sale	400	0.323
22	73763010	2006-12-12	Potlatch Corp.[4]	Announcement	--	0.275
23	83272710	1999-07-30	Smurfit Stone Container Corp.	Sale	725	0.98
24	87986810	2007-02-26	Temple Inland Inc.	Announcement	--	1.8
25	87986810	2007-08-06	Temple Inland Inc.	Sale	2380	1.55
26	96216610	2002-01-16	Weyerhaeuser Co.	Sale	185	0.1
27	96216610	2003-03-11	Weyerhaeuser Co.	Sale	185	0.104
28	96216610	2003-05-21	Weyerhaeuser Co.	Announcement	--	0.344
29	96216610	2003-12-13	Weyerhaeuser Co.	Sale	140	0.16
30	96216610	2004-06-30	Weyerhaeuser Co.	Sale	404	0.304
31	96913310	1998-09-04	Willamette Industries Inc.	Announcement	--	0.117
32	96913310	1998-11-13	Willamette Industries Inc.	Sale	234	0.117

Table 2. Chow test for examining variability of the rate of return surrounding event for various window widths.

Days of window	*F* value	*df(n)*	*df(d)*	*p* statistic
All events (*N*=32)				
2 days: (0, 1)	6.42	2	2620	0.002
3 days: (0, 2)	3.67	2	2652	0.026
4 days: (0, 3)	2.99	2	2684	0.051
5 days: (0, 4)	2.36	2	2716	0.095
Sale events (*N*=21)				
2 days: (0, 1)	3.80	2	1718	0.022
3 days: (0, 2)	2.53	2	1739	0.080
4 days: (0, 3)	2.04	2	1760	0.130
Announcement events (*N*=11)				
2 days: (0, 1)	3.82	2	898	0.022
3 days: (0, 2)	2.01	2	909	0.135

Table 3. Average cumulative abnormal rates of return for *N* industrial timberland sale events as a group over an event window from 1997 to 2007.

Event window	Average cumulative abnormal rates of returns	*t* statistic
All events (*N*=32)		
2 days: (0, 1)	1.78%	3.50 [a]
3 days: (0, 2)	1.46%	3.04 [a]
4 days: (0, 3)	1.52%	3.08 [a]
Sale events (*N*=21)		
2 days: (0, 1)	1.40%	3.23 [a]
3 days: (0, 2)	1.08%	2.38 [b]
4 days: (0, 3)	1.41%	2.42 [b]
Announcement events (*N*=11)		
2 days: (0, 1)	2.51%	2.03 [c]
3 days: (0, 2)	2.18%	1.98 [c]
4 days: (0, 3)	1.74%	1.83 [c]

[a], [b], and [c] indicate significance at the 1%, 5%, and 10% levels, respectively.

Table 4. Capitalization changes associated with all events and sale events for all firms.

Variable	All events (N=32)		Sale events (N=21)	
	Coefficient	t-value	Coefficient	t-value
Constant	825.10	2.16 [b]	1193.26	3.33 [a]
TIME	-132.46	-2.62 [b]	-198.48	-3.01 [a]
TA	0.11	2.17 [b]	0.15	2.53 [b]
TD	-0.19	-1.98 [c]	-0.26	-2.31 [b]
R^2	0.23		0.37	
F-value	2.87 [c]		3.38 [b]	

[a], [b], and [c] indicate significance at the 1%, 5%, and 10% levels, respectively.

Table 5. A comparison of 32 forest products companies before and after the announcement using the Capital Asset Pricing Model using two alternative post-event windows (100, 150).

Company	Date	β_i		γ_i	
		100	150	100	150
Boise Cascade Corp.	2004-07-26	1.512 [a]	1.550 [a]	-0.038	-0.015
Georgia Pacific Corp.	1999-06-17	0.587 [b]	0.476 [b]	0.227 [c]	0.208 [b]
Georgia Pacific Corp.	1999-12-16	0.932 [a]	0.563 [a]	0.077	0.050
Georgia Pacific Corp.	2000-07-20	0.283	0.387 [a]	-0.076	-0.041
International Paper Co.	2001-02-15	0.808 [a]	0.732 [a]	-0.033	-0.027
International Paper Co.	2002-01-03	1.002 [a]	1.058 [a]	0.025	-0.054
International Paper Co.	2003-03-28	0.947 [a]	1.024 [a]	0.214 [c]	0.086
International Paper Co.	2004-11-09	0.975 [a]	1.052 [a]	-0.019	0.007
International Paper Co.	2005-07-19	1.110 [a]	1.255 [a]	-0.117 [c]	-0.155 [a]
International Paper Co.	2006-03-28	1.254 [a]	1.247 [a]	-0.002	-0.014
International Paper Co.	2006-04-04	1.225 [a]	1.264 [a]	-0.006	-0.013
International Paper Co.	2006-04-04	1.234 [a]	1.270 [a]	-0.022	-0.022
International Paper Co.	2006-04-11	1.225 [a]	1.264 [a]	-0.006	-0.013
Kimberly Clark Corp.	1998-05-05	1.000 [a]	0.915 [a]	-0.012	-0.025
Kimberly Clark Corp.	1999-10-01	0.600 [a]	0.487 [a]	-0.004	0.089
Louisiana Pacific Corp.	2002-05-09	1.210 [a]	1.434 [a]	0.076	0.022
Louisiana Pacific Corp.	2003-07-10	1.425 [a]	1.573 [a]	-0.015	-0.168
Meadwestvaco Corp.	2003-05-15	1.167 [a]	1.109 [a]	-0.151	-0.057
Meadwestvaco Corp.	2003-10-01	0.888 [a]	0.993 [a]	-0.180	-0.081
Meadwestvaco Corp.	2007-01-31	1.060 [a]	1.121 [a]	0.012	-0.007
Meadwestvaco Corp.	2007-08-06	1.183 [a]	1.186 [a]	0.037	0.068 [c]
Potlatch Corp.	2006-12-12	1.433 [a]	1.408 [a]	-0.035	0.008
Smurfit Stone Container Corp.	1999-07-30	0.711 [b]	0.531 [b]	0.121	0.175
Temple Inland Inc.	2007-02-26	0.938 [a]	1.096 [a]	0.067	0.047
Temple Inland Inc.	2007-08-06	1.216 [a]	1.200 [a]	0.070	0.296
Weyerhaeuser Co.	2002-01-16	1.039 [a]	1.113 [a]	-0.105	-0.213 [b]
Weyerhaeuser Co.	2003-03-11	1.041 [a]	1.214 [a]	0.070	-0.084
Weyerhaeuser Co.	2003-05-21	1.099 [a]	1.060 [a]	-0.196	-0.035
Weyerhaeuser Co.	2003-12-13	1.140 [a]	1.115 [a]	0.077	0.225 [b]
Weyerhaeuser Co.	2004-06-30	1.391 [a]	1.413 [a]	-0.263	-0.191 [b]
Willamette Industries Inc.	1998-09-04	0.950 [a]	0.970 [a]	-0.092	-0.060
Willamette Industries Inc.	1998-11-13	0.775 [a]	0.880 [a]	0.012	-0.057

[a], [b], and [c] indicate significance at the 1%, 5%, and 10% levels, respectively.

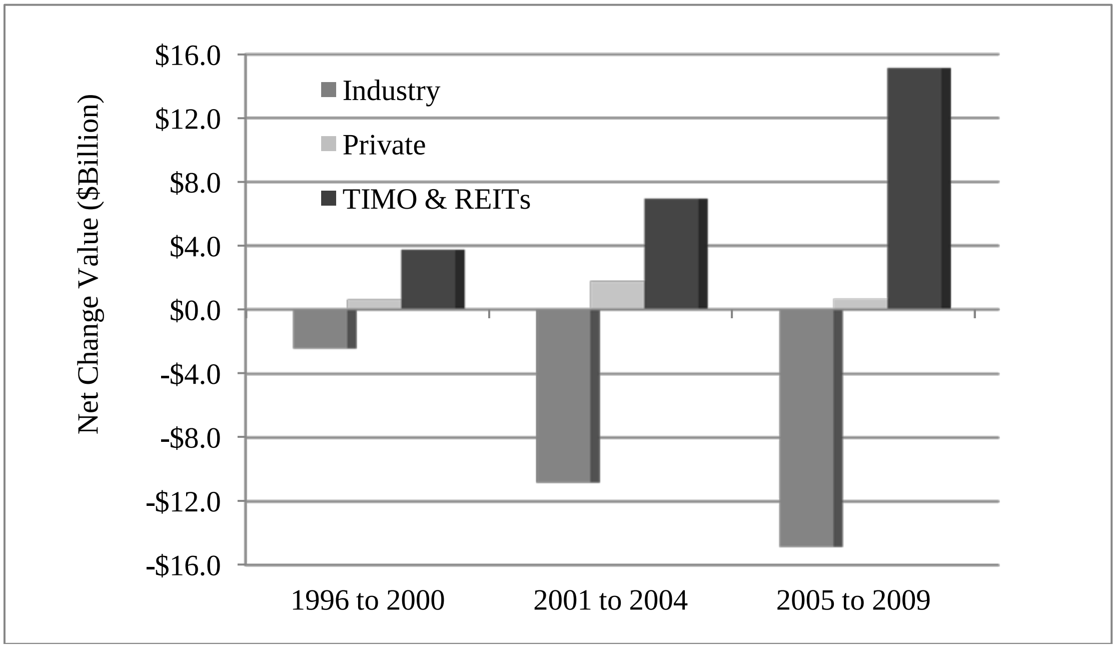

Figure 1. Net change of timberland value in different ownership types during three phases. Source: R&A Investment Forestry; RISI's Timberland Market Report; ForestWeb.

Chapter 3. Harvest Choices and Timber Supply Associated with Timberland Ownership in the Southern U.S.

Abstract

The rise of institutional timberland ownership has led to a significant change in the structure and conduct of the timber industry in the country. In this study, we apply a two-period harvest model to USDA Forest Service FIA forest inventories for nine southern states. Across timberland ownership categories, the probabilities of harvest choices were positively related to current timber value, stand volume, and artificially regenerated stands, and negatively related to expected future timber value, and squared terms of stand volume and net growth volume. Our results also conclude that institutional investors displayed less price-elastic behavior with respect to timber production, compared to both forest industry and NIPF landowners.

1. Introduction

Some principal limitations on timber supply projections have been a lack of information about how various factors are likely to influence the occurrence probability of a type of harvest in forest stands and how timber supply is responsive to market signals based on observed harvest behavior at the micro (forest stand) level. While many studies have investigated aggregate timber supply and individual binary harvest choices (i.e., no harvest and harvest) (Amacher et al. 2003; Wear and Parks 1994), there haven't been many studies on identifying a suitable harvest choice (i.e., no harvest, partial harvest, clearcut) and indicating timber supply on the observed plot at the stand level. Evaluating the response of stand timber supply to market signals through a landowner's harvesting choice on a given parcel of timberland is essentially important for elaborating the stand scheme on wood market.

Ownership type affects decision making and responses in economic terms (Amacher et al. 2003). Issues on harvest decision criteria and timber supply of industrial and nonindustrial owners have been widely studied since the late 1980s, and differences in these two ownerships have been explored in studies by Newman and Wear (1993) and Prestemon and Wear (2000). However, there has been no analysis of harvest behavior and timber supply projections for institutional timberland investors, partly because the rapid rise of this ownership class is a recent phenomenon and scholars haven't yet fully comprehended it.

The rise of institutional investment in timberland has triggered a significant change in the structure and conduct of the timber industry in the country. Some researchers suggest that the unprecedented change will have a long-lasting impact on sustainable forest practices and wood supply (Clutter et al. 2007; Luciw 2008). Since institutional forests would be separated from the mills and institutional behavior in timber harvesting would no longer be driven by the mills' demands, some conservationists assume that institutional owners might be inclined to be more patient in timber harvesting; however, others suspect the validity of this argument. Our motivation for addressing important unanswered questions concerning institutional timberland owners is to empirically provide the understanding of silvicultural forest treatments and timber supply estimates in observed stands managed by this new class of private forest owners in the U.S.

Investigating the impact of ownership change on silvicultural practices (e.g., partial harvest, clearcut) and timber supply has a considerable influence on forest-based manufacturing availability and forest-related aesthetic and ecological sustainability. We construct models that are specified to impose the economic theory of harvest choice on US Forest Service Forest Inventory Analysis (FIA) forest inventories for nine states in the southern United States to provide insights on management activities through remeasurement of plots. FIA forest inventories are the only comprehensive data on forest conditions in the U.S. and provide precise estimates of standing forest attributes (Polyakov et al. 2010). Therefore, through utilizing FIA forest inventory, the objective of this study is to explore the determinants of the probability of a type of harvest by timberland ownership, estimate the elasticity of timber supply at forest stand level in response to stumpage price changes, and compare the impact of ownership type on harvest behaviors at the stand level.

2. TIMOs vs. REITs

REITs (Real Estate Investment Trusts) are designed to reduce corporate income taxes for a corporate entity investing in real estate on behalf of various private investors and are required to distribute 90% of their taxable income back to the investors. Liquidity and tax efficiency are the most attractive REIT characteristics (Mendell et al. 2008). Publicly traded timber REITs have similar aspects on liquidity to traded forest industry C-corporations, which is relatively easy to move their capital into and out of timber REIT investment through stock exchanges on a daily basis, in comparison with direct buying and selling of timberlands. From a tax efficiency perspective, while traditional C-corporations paid 35% tax on all revenue before U.S. Congress temporally changed the corporate tax code, the 2008 Farm Bill gives industrial timberland owners the same treatment as REITs and TIMOs. REITs pay no income tax at the corporate level on earnings from timber activities, with taxes paid by individual shareholders on dividends. This gives REITs a clear advantage over C-corporations.

TIMOs (Timber Investment Management Organizations) manage forest lands in the U.S. on behalf of various institutional investors– not industry and not owned by families or individuals (Binkley 2007). TIMOs don't legally own the timberland, but are responsible for advising and arranging investment markets (e.g., pension plans, insurance companies, endowment and private equity funds) to own and for managing the timberland to achieve desired returns for the investors. Many TIMOs raise the money and invest in timberland for a specific period of time that are 8-15 years to operate the fund and then at the end of the time period to sell the asset (Binkley 2007). TIMOs have the same favorable tax treatment with REITs. Both of TIMOs and REITs may apply the portfolio theory regarding when and where to buy, hold, and sell timberland across region, forest type, and age classes.

3. Literature

Many researchers have investigated aspects of NIPF (Non-industrial Private Forest) landowner timber supply and the Faustmann Model has been widely used to explore the behavior of NIPF landowners (Amacher et al. 2003). Both forest industry and NIPF landowners exhibit behavior that is consistent with profit-maximizing motives (Newman and Wear 1993) although the behavior of NIPF landowners has been argued to be different than forest industry behavior due to the multi-objective nature of NIPF ownership. Generally, the regression models on estimating the behavior of timber harvest include a probit model (Boyd 1984; Dennis 1990; Prestemon and Wear 2000), a conditional logit model (Polyakov et al. 2010), a tobit model (Dennis 1989), a two-stage or three- stage least squares regression on aggregate data (Newman 1987; Liao and Zhang 2008).

Explanatory variables influencing the harvest probability usually include timber stand characteristics (e.g., species composition, region, track size), landowner demographics (e.g., education, organization membership, household income), government programs (e.g., cost sharing, technique service), and market factors (e.g., sawtimber price, pulpwood price, interest rate). An assumption regarding which explanatory variable effect dominates, especially market factors, has been an important empirical question and has evolved over time (Binkley 1981; Hultkrantz and Aronsson 1989; Hyberg and Holthausen 1989; Dennis 1990; Kuuluvainen et al. 1996). Early on, some studies (Binkley 1981; Boyd 1984) found that stumpage prices are significantly and positively related to harvest behavior. However, Dennis (1989) noted that stumpage price has an ambiguous effect on timber harvesting due to the opposing effect of substitution and income effects. Prestemon and Wear (2000) derived a two-period model of harvest choice originally from Max and Lehman (1988) and introduced the variable *Timber Value* to the model when stumpage price has less volatility in a short term. They concluded timber harvest probability was positively influenced by current timber value and negatively influenced by future timber value.

At the forest stand level, a supply elasticity of 7.73 was estimated for sawlog price index but it was not different than zero at the 10% significant level (Dennis 1989). Many studies have investigated aggregate supply responses to stumpage prices. Generally, NIPF owners have been weaker than forest industry owners (Adams and Haynes 1980; Liao and Zhang 2008; Newman and Wear 1993). Specifically, Prestemon and Wear (2000) and Polyakov et al. (2010) applied a two-period harvest choice model to FIA forest inventories. Prestemon and Wear (2000) found that own-price elasticities were 0.12 and 1.96 for NIPF owners and 0.66 and 7.62 for industry, respectively for pulpwood and sawtimber production. Estimation results of Polyakov et al. (2010) were 0.34 and 0.31 for softwood and hardwood sawtimber, and 0.062 and 0.025 for softwood and hardwood pulpwood supply. Estimates of own-price elasticities for aggregate supply in other literatures ranged from 0.27 to 1.20 for industry stumpage and from 0.22 to 0.39 for NIPF stumpage (Adams and Haynes 1980; Haynes and Adams 1985; Liao and Zhang 2008; Newman and Wear 1993).

As timberland transaction has taken place from traditional forest industry to institutional entities since the middle 1990s, no study has empirically examined the impact of institutional ownership on timber harvest and other forest management practices although there have been considerable interests regarding the role of institutional investment in forest sector. These are several studies examining the effect of financial aspects of timberlands on portfolio investment strategies of institutional owners (Rinehart 1985; Binkley et al. 1996). Rinehart (1985) and Binkley et al. (1996) used the Capital Asset Pricing Model and indicated that timberland provided some useful opportunities to diverse portfolios of institutional investment and timberland was an attractive investment for institutional entities. Additionally, Mendell et al. (2008) employed an event study to analyze the events of converting their corporate structure from traditional companies to REITs and suggested that REITs preferred to hold industrial timberlands rather than traditional C-corporation companies.

4. Methodology

We construct a two-period approach of harvest choice to analyze determinants of individual harvest choice and estimate elasticity of timber supply at the stand level for different ownership categories (i.e., industrial timberland owners, TIMOs, REITs, and NIPF landowners).

4.1. Theoretical model

Our theoretical model is based on a two-period approach of optimal harvest choice, which is originally developed by Max and Lehman (1988) based on Faustmann (1849) and Hartman (1976). The model has been used by Koskela (1989), Kuuluvainen (1990), Ovaskainen (1992), Prestemon and Wear (2000), and Polyakov et al. (2010). We assume that a representative landowner maximizes the present utility of consumption over two periods (the present vs. the future, labeled as i = 1, 2, respectively) represented by additive separable utility function U in present period in a general form as:

$$\max\ U = u(C_1) - \beta u(C_2) \quad (1)$$

where

$u(.)$ = a utility function of consumption across periods with a positive but diminishing rate

C_i = consumption in period i

β = $(1+\rho)^{-1}$ where ρ is a discount rate to indicate landowners' preference of timber value.

In what follows, P_i is stumpage price in period i, Q_i is used to denote the volume of timber removal or timber supply in period i, K_i is post-harvest (remaining) timber stock in period i. S is net savings for the first period (saving as S > 0 and borrowing as S < 0), and L represents a harvest cost function and is dependent on site variables Z. In the first period, the landowner's consumption is constrained by the revenue from timber sales minus net saving and cost for harvest. The second-period consumption is defined by the sum of timber revenue and past savings with the interest minus the second-period saving and harvest cost.

$$C_1 = P_1 Q_1 - S - L(Z)$$

$$C_2 = P_2 Q_2 + (1 + r)S - L(Z)$$

$$= P_2 Q_2 + (1 + r)[P_1 Q_1 - C_1 - L(Z)] - L(Z) \qquad (2)$$

where r is an interest rate. To define desirable removal volume of timber Q and post-harvest timber stock K, denote A as the exogenously given initial stock of timber and $g(K_1, Z)$ as the concave growth function of the standing stock of timber across the first period. Hence, the harvests for periods 1 and 2 (excluding corner solutions) are, respectively,

$$Q_1 \leq A$$

$$Q_2 \leq K_1 + g(K_1, Z) \qquad (3)$$

and the respective expression of the post-harvest stock is expressed as

$$K_1 = A - Q_1$$

$$K_2 = (A - Q_1) + g(A - Q_1, Z). \qquad (4)$$

Substitute Equations (2), (3) and (4) into (1).

The maximized discounted utility over the two periods becomes:

$$\max\ U = u(C_1) - \beta u\{P_2[(A - Q_1) + g(A - Q_1, Z)] + (1 + r)[P_1 Q_1 - C_1 - L(Z)] - L(Z)\}. \qquad (5)$$

The choice variables of this optimization problem are present consumption, harvest, and site factors. The first-order conditions for present consumption and harvest can be written as

$$U_{Q1} = \beta u'(C_2)\{(1 + r)P_1 - [1 + g'(A - Q_1, Z)]P_2\} = 0. \qquad (6)$$

Because we assume $u'(.) > 0$, the condition for optimal first-period harvest simplifies to

$$P_1 = [1 + g'(A - Q_1, Z)]P_2/(1 + r). \qquad (7)$$

At the optimal point, the left-hand side of Equation (7) represents the marginal revenue with respect to the present harvest and the right-hand side represents its marginal opportunity cost (the discounted value of the future harvest). Equation (7) can be utilized as a two-period model as long as the marginal revenue is greater than the marginal cost for the present harvest between the two periods. Note that, if non-timber value metrics were incorporated, which are typically associated with timber age or timber volume, into Equation (2), the optimal condition in Equation (7) will be a little more complicated. Nonetheless, the basic identity of revenue and cost holds (Polyakov et al. 2010).

4.2. Empirical model

4.2.1. Harvest choice

Linking Equation (7) of theoretical model to an empirical application of the two-period harvest choice model (Prestemon and Wear 2000) for sampled forest stands along with estimation of timber benefits, the objective of the discounted utility-maximizing landowner can be generally expressed as

$$\begin{aligned} Y &= P_1Q_1 - L(Z) + \Psi(Q_1, Z) - \beta E[P_2Q_2 - L(Z) + \Psi(Q_1, Z)] + \epsilon \\ &= f(\omega' x) + \epsilon \end{aligned} \tag{8}$$

where $\Psi(Q_1, Z)$ is the discounted residual value of the harvested stand. The variable Y suggests a set of explanatory variables that directly influence the harvest choice that is denoted as x and is estimated with a multinomial logit model. The dependent variable (Y_{ij}) is a set of neutrally exclusive binary choices (denoting the harvest choice as *i* and the ownership category as j), and is defined as:

$$Y_{1j} = \{1 \; if \; a \; partial \; harvest \; was \; conducted, 0 \; otherwise\}$$

$$Y_{2j} = \{1\ if\ a\ final\ harvest\ was\ conducted, 0\ otherwise\}$$

and

$$Y_{0j} = \{1\ if\ no\ harvest\ was\ conducted, 0\ otherwise\}.$$

A probability of harvest choice is estimated from the multinomial logit model:

$$PR(Y_{1j}) = \frac{e^{\omega_1' x}}{1+e^{\omega_1' x}+e^{\omega_2' x}},$$

$$PR(Y_{2j}) = \frac{e^{\omega_2' x}}{1+e^{\omega_1' x}+e^{\omega_2' x}},$$

and

$$PR(Y_{0j}) = \frac{1}{1+e^{\omega_1' x}+e^{\omega_2' x}}. \quad (9)$$

where ω_1 and ω_2 are the estimated parameters in each of harvest choice. Then, $\sum_{i=1}^{3} PR(Y_{ij}) = 1$. The log-likelihood for the multinomial logit model is generated by Newton's method:

$$\log L = \sum_{i=1}^{3} \sum_{j=1}^{n} d_{ij} \log PR(Y_{ij}) \quad (10)$$

where $d_{ij} = 1$ if $Y_{ij} = i$ and 0 otherwise.

The estimated coefficients in multinomial logit are difficult to explain since the coefficients for the *i*th choice are not directly tied to the other choices (Greene 2003), expressed as the following equation:

$$\ln \frac{P_{ij}}{P_{0j}} = \omega_i' x. \quad (11)$$

Thus, more attention is often paid on marginal effects, which represent a percent change in the dependent variable due to an incremental change in the respective independent variable. By differentiating Equation (9), the marginal effect of a variable, denoting as the variable *b*, on the probabilities is mathematically expressed as if there are *d* independent variables:

$$Marginal\ Effect = PR_b(\beta_b - \sum_{c=1}^{d-1} PR_c\, \beta_c) \quad (12)$$

where *c* indicates all other independent variables except *b*.

Empirical estimation of Equation (8) is conducted by using stand level data on harvest choices and correlated explanatory variables in this study. Systematic differences in the distribution of Y across stands might not meet the optimality properties of maximum likelihood estimation (Greene 2003). Previous studies find that different forest ownerships have different alternative rates of return (Newman and Wear 1993; Prestemon and Wear 2000) as they manage their forests for various production objectives, which reflects different market preferences among owners (Young and Reichenbach 1987; Pattanayak et al. 2002). This indicates that different ownership categories need to be analyzed through separate estimation models. Furthermore, as mentioned above, there are some different aspects of management operation and capital availability between TIMOs and REITs although they generally take the advantage of tax treatment. Hence, this study generates the four concerned ownership categories (i.e., forest industry, TIMOs, REITs, and NIPF landowners).

FIA forest inventory provides more observed variables with detail so that timber revenue and net growth volume terms can be involved in estimating harvest choice models to be empirically improved, theoretically based on Equation (5). All of sawtimber and pulpwood revenues, merchandise volumes, as well as net growth volumes are defined and applied to the estimation models. Separating revenues of timber stumpages can be used to examine the substitute or complementary relationship between two timber products. Furthermore, conditions of empirical estimation on the influences of sawtimber and pulpwood values would ensure the inclusion of all wood values, regardless of the timber product from which stumpage they originate (Prestemon and Wear 2000). Introducing stand merchandise volume and net growth volume, rather than stand age and site index, could provide more accurate and closer information on stand condition and structure, due to a 5-year cycle design on re-measurement of FIA plot.

In particular, Equation (8) is mathematically expressed as (denoting the ownership category as j, pulpwood as p, and sawtimber as s):

$$Y_j = \omega_{0j} + \omega_{1j}TimberValue_{p,1} + \omega_{2j}TimberValue_{s,1} + \omega_{3j}TimberValue_{p,2} + \omega_{4j}\,TimberValue_{s,2} + \omega_{5j}Volume_1 + \omega_{6j}Volume_1^2 + \omega_{7j}Growth_1 + \omega_{8j}Growth_1^2 + \omega_{9j}StandOrigin + \omega_{10j}CoastalPlain + \omega_{11j}Distance + \omega_{12j}Slope + \epsilon_j \quad (13)$$

where *Stand Origin*, representing a management class, is equal to one if the method of artificial regeneration for the trees was established in the stand condition and zero otherwise. *Distance* is equal to one if horizontal distance to improved road was less than or equal to 0.5 miles and zero otherwise, as well as *Coastal Plain* is a dummy variable and indicates whether the stand was sampled from coastal plain physiographic region or not. *Slope* engages in expressing the angle of slope of the stand condition. Additionally, for all sampled stands estimated in the model, three additional independent variables are defined as *Forest Industry*, *TIMOs*, and *REITs* that are equal to one, separately representing the timberland ownership, and zero otherwise. As described above, conditions of empirical estimation are imposed to meet the effects of pulpwood and sawtimber revenues to be equal: $\omega_{1j} = \omega_{2j}$, and $\omega_{3j} = \omega_{4j}$. Furthermore, Equation (8) suggests that $\beta_j\omega_{1j} = -\omega_{3j}$, and $\beta_j\omega_{2j} = -\omega_{4j}$, reminding that β_j is unknown and equal to $\left(1+\rho_j\right)^{-1}$ where ρ_j is a discount rate of return, applicable to each ownership category. Therefore, the discount rate of return for each ownership category, ρ_j, equal to $\beta_j^{-1/t} - 1$, where t is the number of years elapsed between two periods.

4.2.2. Elasticity of timber supply and hypothesis

The choice variables have different effects on the sensibility of the optimal harvest. Let denote the present timber supply by Q^{1S}. The total differentiation of Equation (7) derives comparative statics mathematically expressing as $(1+r)dP_1 - [(1+g'(A-Q_1,Z)]dP_2 + P_1dr - g''(A-Q_1,Z)P_2dA + g''(A-Q_1,Z)P_2dQ_1 = 0$. Then, we derive the additive supply effects on the present harvest from the differential. Present timber supply is positively related to current timber price and negatively related to future timber price, mathematically expressed as $Q_{P1}^{1S} = -\frac{1+r}{g''P_2} > 0$ and $Q_{P2}^{1S} = \frac{1+g'}{g''P_2} < 0$. The relationship that is extended to the percent change keeps the same as the change in present removal volume as well as current and future stumpage prices. Therefore, two-period harvest choice model hypothesizes that the elasticity of timber supply positively responds to current stumpage prices and oppositely responds to future stumpage prices.

5. Data

Since the late-1990's, the USFS-FIA program has conducted an annual approach (approximately 20% of plots are re-measured annually and all sample plots are re-measured on a 5/7-year cycle in the southern U.S.) with a fixed radius plot design. We selected the most recent pair of inventories with the fixed radius plot design across nine southern states (Table 6). USFS FIA had data for all variables mentioned in Equation (13) in the sampled states, except stumpage prices and future product volumes for pulpwood and sawtimber. FIA data on volumes by forest product type, ownership, harvest choices and site characteristics can be compiled for matched stands for these two inventories. Volumes of all live trees and sawtimber were estimated from the stand records of FIA and volume of pulpwood was calculated as the difference between the volume of all live trees and the sawtimber volume for every stand. FIA defined a final harvest and a partial harvest as well. A final harvest was defined as the removal of the vast majority of merchantable on the site and a partial harvest defined as undertaking the selection and high-grading harvests, commercial thinning, or shelterwood harvest on the site.

Stumpage prices were obtained from Timber Mart-South. Since FIA provides calculation estimates on an annual average timber harvest (and thus total timber harvest) on stands in each period, we can tie prices to the timber harvest by using the averaged price between the two specific measurement years during the present and the future periods. Hence, real stumpage prices for every sampled stand were taken as the mean stumpage prices with deflated consumer price index (setting the average consumer price index of the first quarter 1992 equal to 100). Similar techniques are used by Prestemon and Wear (2000) and Polyakov et al. (2010).

For unharvested stands during the present period, expected volumes for pulpwood and sawtimber were not observed during the future period. Quadratic regression models, separately for pulpwood and sawtimber, were applied to estimate the expected merchandise volumes in future period (Prestemon and Wear 2000). The quadratic function was expressed as a set of variables during the present period, including merchandise volumes and net growth volumes of stumpage products, stand basal area, and stand age.

For every forested stand, the ownership was determined from tax records and forest mensuration data were collected in the field. Traditionally, the ownership of the private forest plots has been categorized as corporate, conservation organizations, unincorporated partnerships, tribal, or individual, and whether or not they own a primary forest products processing facility. TIMOs and REITs were not specifically identified in the FIA database; they were simply lumped in with all other corporate owners. Using the name and address information obtained from the tax records maintained by FIA program, we further classified the owners and identified these TIMO and REIT owners. After this has been completed, we are able to join the new ownership categorization data with the underlying FIA database and assess timber supply from (and even the history, status, and use of) these forested plots.

For every privately owned forested stand, a series of criterion were defined (Figure 1): owner class (i.e., these are the traditional categories used by FIA (*e.g.*, on the private side they are corporate, conservation organizations, unincorporated partnerships, tribal, and individual)), industrial status (i.e., a variable indicating the owner's objectives towards commercial timber production), mill status (i.e., a variable indicating if the owner owns or operates a primary wood processing plant within the state or a nearby state or province), and TIMO/REIT status (i.e., a variable indicating whether the owner is a Timber Investment Management Organization (TIMO) or a Real Estate Investment Trust (REIT)). To maximize the flexibility of the data, each variable was recorded separately.

FIA has collected and maintained the name and address information from the tax records since 2004, while the present period covered the length from 1998 to 2007 across different southern states. Consequently, taking Alabama as example, there were about 20-25% of all stands measured by FIA which ownership categories can be classified during the present period. Among the stands with the obtainable ownership details, there were about 13% of the stands about which ownership categories were different between the present period and the future period. Since there is limited information on a legal transformation year of timberland ownership, we identified timberland ownership of the present period the same as the ownership of the future period. Given this limitation of representation, the results of this study should be viewed with caution.

6. Results

Table 7 summarizes the descriptive statistics for variables used in the regression analysis for two-period harvest choice models with regard to four forest ownership categories. Overall, the mean harvest probabilities of partial and final harvest, for forest industry, TIMOs, and

REITs, were higher than NIPF owners. Across four ownerships, removal merchandise volume and net growth volume for pulpwood were approximately two times higher than, or as high, as for sawtimber. The average stand ages were around 21 years, 18 years, 19 years, and 26 years, respectively, managed by forest industry, TIMOs, REITs, and NIPF landowners. Since the mean stand age owned by NIPF was older than owned by forest industry and institutional entities, net growth volume of NIPF all live trees was smaller than owned by two others.

6.1. Harvest choices

The results of multinomial logit model for all sampled stands are reported concerning harvest choices in Table 8, and separate multinomial logit models are estimated for four ownerships in Tables 9-12. In general, the goodness of fits and model significance measures demonstrate that the models fit well for all of the ownerships. Similar results were generated by employing the model to all the stands in terms of both partial and final harvest choices. Present timber value and stand volume were positively related to the probability of partial and final harvest at the 1% significant level and their marginal effects were significant at the 1% level. Net growth volume was positively associated with the probability of partial harvest, and negatively with final harvest at the 1% significant level. Their marginal effects were significant at the 1% level. Future timber value and the squared terms of stand volume and net growth volume significantly and adversely impacted both of the probabilities of the partial and final harvest. The coefficient and marginal effect of *Stand Origin* was positive at the 1% significant level, suggesting that the presence of an artificially regenerated stand increases the probability of a partial harvest by 4% or a final harvest by 9%. In comparison with NIPF landowners, coefficients and marginal effects of the variables *FI* and *TIMOs* were positive at the 1% significant level. The variable *REITs* was positively related to the probability of the partial and final harvest at the 10% significant level or better. This implies that landowners in industrial, TIMO, and REIT forest stands are more likely to conduct a partial or final harvest than NIPF landowners. The probability of a partial harvest was increased by 6%, 8%, and 3%, and the probability of a final harvest increased by 2%, 3%, and 6%, respectively, in industrial, TIMO, and REIT stands. Additionally, the variables *Coastal Plain* and *Slope* adversely affected the probability of a partial harvest. Horizontal distance to improved road increased the probability of a final harvest.

Separate regression models generate similar results for forest industry and NIPF landowners with respect to the coefficients and marginal effects of explanatory variables. For TIMOs and REITs, the regression models estimate expected signs for the coefficients of explanatory variables (Tables 10 and 11). In TIMO stands, the variable *Slope* was significantly and negatively related to a partial harvest probability and the marginal effect was significant at the 1% level. For the choice of a final harvest, the coefficients of present timber value, stand volume, net growth volume, artificially regenerated stands, and distance to improved road, were positive and significant at the 10% level or better. The stand slope and the squared term of net growth volume were negatively related to a final harvest at the 5% significant level. The marginal effects of the term and squared term of net growth volume were significant at the 5% level or better. In REIT stands, stand volume and net growth volume positively influenced the probability of a partial harvest. For the choice of a final harvest, the coefficients of present timber value and stands with artificial regeneration were significant and positive. The variable *Coastal Plain* was negatively associated with the probabilities of both partial and final harvest, significantly at the 1% level. Among the significant explanatory variables, the largest amount of marginal effect was -0.26 of *Coastal Plain* for the partial harvest and 0.14 of *Stand Origin* for the final harvest.

Respectively in industry, TIMOs, REITs, and NIPF stands, the implied real discount rates of conducting a partial harvest were 1.1%, 1.9%, 1.6%, and 0.4%, and the implied real discount rates of conducting a final harvest were 3.3%, 0.7%, 1.9%, and 3.9%. Given the implied discount rates, expected change in discounted timber value can be calculated as $TimberValue_{j,1} - \beta_j TimberValue_{j,2}$, and re-reported in Table 13. The discounted change in timber value was significantly and positively related to the probability of timber partial or final harvest across the four ownership categories, except the partial harvest choice in TIMO stands. Other explanatory variables had the same effect in harvest choice as the result shown in Tables 9-12.

6.2. Elasticity of timber supply

Table 14 reports the mean estimates and standard deviations of timber supply elasticities with respect to current and future prices across the four forest ownerships. As described as our hypothesis, overall, timber supply was positively associated with current stumpage prices and negatively associated with future stumpage prices. Sawtimber products were more price elastic than pulpwood products, which is consistent with previous studies (Newman and Wear 1993; Prestemon and Wear 2000; Polyakov et al. 2010). Pulpwood production was more responsive to sawtimber price change than pulpwood price change. Coefficients of cross-price elasticities in timber supply between sawtimber and pulpwood across four ownerships were significant and positive, indicating that these two types of timber products are complementary in production.

In terms of percentage change in current price, own-price elasticities for sawtimber were 3.61 for forest industry, 1.02 for TIMOs, 1.38 for REITs, and 2.83 for NIPF owners. For pulpwood, own-price elasticities were 0.36 for forest industry, 0.11 for TIMOs, 0.15 for REITs, and 0.22 for NIPF owners. Cross-price elasticities in sawtimber production ranged from 0.13 for TIMOs to 0.41 for forest product owners, and in pulpwood production from 0.78 for TIMOs to 2.79 for industry owners.

Elasticity of timber supply adversely responded to future price change, consistent with our hypothesis. Own-price elasticity had the similar magnitude as cross-price elasticity with respect to price increase in one product across the four ownership categories. With 1% future sawtimber price increases, forest industry owners decreased both sawtimber and pulpwood harvest volumes by 3.37%; TIMOs decreased by 1.05%; REITs decreased by 1.39%; and NIPF owners decreased by 2.59%. With 1% future pulpwood price increases, forest industry owners decreased timber supply for both of two products by 0.41%; TIMOs decreased by 0.15%; REITs decreased by 0.19%; and NIPF owners decreased by 0.25%. Table 15 reports pairs of comparison of the mean elasticity estimates of stumpage supply. All of pairs of comparison between two ownership categories were significantly different at the 1% level with regard to current and future stumpage prices.

Many studies model landowner harvest decisions as a binary choice: harvest or no harvest (Dennis 1990; Prestemon and Wear 2000). This study employs a probit model as well to be compared with previous studies with respect to exploring harvest choice and estimating elasticities of timber supply (Tables 16-20). Stands defined as the partial and final harvest in the multinomial logit regression analysis were classified to harvested stands in the probit analysis. The probit model generated similar results about what explanatory variables affected the harvest choice. The average price elasticity estimated from the probit model for forest industry and TIMOs was similar to from the multinomial logit model. For REITs and NIPF landowners, the magnitude of own-price or cross-price elasticities with regard to stumpage prices was a little smaller estimated from the probit model than from the multinomial logit model. In terms of comparison of price elasticity estimated from the probit model between ownerships, there was no significant difference between TIMOs and REITs with regard to current stumpage price changes and future sawtimber price change, but there was a significant difference at the 5% level with regard to future pulpwood price change.

6.3. A comparison with earlier studies

The estimated results can be partially compared with the findings in Prestemon and Wear (2000) because the same theoretical methodology and data source are accounted for examining price elasticity of timber supply by ownership. The difference between the two studies is that stand timber supply was estimated across nine southern states in this study, but Prestemon and Wear (2000) estimated aggregate timber supply only in North Carolina. Additionally, these two studies draw conclusions based on different sample periods. Regardless of estimates at aggregate or stand level, forest firms do more timber production with respect to stumpage changes than NIPF owners. Sawtimber harvests are elastically responsive to own-price change, while pulpwood prices affect supply quantities inelastically. Positive cross-price elasticities for both sawtimber and pulpwood indicate the complementary effects on supplies of each product for both aggregate and stand timber supply model. Compared with Prestemon and Wear (2000), this study estimates smaller own-price elasticity for industry, but relatively larger elasticity for NIPF, although Prestemona and Wear (2000) find no significant difference about NIPF responses at 5% level. Additionally, the elasticity of stand timber supply in this study is relatively larger for two forest products than estimations of aggregate supply in other literatures.

In contrast, concerning the price elasticity of timber supply at the stand level, timber harvesting is more elastically responsive to stumpage price change in Dennis (1989).

7. Discussion

This study extends the two-period harvest choice model addressed by Prestemon and Wear (2000) to be applied to institutional organizations (i.e., TIMOs or REITs), new emerging ownerships on forestland, to explore their behaviors on projecting harvest choices in forest stands and compare the impact on timber supply with other forest ownerships (i.e., forest industry and NIPF landowners). The study is the first to employ econometric analysis to estimate the behavior of institutional owners who invest in forestland and assumes that all individuals exhibit identical behavior within an ownership category.

The result indicates that institutional timberland owners are more likely to conduct harvest activities than NIPF landowners. Institutional timberland owners might be more inclined to conduct harvesting practice during limited investment period, usually between 8 and 15 years. Institutional owners need to utilize a shorter timberland management horizon to maximize their returns than NIPF landowners. On the other hand, institutional timberland owners manage large parcel size of forestland (Yale Forest Forum Review 2002); however, the mean holding size of NIPF landowners is 24 acres (Tyrell and Dunning 2000). Small size landholdings tend to operate infrequent forest management practices and are reluctant to undertake timber harvesting since small parcel size significantly increase the production costs per unit in silvicultural forest practices (Cubbage 1983; Gardner 1981; Siry 2002). Therefore, institutional timberland owners have higher economic benefits to conduct timber harvesting than NIPF landowners.

Forest industry firms act more elastic behavior on timber production, compared with both institutional entity and NIPF landowners. With regard to forest industry firms that still own their timberland, they cannot separate the forests from the mill production and timber harvesting would be driven by their owned mills' demands. When prices for forest products rise as stumpage price increases, the objective of shareholder profit maximization prompts forest product firms to generate more production of forest products through timber harvesting. Hence, traditional forest products firms would conduct more intensely harvesting activities than other timberland ownerships.

Stumpage prices generally affect less harvest quantities in institutional stands than in forest industry and NIPF stands. Two factors might influence less price elasticity on institutional timber production. Firstly, TIMOs and publicly traded REITs have similar strategic objective that timber is cut and sold to the highest bidder in open-market auctions when market conditions are favorable, otherwise timber is left to be appreciated in value. When stumpage price has gradually decreased in general since 1998, institutional timberland investors would not supply more timber quantities. Secondly, institutional timberland investors do not need to confront hard annual cash flow targets as required by industry and NIPF owners (Browne 2001). Institutional investors would more likely contribute themselves to returns over the life of the investment, while the traditional industry firms have a more varied set of objectives including returns, wood supply, and other social objectives (Clutter et al. 2007).

Through comparing with other studies' estimations, timberland owners have more elastic response to stumpage price change at stand level than at regional level. An aggregate timber supply curve is the sum of individual supply curves for different sectors of the economy. Then, rate of change in individual supply curve is larger than in aggregate supply curve. As regional wood market potentially provides the larger quantities of timber harvesting than individual plot, stand timber supply is more responsive to stumpage price change than aggregate timber supply.

Additionally, stumpage price elasticity of timber supply varies considerably depending on the differences in methodology, data sources, regional range, and sample period.

The study has revealed some interesting behaviors on harvest choices and timber supply on the institutional timberland. However, there still exist many unstudied aspects, relevant to this emerging institutional ownership group. Extensive studies may empirically explore forest management tendencies, forest land use, and biodiversity conservation and carbon sequestration, directed to timberland owned and managed by institutional investors. Specifically, future research may include topics such as: assessing interactions of overstory, understory, and below ground carbon components in silvilcultural forest operation as affected by management and prompting the adaptive capacity of forest landowners to build and maintain forest landowners' perception of and responses to increasing drought, insect outbreak, and fire under a range of environmental challenges.

Table 6. Summary of the most recent pair of inventories with the fixed radius plots[1] sampled from USDA FIA database covering nine[2] southern states.

State	Present Period	Future Period
Alabama	2001-2005	2006-2010
Arkansas	2000-2005	2006-2010
Florida	2002-2007	2008-2010
Georgia	1998-2004	2005-2010
North Carolina	2003-2007	2008-2010
South Carolina	2002-2006	2007-2010
Tennessee	2000-2004	2005-2009
Texas (Eastern Region)	2001-2003	2004-2008
Virginia	1998-2001	2002-2007

[1]: Only stands with the obtainable re-measurement data during the present and future period were selected in the study in response to the nature of constructing a two-period production function.

[2]: Due to FIA annual data availability, Mississippi, Louisiana, and Oklahoma were excluded from the study.

Table 7. Summary statistics for the present period (period *t*) and for the future period (period *t + 1*) with regard to ownership category.

	Variable	Units	Sample Mean	Sample SD	Sample Min	Sample Max
All Owners	Present sawtimber net volume	m^3ha^{-1}	48.77	80.97	0.00	910.33
	Present sawtimber removal volume	m^3ha^{-1}	9.58	35.73	0.00	432.07
	Present sawtimber net growth volume	m^3ha^{-1}	17.70	30.81	-328.14	290.92
	Present pulpwood net volume	m^3ha^{-1}	95.95	98.20	0.00	678.41
	Present pulpwood removal volume	m^3ha^{-1}	18.09	51.39	0.00	556.63
	Present pulpwood net growth volume	m^3ha^{-1}	34.37	53.10	-203.04	469.85
	Future sawtimber net volume	m^3ha^{-1}	45.78	67.98	0.00	893.99
	Future pulpwood net volume	m^3ha^{-1}	79.78	73.44	0.00	562.32
	Stand age	year	23.64	17.19	0.00	130.00
	Basal area	m^2ha^{-1}	20.39	11.33	0.00	74.47
	Stand origin		0.60	--	0.00	1.00
	Coastal plain		0.52	--	0.00	1.00
	Distance to road		0.55	--	0.00	1.00
	Slope		4.71	7.73	0.00	90.00
Forest Industry	Present sawtimber net volume	m^3ha^{-1}	42.60	69.59	0.00	470.95
	Present sawtimber removal volume	m^3ha^{-1}	13.58	44.07	0.00	421.88
	Present sawtimber net growth volume	m^3ha^{-1}	19.73	32.92	-33.85	290.92
	Present pulpwood net volume	m^3ha^{-1}	94.81	102.84	0.00	678.41
	Present pulpwood removal volume	m^3ha^{-1}	25.68	60.31	0.00	436.12
	Present pulpwood net growth volume	m^3ha^{-1}	38.60	54.01	-50.47	398.98
	Future sawtimber net volume	m^3ha^{-1}	37.63	50.59	0.00	302.61
	Future pulpwood net volume	m^3ha^{-1}	73.93	69.53	0.00	495.97
	Stand age	year	21.19	15.50	1.00	90.00
	Basal area	m^2ha^{-1}	19.02	10.96	0.00	48.72
	Stand origin		0.80	--	0.00	1.00
	Coastal plain		0.51	--	0.00	1.00
	Distance to road		0.53	--	0.00	1.00
	Slope		5.38	7.73	0.00	42.00
TIMO	Present sawtimber net volume	m^3ha^{-1}	29.12	54.23	0.00	423.62
	Present sawtimber removal volume	m^3ha^{-1}	10.02	32.72	0.00	316.93
	Present sawtimber net growth volume	m^3ha^{-1}	17.61	37.87	-42.96	282.08
	Present pulpwood net volume	m^3ha^{-1}	76.10	89.53	0.00	632.09
	Present pulpwood removal volume	m^3ha^{-1}	25.20	64.17	0.00	494.03
	Present pulpwood net growth volume	m^3ha^{-1}	40.58	64.30	-34.13	384.78
	Future sawtimber net volume	m^3ha^{-1}	37.74	66.16	0.00	649.35
	Future pulpwood net volume	m^3ha^{-1}	78.95	71.12	0.00	403.31
	Stand age	year	18.45	13.81	0.00	113.00
	Basal area	m^2ha^{-1}	18.69	10.94	0.00	49.19
	Stand origin		0.83	--	0.00	1.00
	Coastal plain		0.54	--	0.00	1.00
	Distance to road		0.56	--	0.00	1.00
	Slope		4.77	8.29	0.00	80.00

Table 7. Continued.

	Variable	Units	Sample Mean	Sample SD	Sample Min	Sample Max
REITs	Present sawtimber net volume	m^3ha^{-1}	33.39	60.35	0.00	501.29
	Present sawtimber removal volume	m^3ha^{-1}	17.04	41.15	0.00	282.66
	Present sawtimber net growth volume	m^3ha^{-1}	18.78	32.17	-32.66	280.91
	Present pulpwood net volume	m^3ha^{-1}	73.19	88.27	0.00	508.94
	Present pulpwood removal volume	m^3ha^{-1}	29.79	67.20	0.00	556.63
	Present pulpwood net growth volume	m^3ha^{-1}	36.04	55.65	-19.79	469.85
	Future sawtimber net volume	m^3ha^{-1}	25.80	50.95	0.00	315.75
	Future pulpwood net volume	m^3ha^{-1}	59.31	69.68	0.00	333.29
	Stand age	year	18.76	15.53	1.00	75.00
	Basal area	m^2ha^{-1}	16.53	11.01	0.00	46.13
	Stand origin		0.76	--	0.00	1.00
	Coastal plain		0.50	--	0.00	1.00
	Distance to road		0.61	--	0.00	1.00
	Slope		2.27	5.23	0.00	46.00
NIPF	Present sawtimber net volume	m^3ha^{-1}	55.14	88.11	0.00	910.33
	Present sawtimber removal volume	m^3ha^{-1}	7.57	32.66	0.00	432.07
	Present sawtimber net growth volume	m^3ha^{-1}	17.04	28.81	-328.14	226.15
	Present pulpwood net volume	m^3ha^{-1}	101.85	98.51	0.00	671.26
	Present pulpwood removal volume	m^3ha^{-1}	13.63	43.36	0.00	463.99
	Present pulpwood net growth volume	m^3ha^{-1}	32.11	50.52	-203.04	444.90
	Future sawtimber net volume	m^3ha^{-1}	51.48	73.10	0.00	893.99
	Future pulpwood net volume	m^3ha^{-1}	83.85	74.74	0.00	562.32
	Stand age	year	25.64	17.90	1.00	130.00
	Basal area	m^2ha^{-1}	21.47	11.35	0.00	74.47
	Stand origin		0.50	--	0.00	1.00
	Coastal plain		0.52	--	0.00	1.00
	Distance to road		0.54	--	0.00	1.00
	Slope		4.80	7.84	0.00	90.00

Table 8. Estimation results of multinomial logit regression equations for ALL landowners' harvest choices of a specific type of timber harvesting (N = 4720).

Variable	Partial Harvest (N = 900)		Final Harvest (N = 399)	
	Coefficient (z test)	Marginal effect	Coefficient (z test)	Marginal effect
Constant	-1.49***	--	-4.21***	--
	(-9.44)		(-15.13)	
Timber value ($/acre), t	7.93E-4***	1.11E-4***	7.83E-4***	2.73E-5***
	(7.61)		(4.36)	
Timber value ($/acre), $t + 1$	-7.51E-4***	-1.05E-4***	-6.60E-4***	-2.24E-5***
	(-7.08)		(-3.61)	
Stand volume ($m^3 acre^{-1}$)	0.01***	7.57E-4***	0.01***	2.06E-4***
	(6.82)		(5.04)	
(Stand volume)^2	-5.59E-6***	-7.58E-7***	-8.20E-6***	-3.09E-7***
	(-5.88)		(-5.47)	
Growth volume ($m^3 acre^{-1}$)	0.01***	1.17E-3***	-0.01***	-2.90E-4***
	(6.30)		(-2.64)	
(Growth volume)^2	-1.22E-5***	-1.46E-6***	-4.20E-5***	-1.71E-6***
	(-3.72)		(-3.69)	
Stand origin	0.40***	0.04***	2.26***	0.09***
	(4.18)		(12.13)	
Coastal plain	-0.68***	-0.10***	-0.19	-2.73E-3
	(-8.04)		(-1.54)	
Distance to road	2.26E-3	-1.96E-3	0.28*	0.01*
	(0.02)		(1.75)	
Slope	-0.04***	-0.01***	-0.01	-2.19E-4
	(-6.18)		(-1.38)	
FI	0.42***	0.06***	0.63***	0.02***
	(4.09)		(4.30)	
TIMOs	0.60***	0.08***	0.92***	0.03***
	(4.64)		(5.40)	
REITs	0.26*	0.03	1.45***	0.06***
	(1.69)		(8.67)	
Log likelihood	-3183.49			
Chi-square	789.75***			

***, **, and * indicate significance at the 1%, 5%, and 10%, respectively.

Table 9. Estimation results of multinomial logit regression equations for Forest Industry landowners' harvest choices of a specific type of timber harvesting (*N* = 827).

Variable	Partial Harvest (*N* = 193)		Final Harvest (*N* = 95)	
	Coefficient (*z* test)	Marginal effect	Coefficient (*z* test)	Marginal effect
Constant	-0.48 (-1.24)	--	-4.27*** (-5.93)	--
Timber value ($/acre), *t*	1.42E-3*** (4.87)	2.22E-4***	1.40E-3*** (3.10)	7.08E-5**
Timber value ($/acre), *t + 1*	-1.35E-3*** (-4.57)	-2.13E-4***	-1.19E-3*** (-2.60)	-5.79E-5**
Stand volume (m^3acre^{-1})	4.80E-3** (2.46)	7.05E-4**	0.01*** (2.69)	4.36E-4**
(Stand volume)^2	-3.66E-6 (-1.43)	-4.26E-7	-1.28E-5*** (-2.67)	-7.97E-7**
Growth volume (m^3acre^{-1})	0.01*** (3.21)	1.69E-3***	-4.23E-3 (-0.65)	-4.31E-4
(Growth volume)^2	-8.94E-6 (-1.15)	-1.13E-6	-2.57E-5 (-0.65)	-1.57E-6
Stand origin	0.20 (0.85)	-0.01	2.72*** (5.27)	0.18***
Coastal plain	-1.06*** (-5.21)	-0.17***	-0.50* (-1.80)	-0.02
Distance to road	0.29 (1.26)	0.03	1.06*** (2.89)	0.07***
Slope	-0.04*** (-3.05)	-0.01***	-0.04** (-2.22)	-2.34E-3*
Log likelihood	-624.27			
Chi-square	185.77***			

***, **, and * indicate significance at the 1%, 5%, and 10%, respectively.

Table 10. Estimation results of multinomial logit regression equations for TIMOs' harvest choices of a specific type of timber harvesting (*N* = 459).

Variable	Partial Harvest (*N* = 112)		Final Harvest (*N* = 64)	
	Coefficient (*z* test)	Marginal effect	Coefficient (*z* test)	Marginal effect
Constant	-0.39	--	-3.73	--
	(-0.73)		(-3.86)	
Timber value	4.42E-4	7.65E-5	1.07E-3*	2.81E-5
($/acre), *t*	(1.10)		(1.66)	
Timber value	-4.01E-4	-6.90E-5	-1.03E-3	-2.73E-5
($/acre), *t + 1*	(-0.98)		(-1.59)	
Stand volume	3.31E-3	5.67E-4	0.01**	2.29E-4
(m^3acre^{-1})	(1.17)		(2.28)	
(Stand volume)^2	-3.71E-6	-6.77E-7	-4.64E-6	-1.07E-7
	(-0.77)		(-0.60)	
Growth volume	3.26E-3	4.75E-4	0.02*	5.43E-4**
(m^3acre^{-1})	(0.91)		(1.83)	
(Growth volume)^2	-4.87E-6	8.35E-7	-2.25E-4**	-6.58E-6***
	(-0.73)		(-2.40)	
Stand origin	0.02	-0.01	1.94***	0.06
	(0.07)		(2.94)	
Coastal plain	-0.31	-0.06	0.29	0.01
	(-1.22)		(0.81)	
Distance to road	-0.17	-0.04	0.82*	0.03
	(-0.55)		(1.73)	
Slope	-0.09***	-0.02***	-0.08**	-1.58E-3
	(-3.72)		(-2.30)	
Log likelihood	-376.89			
Chi-square	88.07***			

***, **, and * indicate significance at the 1%, 5%, and 10%, respectively.

Table 11. Estimation results of multinomial logit regression equations for REITs' harvest choices of a specific type of timber harvesting (*N* = 357).

Variable	Partial Harvest (*N* = 69)		Final Harvest (*N* = 79)	
	Coefficient (*z* test)	Marginal effect	Coefficient (*z* test)	Marginal effect
Constant	-1.07	--	-2.02**	--
	(-1.58)		(-2.54)	
Timber value	6.50E-4	8.39E-5	9.72E-4*	4.96E-5
($/acre), *t*	(1.37)		(1.71)	
Timber value	-6.00E-4	-7.75E-5	-8.86E-4	-4.51E-5
($/acre), *t + 1*	(-1.23)		(-1.53)	
Stand volume	0.01**	9.67E-4**	2.22E-3	5.47E-5
(m^3acre^{-1})	(2.03)		(0.64)	
(Stand volume)^2	-4.81E-6	-8.09E-7	9.85E-6	6.28E-7*
	(-1.05)		(1.42)	
Growth volume	0.01*	1.06E-3	0.02	8.51E-4*
(m^3acre^{-1})	(1.76)		(1.36)	
(Growth volume)^2	-1.46E-5	1.45E-6	-3.25E-4***	-1.88E-5***
	(-1.32)		(-2.78)	
Stand origin	0.09	-0.01	2.49***	0.14**
	(0.23)		(4.47)	
Coastal plain	-1.85***	-0.26***	-1.19***	-0.05*
	(-4.62)		(-3.41)	
Distance to road	-0.09	-0.01	0.08	0.01
	(-0.20)		(0.17)	
Slope	-0.03	-4.11E-3	-0.04	-1.85E-3
	(-0.98)		(-1.11)	
Log likelihood	-274.12			
Chi-square	140.69***			

***, **, and * indicate significance at the 1%, 5%, and 10%, respectively.

Table 12. Estimation results of multinomial logit regression equations for NIPF Landowners' harvest choices of a specific type of timber harvesting (N = 3077).

Variable	Partial Harvest (N = 526)		Final Harvest (N = 161)	
	Coefficient (z test)	Marginal effect	Coefficient (z test)	Marginal effect
Constant	-1.71***	--	-3.91***	--
	(-8.62)		(-10.93)	
Timber value	7.90E-4***	1.00E-4***	6.19E-4**	1.48E-5**
(\$/acre), t	(6.03)		(2.46)	
Timber value	-7.75E-4***	9.89E-5***	-5.10E-4**	-1.16E-5
(\$/acre), $t + 1$	(-5.82)		(-1.98)	
Stand volume	0.01***	8.51E-4***	4.24E-3**	9.51E-5**
(m^3acre^{-1})	(6.60)		(2.57)	
(Stand volume)^2	-5.66E-6***	-7.07E-7***	-6.72E-6***	-1.74E-7***
	(-4.96)		(-3.50)	
Growth volume	0.01***	1.30E-3***	-0.01***	-2.63E-4***
(m^3acre^{-1})	(5.29)		(-2.65)	
(Growth volume)^2	-2.61E-5***	-3.24E-6***	-3.55E-5**	-9.37E-7**
	(-3.73)		(-2.43)	
Stand origin	0.58***	0.06***	2.16***	0.06***
	(4.95)		(9.26)	
Coastal plain	-0.58***	-0.08***	0.06	4.69E-3
	(-5.41)		(0.35)	
Distance to road	-0.02	-1.93E-3	-0.19	-0.01
	(-0.15)		(-0.89)	
Slope	-0.04***	-4.92E-3***	0.02*	7.77E-4**
	(-4.41)		(1.93)	
Log likelihood	-1837.32			
Chi-square	341.34***			

***, **, and * indicate significance at the 1%, 5%, and 10%, respectively.

Table 13. Estimated multinomial logit regression model for stumpage stands with discount rates calculated by ownership in terms of types of harvest.

Variable	Forest Industry		TIMOs		REITs		NIPF	
	Partial	Final	Partial	Final	Partial	Final	Partial	Final
	Coefficient (*z* test)	Coefficient (*z* test)	Coefficient (*z* test)	Coefficient (*z* test)	Coefficient (*z* test)	Coefficient (*z* test)	Coefficient (*z* test)	Coefficient (*z* test)
Constant	-0.46	-3.57***	-0.41	-5.11***	-1.07*	-1.75**	-1.73***	-0.64
	(-1.30)	(-3.61)	(-0.85)	(-5.36)	(-1.86)	(-2.49)	(-8.92)	(-1.31)
Discounted Timber value	1.42E-3***	0.01***	4.20E-4	-1.91E-3***	6.54E-4*	1.58E-3***	7.41E-4***	0.01***
($/ha), *t* to *t+1*	(5.24)	(9.46)	(1.31)	(-2.89)	(1.70)	(2.98)	(5.84)	(13.77)
Stand volume	4.61E-3***	0.01*	3.33E-3	0.01**	0.01**	1.49E-3	0.01***	3.26E-3
(m^3ha^{-1})	(2.94)	(1.91)	(1.32)	(2.44)	(2.45)	(0.49)	(7.62)	(1.52)
(Stand volume)^2	-3.28E-6	-1.12E-5*	-4.07E-6	-9.99E-6	-4.82E-6	1.22E-5*	-5.47E-6***	-1.13E-5***
	(-1.40)	(-1.86)	(-0.94)	(-1.23)	(-1.18)	(1.91)	(-5.03)	(-5.74)
Growth volume	0.01***	0.01	3.36E-3	0.01	0.01*	0.02	0.01***	0.03***
(m^3ha^{-1})	(3.15)	(1.63)	(0.95)	(1.16)	(1.74)	(1.58)	(5.05)	(5.51)
(Growth volume)^2	-8.06	-2.31E-5	-4.88E-6	-2.69E-4**	-1.46E-5	-3.25E-4***	-2.57E-5***	-1.66E-4***
	(-1.02)	(-0.88)	(-0.75)	(-2.57)	(-1.32)	(-2.99)	(-3.55)	(-4.33)
Stand origin	0.23	5.76***	0.02	1.36**	0.08	2.65***	0.57***	3.63***
	(0.97)	(6.09)	(0.08)	(2.15)	(0.22)	(4.59)	(5.09)	(9.89)
Coastal plain	-1.06***	-0.61*	-0.33E	0.34	-1.87***	-1.14***	-0.59***	0.32
	(-5.21)	(-1.71)	(-1.27)	(0.95)	(-4.73)	(-3.44)	(-5.46)	(1.22)
Distance to road	0.28	1.98***	-0.15	0.64	-0.09	0.12	-0.01	-0.19
	(1.19)	(3.29)	(-0.51)	(1.38)	(-0.21)	(0.23)	(-0.10)	(-0.63)
Slope	-0.04***	-0.06**	-0.09***	-0.09***	-0.03	-0.04	-0.04***	3.74E-3
	(-3.11)	(-2.39)	(-3.73)	(-2.74)	(-1.01)	(-1.06)	(-4.42)	(0.27)
Log likelihood	-521.80		-371.01		-271.47		-1565.46	
Chi-square	390.71***		99.85***		145.99***		885.07***	

***, **, and * indicate significance at the 1%, 5%, and 10%, respectively.

Table 14. Average estimates of elasticities of stumpage supply with respect to present and future price changes.

Quantity Supply	Price, Period	Average Estimate (Std. Dev.)			
		Forest Industry	TIMOs	REITs	NIPF
	Current price change				
Sawtimber	Sawtimber, *t*	3.61***	1.02***	1.38***	2.83***
		(4.47)	(1.15)	(1.37)	(3.78)
Sawtimber	Pulpwood, *t*	0.41***	0.13***	0.17***	0.25***
		(0.43)	(0.13)	(0.17)	(0.21)
Pulpwood	Sawtimber, *t*	2.79***	0.78***	1.07***	2.28***
		(4.21)	(1.10)	(1.33)	(3.57)
Pulpwood	Pulpwood, *t*	0.36***	0.11***	0.15***	0.22***
		(0.41)	(0.12)	(0.17)	(0.21)
	Future price change				
Sawtimber	Sawtimber, *t + 1*	-3.37***	-1.05***	-1.39***	-2.59***
		(3.83)	(1.11)	(1.34)	(3.18)
Sawtimber	Pulpwood, *t + 1*	-0.41***	-0.15***	-0.19***	-0.25***
		(0.39)	(0.11)	(0.15)	(0.20)
Pulpwood	Sawtimber, *t + 1*	-3.37***	-1.05***	-1.39***	-2.59***
		(3.83)	(1.11)	(1.34)	(3.18)
Pulpwood	Pulpwood, *t + 1*	-0.41***	-0.15***	-0.19***	-0.25***
		(0.39)	(0.11)	(0.15)	(0.20)

***, **, and * indicate statistical significance, different from zero at the 1%, 5%, and 10%, respectively.

Table 15. Pairwise comparison of average estimates of elasticities of stumpage supply with respect to present and future price changes between ownership groups.

Quantity Supply	Price, Period	Difference on averaged estimates of supply elasticities (t – test)					
		FI vs. TIMOs	FI vs. REITs	FI vs. NIPF	TIMOs vs. REITs	TIMOs vs. NIPF	REITs vs. NIPF
	Current price change						
Sawtimber	Sawtimber, *t*	2.59***	2.23***	0.78***	-0.36***	-1.81***	-1.45***
		(10.46)	(7.92)	(4.39)	(-3.53)	(-8.73)	(-6.15)
Sawtimber	Pulpwood, *t*	0.28***	0.24***	0.16***	-0.04***	-0.12***	-0.08***
		(11.54)	(8.79)	(13.33)	(-2.88)	(-9.80)	(-5.92)
Pulpwood	Sawtimber, *t*	2.02***	1.73***	0.52***	-0.29***	-1.51***	-1.21***
		(9.89)	(7.39)	(3.47)	(-3.35)	(-8.77)	(-6.18)
Pulpwood	Pulpwood, *t*	0.24***	0.20***	0.14***	-0.04***	-0.10***	-0.06***
		(12.22)	(8.84)	(13.36)	(-3.93)	(-10.16)	(-5.36)
	Future price change						
Sawtimber	Sawtimber, *t + 1*	-2.31***	-1.98***	-0.78***	0.34***	1.54***	1.20***
		(-12.65)	(-9.51)	(-5.96)	(3.94)	(10.27)	(7.07)
Sawtimber	Pulpwood, *t + 1*	-0.26***	-0.22***	-0.15***	0.04***	0.11***	0.06***
		(-13.99)	(-10.20)	(-15.42)	(4.86)	(11.38)	(5.96)
Pulpwood	Sawtimber, *t + 1*	-2.32***	-1.98***	-0.78***	0.34***	1.54***	1.20***
		(-12.67)	(-9.51)	(-5.98)	(3.97)	(10.28)	(7.05)
Pulpwood	Pulpwood, *t + 1*	-0.26***	-0.22***	-0.15***	0.04***	0.11***	0.06***
		(-14.02)	(-10.20)	(-15.44)	(4.89)	(11.41)	(5.95)

***, **, and * indicate statistical significance, different from zero at the 1%, 5%, and 10%, respectively.

Table 16. Estimated probit regression model for stumpage stands owned by ALL landowners across nine states (N = 4720).

Variables	Coefficient (z-test)	Marginal effect
Constant	-0.91*** (-11.05)	--
Timber value (\$/ha), t	4.00E-4*** (7.78)	1.29E-4
Timber value (\$/ha), $t + 1$	-3.65E-4*** (-6.84)	-1.18E-4
Stand volume (m^3ha^{-1})	2.94E-3*** (7.24)	9.53E-4
(Stand volume)^2	-3.22E-6*** (-7.10)	-1.04E-6
Growth volume (m^3ha^{-1})	1.44E-3** (2.24)	4.65E-4
(Growth volume)^2	-2.88E-6 (-1.60)	-9.32E-7
Stand origin	0.47*** (9.68)	0.15
Coastal plain	-0.32*** (-7.26)	-0.10
Distance to road	0.04 (0.78)	0.01
Slope	-0.02*** (-5.94)	-0.01
Forest industry	0.28*** (5.19)	0.09
TIMO	0.42*** (6.23)	0.14
REITs	0.44*** (5.96)	0.14
Log likelihood	-2559.98	
Chi-square	434.30***	

***, **, and * indicate significance at the 1%, 5%, and 10%, respectively.

Table 17. Estimated probit regression model for stumpage stands by ownership.

Variable	Forest Industry (*N* = 827)		TIMO (*N* = 459)		REITs (*N* = 357)		NIPF (*N* = 3077)	
	Coefficient (*z*-test)	Marginal effect	Coefficient (*z*-test)	Marginal effect	Coefficient (*z*-test)	Marginal effect	Coefficient (*z*-test)	Marginal effect
Constant	-0.43**	--	-0.35	--	-0.33	--	-0.93***	--
	(-2.07)		(-1.15)		(-1.00)		(-9.25)	
Timber value	8.16E-4***	2.96E-4	3.73E-4*	1.40E-4	3.40E-4	1.32E-4	3.72E-4***	1.07E-4
($/ha), *t*	(5.53)		(1.70)		(1.54)		(6.05)	
Timber value	-7.52E-4***	-2.73E-4	-3.47E-4	-1.31E-4	-3.02E-4	-1.17E-4	-3.52E-4***	-1.02E-4
($/ha), *t + 1*	(-4.99)		(-1.54)		(-1.31)		(-5.52)	
Stand volume	3.28E-3***	1.19E-3	3.16E-3**	1.19E-3	3.57E-3**	1.38E-3	3.13E-3***	9.03E-4
(m^3ha^{-1})	(3.36)		(2.12)		(2.40)		(6.23)	
(Stand volume)^2	-3.26E-6***	-1.18E-6	-2.97E-6	-1.12E-6	-2.23E-6	-8.63E-7	-2.93E-6***	-8.44E-7
	(-2.95)		(-1.13)		(-0.96)		(-5.34)	
Growth volume	2.21E-3	8.01E-4	-1.21E-4	-4.56E-5	-2.66E-3	-1.03E-3	2.54E-3***	7.32E-4
(m^3ha^{-1})	(1.39)		(-0.06)		(-1.11)		(2.91)	
(Growth volume)^2	-7.21E-7	-2.62E-7	-7.43E-7	-2.79E-7	4.07E-6	1.58E-6	-8.43E-6**	-2.43E-6
	(-0.15)		(-0.19)		(0.65)		(-2.52)	
Stand origin	0.45***	0.16	0.29*	0.11	0.57***	0.22	0.51***	0.15
	(3.43)		(1.68)		(3.05)		(8.61)	
Coastal plain	-0.52***	-0.19	-0.08	-0.03	-0.87***	-0.34	-0.26***	-0.07
	(-4.97)		(-0.57)		(-5.16)		(-4.62)	
Distance to road	0.29**	0.11	0.08	0.03	0.04	0.02	-0.04	-0.01
	(2.40)		(0.49)		(0.19)		(-0.59)	
Slope	-0.03***	-0.01	-0.05***	-0.02	-0.02	-0.01	-0.01***	-3.49E-3
	(-3.36)		(-4.31)		(-1.49)		(-3.16)	
Log likelihood	-482.57		-282.51		-214.01		-1542.12	
Chi-square	103.92***		46.12***		56.41***		183.62***	

***, **, and * indicate significance at the 1%, 5%, and 10%, respectively.

Table 18. Estimated probit regression model for stumpage stands with discount rates calculated by ownership.

Variable	Forest Industry	TIMOs	REITs	NIPF
	Coefficient (*z*-test)	Coefficient (*z*-test)	Coefficient (*z*-test)	Coefficient (*z*-test)
Constant	-0.43**	-0.35	-0.33	-0.93***
	(-2.28)	(-1.27)	(-1.22)	(-9.69)
Discounted Timber value	8.16E-4***	3.73E-4**	3.40E-4**	3.72E-4***
($/ha), *t* to *t+1*	(6.66)	(2.00)	(2.18)	(6.59)
Stand volume	3.28E-3***	3.17E-3**	3.57E-3***	3.13E-3***
(m^3ha^{-1})	(4.42)	(2.37)	(2.77)	(8.00)
$(\text{Stand volume})^2$	-3.27E-6***	-2.97E-6	-2.22E-6	-2.93E-6***
	(-3.07)	(-1.23)	(-1.14)	(-5.64)
Growth volume	2.21E-3	-1.21E-4	-2.66E-3	2.54E-3***
(m^3ha^{-1})	(1.39)	(-0.06)	(-1.11)	(2.93)
$(\text{Growth volume})^2$	-7.21E-7	-7.44E-7	4.07E-6	-8.43E-6**
	(-0.15)	(-0.20)	(0.65)	(-2.56)
Stand origin	0.45***	0.29*	0.57***	0.51***
	(3.44)	(1.70)	(3.08)	(8.79)
Coastal plain	-0.52***	-0.08	-0.87***	-0.26***
	(-4.99)	(-0.57)	(-5.31)	(-4.62)
Distance to road	0.29**	0.08	0.04	-0.04
	(2.40)	(0.50)	(0.19)	(-0.59)
Slope	-0.03***	-0.05***	-0.02	-0.01***
	(-3.67)	(-4.31)	(-1.50)	(-3.21)
Log likelihood	-482.57	-282.51	-214.01	-1542.12
Chi-square	103.92***	46.12***	56.41***	183.62***

***, **, and * indicate significance at the 1%, 5%, and 10%, respectively.

Table 19. Average estimates of elasticities of stumpage supply with respect to present and future price changes.

Quantity Supply	Price, Period	Average Estimate (Std. Dev.)			
		Forest Industry	TIMOs	REITs	NIPF
	Current price change				
Sawtimber	Sawtimber, *t*	3.64***	1.04***	1.02***	2.39***
		(5.38)	(1.25)	(0.91)	(3.54)
Sawtimber	Pulpwood, *t*	0.43***	0.14***	0.12***	0.21***
		(0.66)	(0.17)	(0.12)	(0.20)
Pulpwood	Sawtimber, *t*	2.81***	0.79***	0.79***	1.93***
		(4.97)	(1.18)	(0.91)	(3.31)
Pulpwood	Pulpwood, *t*	0.37***	0.12***	0.11***	0.19***
		(0.60)	(0.16)	(0.12)	(0.19)
	Future price change				
Sawtimber	Sawtimber, *t + 1*	-3.37***	-1.08***	-0.99***	-2.20***
		(4.32)	(1.28)	(0.91)	(2.82)
Sawtimber	Pulpwood, *t + 1*	-0.42***	-0.15***	-0.13***	-0.22***
		(0.63)	(0.17)	(0.11)	(0.19)
Pulpwood	Sawtimber, *t + 1*	-3.37***	-1.08***	-0.99***	-2.20***
		(4.32)	(1.28)	(0.91)	(2.82)
Pulpwood	Pulpwood, *t + 1*	-0.42***	-0.15***	-0.13***	-0.22***
		(0.63)	(0.17)	(0.11)	(0.19)

***, **, and * indicate statistical significance, different from zero at the 1%, 5%, and 10%, respectively.

Table 20. Pairwise comparison of average estimates of elasticities of stumpage supply with respect to present and future price changes between ownership groups.

Quantity Supply	Price, Period	Difference on averaged estimate of supply elasticity (t – test)					
		FI vs. TIMOs	FI vs. REITs	FI vs. NIPF	TIMOs vs. REITs	TIMOs vs. NIPF	REITs vs. NIPF
	Current price change						
Sawtimber	Sawtimber, *t*	2.59***	2.62***	1.24***	0.02	-1.35***	-1.38***
		(8.71)	(7.82)	(6.87)	(0.25)	(-6.96)	(-6.27)
Sawtimber	Pulpwood, *t*	0.28***	0.30***	0.21***	0.02	-0.07***	-0.09***
		(7.77)	(7.37)	(13.66)	(1.44)	(-6.13)	(-7.04)
Pulpwood	Sawtimber, *t*	2.02***	2.03***	0.88***	0.01	-1.13***	-1.14***
		(8.41)	(7.44)	(5.93)	(0.09)	(-7.13)	(-6.31)
Pulpwood	Pulpwood, *t*	0.25***	0.26***	0.18***	0.01	-0.06***	-0.07***
		(8.53)	(7.78)	(14.10)	(0.74)	(-6.75)	(-6.79)
	Future price change						
Sawtimber	Sawtimber, *t + 1*	-2.29***	-2.39***	-1.17***	-0.09	1.12***	1.22***
		(-11.10)	(-10.34)	(-9.33)	(-1.17)	(8.39)	(8.10)
Sawtimber	Pulpwood, *t + 1*	-0.26***	-0.29***	-0.20***	-0.02**	0.06***	0.09***
		(-8.82)	(-8.54)	(-15.19)	(-2.09)	(6.77)	(8.28)
Pulpwood	Sawtimber, *t + 1*	-2.29***	-2.39***	-1.17***	-0.09	1.12***	1.22***
		(-11.12)	(-10.34)	(-9.34)	(-1.15)	(8.41)	(8.10)
Pulpwood	Pulpwood, *t + 1*	-0.27***	-0.29***	-0.20***	-0.02**	0.06***	0.09***
		(-8.84)	(-8.54)	(-15.20)	(-2.06)	(6.80)	(8.28)

***, **, and * indicate statistical significance, different from zero at the 1%, 5%, and 10%, respectively.

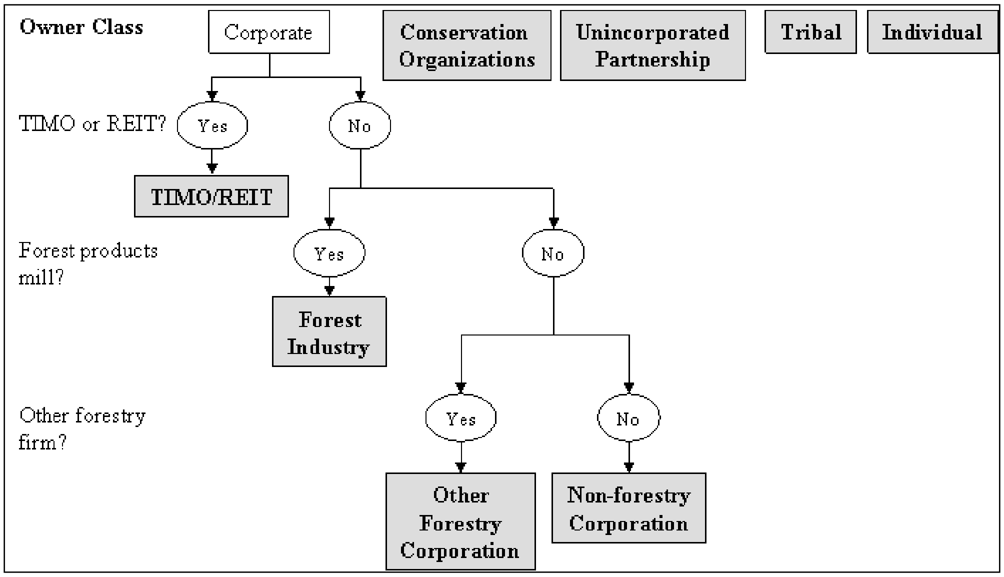

Figure 2. Procedure plot with a series of criterion on verifying forest ownership categories.

Chapter 4. Determinants of Reforestation Behavior by Ownership in the Southern U.S.

Abstract

Owners with different objectives and economic incentives may have different management strategies for their reforestation practices. We apply a binomial logit model to qualified forest stands from the latest complete USDA Forest Service Forest Inventory and Analysis (FIA) cycle for nine southern states to investigate the impact of timberland ownership on replanting probability. The probability of reforestation was about 0.83 for institutional entity, 0.80 for forest industry, and 0.69 for NIPF landowners. The findings indicate that timberland ownerships have an impact on reforestation and that institutional timberland owners with limited investment period of 8-15 years do not hinder their efforts on reforestation and stewardship in forest management.

1. Introduction

One of critical silvicultural management decisions is whether to reforest after harvesting. Replanting following a clearcut harvest is a process of re-establishing sustainable forest. Owners with different objectives and economic incentives may have different management strategies for their reforestation practices. However, over the past decades, the private forests in United States have experienced dramatic changes in timberland ownership (Sun and Zhang 2011).

Beginning in the 1990s, forest products firms sold their timberland to institutional investors. The timberland investment can provide an attractive return to institutional buyer into timberland ownership since the long-term investment in timberland can meet institutional needs which require a greater benefit in the long run with low risk, moderate return or better, and non-correlated with traditional investment (Rinehart 1985; Binkley et al. 1996). On behalf of financial institutions, two classes of timberland organizations emerged in the 1990s (i.e., timberland investment management organizations (TIMOs) and real estate investment trusts (REITs)). TIMOs and REITs are responsible for managing the timberland to maximize the long-term total return on their timberland assets, rather than annual cash flows from timber sales (Yale Forest Forum Review 2002). If silvicultural practices can enhance the sustainability, productivity, and marketability of the lands, consistent forest management may be likely to be performed on institutional investment timberland.

The objective of forest products firms focuses on using the forestland base as a supply for manufacturing facilities (Jin and Sader 2006). Traditional forest industry is oriented toward converting raw materials into solid wood or paper products which is a capital intensive process and is dependent on continuous output and high short-term cash flows (Mendell et al. 2008).

Therefore, forest products firms might experience period scarcity of capital availability for silvicultural investment.

Understanding the role of ownership in silvicultural forest practices would be useful in developing sustainable forest management. However, there have been few studies with regard to institutional timberland ownership which explore the ownership impact on silvicultural forest operations, empirically analyze the determinants on reforestation behavior, and compare reforestation probability between different timberland ownership groups. This study will shed some lights on these unanswered areas. To model landowner's replanting behavior, we use a utility maximization approach which has been commonly introduced in the forestry literature (Hyberg and Holthausen 1989; Nagubadi et al. 1996; Amacher et al. 2003; Sun et al. 2008). It is assumed that landowners are rational utility maximizing managers. Since reforestation management activities usually occur following harvest (Li and Zhang 2007; Sun et al. 2008), we empirically exclude the stands without conducting timber harvesting prior to landowners' reforestation choices.

2. Literatures

Many studies have investigated landowner reforestation behavior with regard to forest industry and non-industry private forest (NIPF) landowners (Amacher et al. 2003). In general, these studies modeled landowner reforestation choices as a binary choice: reforestation or no reforestation. Royer (1987), for example, employed logistic regression to model reforestation probabilities. Income, reforestation costs, government cost-sharing, technical assistance, and pulpwood price were highly significant determinants of reforestation. Hyberg and Holthausen (1989) also used logistic regression to investigate harvest timing and reforestation investment choices of private landowners and obtained similar results.

Other modeling approaches included Zhang and Flick (2001), who estimated a two-step selectivity model, and found income and government financial assistance programs positively related to increased reforestation probabilities. Li and Zhang (2007) used panel data models to analyze tree planting, separately with regard to nonindustrial private forestland (NIPF) and forest industry in the US South. They concluded that sawtimber price, income, cost of capital, and cost-share programs were significantly related to NIPF tree planting, and stumpage prices and reforestation cost significantly influenced forest industry tree planting. Besides the above variables which were usually included in reforestation analysis, population growth and migration accelerated the conversion of forest lands for urban uses, which increase the opportunity cost of reforestation (Kline et al. 2004; Nagubadi and Zhang 2005; Polyakov and Zhang 2008).

3. Methodology

A discrete regression analysis has been widely used in empirical research to estimate the reforestation behavior (Royer 1987; Straka and Doolittle 1988; Hyberg and Holthausen 1989; Zhang and Mehmood 2001). In this study, a logistic probability model is employed to estimate the determinants of the probability of reforestation with regard to different land ownerships. A binary variable labeled as Y^* indicates whether a landowner carries out reforestation activity or not. The landowners' replanting behavior is modeled as a function of variables, x_i, that are composed of stand conditions, market factors, and land ownerships. Conceptually, the binary logit model is mathematically expressed as:

$$Y^* = \beta' x_i + \epsilon, \quad (1)$$

$$Y = 1 \text{ if } Y^* > 0 \text{ and } Y = 0 \text{ if } Y^* \leq 0, \epsilon \sim N(0, 1),$$

where Y^* is not observed and Equation (1) represents what is observed from Y and x_i is defined as landowner i's reforestation choice.

A probability of reforestation is estimated from the binomial logit model, specified as $\Lambda(\cdot)$ to indicate the logistic cumulative distribution function:

$$Prob(Y = 1) = \frac{e^{\beta' x_i}}{1+e^{\beta' x_i}} = \Lambda(\beta' x_i). \quad (2)$$

Estimation of binomial model is usually based on the method of maximum likelihood (Greene 2003). For the logistic distribution, the log-likelihood is expressed as:

$$\ln L = \sum_{Y=0} \ln[1 - \Lambda(\beta' x_i)] + \sum_{Y=1} \ln \Lambda(\beta' x_i). \quad (3)$$

Furthermore, marginal effect is mathematically equal to $\Lambda(\beta' x_i)[1 - \Lambda(\beta' x_i)]\beta$ for the binomial logit model.

Empirical estimation of Equation (1) is conducted by using stand level data on replanting choice and correlated explanatory variables in this study. Systematic differences in the distribution of Y^* across stands might not meet the optimality properties of maximum likelihood estimation (Greene 2003). Previous studies empirically derive and prove that different forest ownership categories have different alternative rates of return (Newman and Wear 1993) and intend to manage their forests examined toward different production objectives and different market preferences (Prestemon and Wear 2000; Li and Zhang 2007). This indicates that different ownership categories (i.e., forest industry, institutional entity, and nonindustrial private forest owners) need to be analyzed through separate estimation models.

This study would empirically ensure that a clearcut harvest is conducted on all sample plots, and timber harvest and reforestation management activities take place during the inventory cycle. A clearcut harvest is empirically defined by Forest Inventory Analysis (FIA) as: the removal of the marjority of the merchantable trees in a stand. Although reforestation behavior is not necessarily undertaken upon harvesting (Amacher et al. 2003), tree planting is significantly and positively related to previous-year harvest (Li and Zhang 2007). Moreover, for landowners who replanted after harvest, majority of them did reforestation within 1 year (Sun et al. 2008).

FIA database provide estimation calculation of timber supply for both of sawtimber and pulpwood. Particularly, Equation (1) is mathematically expressed as (denoting the ownership category as *j*, pulpwood as *p*, and sawtimber as *s*):

$$Y_j^* = \omega_{0j} + \omega_{1j} NetValue_p + \omega_{2j} NetValue_s + \omega_{3j} Distance$$
$$+\omega_{4j} Slope + \omega_{5j} CoastalPlain + \omega_{6j} Population$$
$$+\omega_{7j} ForestIndustry + \omega_{8j} InstitutionalEntity + \epsilon_j \quad (4)$$

where *NetValue* is the expected total timber revenue minus the costs of silvicultural effort in this study. *Distance* is equal to one if horizontal distance to improved road was less than or equal to 0.5 miles and zero otherwise, as well as *Coastal Plain* is a dummy variable and indicates whether the stand is sampled from coastal plain or not. *Slope* engages in expressing the angle of slope of the stand condition. *Population* is a proxy index to indicate urbanization. *Forest Industry* and *Institutional Entity* are equal to one, separately representing the timberland ownership, and zero otherwise. As describe above, conditions of empirical estimation are imposed to meet the effects of pulpwood and sawtimber net income to be equal: $\omega_{1j} = \omega_{2j}$. Thus, net timber value in this study is the expected total timber value of pulpwood and sawtimber minus the costs of reforestation effort.

4. Data

A study region for nine states in the southern U.S. was used to investigate the occurrence probability of reforestation with regard to three timberland ownership groups (i.e., forest industry, institutional entity, and NIPF landowners). We selected the most recent completed inventory cycle with the fixed radius plot design across nine southern states: Alabama cycle 8

(2001-2005), Arkansas cycle 8 (2000-2005), Florida cycle 8 (2002-2007), Georgia cycle 8 (1998-2004), North Carolina cycle 8 (2003-2007), South Carolina cycle 9 (2002-2006), Tennessee cycle8 (2005-2009), Texas cycle 8 (2004-2008), and Virginia cycle 8 (2002-2007). USFS FIA forest inventories during the study period provide data for all variables, except stumpage prices, reforestation cost, and county population. FIA data on volumes by forest product, ownership, reforestation choices, and site characteristics can be compiled for matched stands. For every forested stand, the ownership was determined from tax records and forest mensuration data were collected in the field. Since TIMOs and REITs were not specifically identified in the FIA database, we further classified the owners and identified these TIMO and REIT owners by using the name and address information obtained from the tax records maintained by FIA program. Finally, three timberland ownership categories were labeled as forest industry, institutional entity (TIMO or REIT), and NIPF landowners.

Three variables were constructed from non-FIA data to represent market factors: sawtimber price, pulpwood price, and reforestation cost. Nominal prices for sawtimber and pulpwood at the time of harvest were obtained from Timber-Mart South. Nominal costs for forestry practices in the South at the time of harvest were obtained from the Cost and Cost Trends series produced on two-year intervals (Dubois et al. 1995; Dubois et al. 1997; Dubois et al. 1999; Dubois et al. 2001; Dubois et al. 2003; Folegatti et al. 2007). For the unreported years, cost was calculated by averaging the costs over adjacent years. Reforestation costs included mechanical site preparation and hand planting. Real prices and costs (adjusted for inflation, expressed in 1992 dollars) were calculated by dividing their nominal values by the Producer Price Index. Thus, sawtimber price, pulpwood price, and reforestation cost were expressed in real terms. Real stumpage prices and reforestation costs between the beginning year of FIA cycle and specific measure year for a stand were taken as the average annual index-deflated stumpage prices and reforestation cost. For example, a stand in Alabama was measured in 2004 during the FIA cycle 8 and then the real stumpage prices and reforestation cost were averaged over the year 2001 through 2004. Additionally, the variable *Population* was obtained from the 2010 complete economic and demographic data source (CEDDS) to indicate urbanization level by county and year.

5. Results

We analyze the behavior of landowner reforestation in forest stands and estimate the probability of replanting across the three private ownership categories. Accordingly, a binomial logit model is applied to the problem whether to replant or not, based on the method of maximum likelihood.

5.1. Descriptive summary

Tree replanting model is firstly conducted for all landowners to explore the ownership's effect on reforestation and then separate regression models are specified for three ownerships to distinguish the speculative contribution of explanatory variables into reforestation choices by timberland ownership. Table 21 summarizes descriptive statistics on stand attributes with regard to ownerships. About 49% of timberland stands were owned by NIPF landowners, about 23% by forest industry, and about 28% by institutional entities. Of the 583 qualified stands, there were 437 stands which were replanted following a clearcut harvest. Reforestation probabilities in industry and institution stands were higher than in NIPF stands.

The descriptive statistics for the independent variables are similar across the three ownership groups. Taking forest industry as an example, the average removal volume for sawtimber harvested by the 133 qualified landowners was 69 cubic meters per hectare and for pulpwood was 104 cubic meters per hectare. The predominant mileage of horizontal distance to improved road for 83% landowners was less than or equal to 0.5 miles. Coastal plain was the predominant physiographic survey region for 65% stands while the remainder had either piedmond, mount, or delta physiographic regions. Average angle of slope, in percent, of the site condition was 3.6. The mean of total county population was 43.33 thousands. For market factors, real sawtimber price was 65.25 dollar per cubic meter, real pulpwood price was 3.29 dollar per cubic meter, and real reforestation cost was 332.40 dollar per hectare. Additionally, *REITs* was defined only for institutional entity group as: the stand managed by REITs for 65% while the remainder was managed by TIMOs.

5.2. Reforestation choices

Table 22 reports maximum likelihood estimation of a logit model of tree reforestation for all stands. Industry and institutional stands were positive and significant, respectively at the 5% and 1 % level, implying that forest industry and institutional timberland investors are more likely to conduct reforestation than NIPF landowners. The coefficient for *Coastal Plain* was positive and significant at the 1% level. Thus, trees are more likely to be replanted in coastal plain region. Additionally, landowners who reside in a county with more population have lower probability of undertaking reforestation activities following harvest than others who live in the less-population administrative county since *Population* was negatively related to reforestation probability at the 10% level.

Separate logit models are employed to specify the distinctive contribution of interested characteristics to reforestation across three ownership categories (Table 23). For all the three ownerships, *Coastal Plain* had positive and significant effect on the probability of replanting. Landowners are more likely to replant trees following a clearcut harvest if the stands located in the coastal plain physiographic region. The variable *Distance* was negatively and significantly related to the probability of reforestation at the 10% level for NIPF landowners, but positively for institutional entity. *Slope* was negative and only significant for institutional investment group, implying that institutional stands with steeper inclines are less likely to be replanted than other institutional entities. The variable *Population* negatively influenced the reforestation probability only for forest industry at the 5% significance level. Overall, the variable *Coastal Plain* positively influenced the landowner's reforestation choice across all the three ownership categories. Distance to improved road, county population, and slope of the site condition demonstrated different degrees of influence on landowner reforestation behavior in a specific ownership group. Among these significant variables, *Coastal Plain* had the largest marginal effect at 0.18 for forest industry and 0.23 for NIPF landowners and *Distance* had the largest marginal effect at 0.20 for institutional entity.

5.3. Estimated reforestation probability and comparison

Table 24 addresses the mean estimates and standard deviation of reforestation probabilities across three ownerships and the pairwise comparison between two given ownership categories. Coefficient of the variable *REITs* was not statistically significant in Table 23, implying that TIMOs and REITs displayed similar reforestation behavior. Hence, TIMOs and REITs were classified as the one ownership group in Table 24, institutional landowners. In general, the average probability of stumpage reforestation was 0.75 for all-managed stands estimated from the binomial logit model in Table 22. The reforestation probability was 0.83 for institutional landowners, 0.80 for forest industry, and 0.69 for NIPF landowners.

The process of comparing probability in pair of ownership groups is to judge which of each ownership group is more likely to replant trees following a clearcut harvest, or has a greater amount of reforestation probability. Wald test is commonly used to perform multiple degree of freedom tests on sets of dummy variables used to model categorical variables in regression (Greene 2003), and to test that the difference of estimated probabilities in pairs is equal to zero in this study. The greater amount of difference was 0.14 and 0.12 at the 1% significant level, by examining reforestation probabilities of institutional entity and forest industry in comparison with NIPF landowners. The difference of reforestation probabilities in pair of forest industry and institutional entity groups was negative at the 5% significant level with relatively smaller value of 0.02 than other two pairs. In terms of different ownerships, institution and industry stands are more likely to be replanted than NIPF stands.

6. Discussion

A binomial logit model is employed to examine the probability of reforestation among timberland ownership groups. The study empirically examines the impact of timberland ownership on replanting behavior and reveals that institutional timberland owners with limited investment period do not hinder their efforts on reforestation management. It indicates distinctive features of forest management strategies with regard to different owners.

Institutional investors are inclined to operate silvicultural treatment in forest management. Although TIMOs and REITs manage the timberland on behalf of their clients for a specified period of time (8-15 years), they tend to conduct management practices on a given piece of land and have an incentive to leave the land as good or better condition than previously when they acquired it. There might be three factors that influence institutional inclination on silvicultural management. Firstly, tax exemption policy allows institutional investors to obtain a greater return in the long run. As long as the investment can be economically justified, TIMOs and REITs have inclination to conduct management practices to enhance stand value and improve stand health. Secondly, institutional investors do not suffer the limitation on capital availability (Browne 2001). They can move their capital into management practices with relative ease, in comparison with traditional industry C-corporations and NIPF landowners. Finally, since timberland has low correlation with other traditional asset such as stocks (Clutter et al. 2007), reforestation can be viewed as an investment that can provide an appropriate return. In general, TIMO and REITs would generate regular and consistent investment in silvicultural practices which offer potential profitable returns.

Ownership is a critical variable in propensity of reforestation. Institutional landowners are more likely to replant timber than other industry and NIPF landowners. Generating interest in timber production among institutional entities would be an approach to enhance reforestation likelihood and expand forest area. Strategically, TIMOs and REITs generally rely on professional foresters to oversee their lands, compared to NIPF landowners. They tend to employ professional forestry experts to advise them to build forest management functions and acquire specialized silvicultural expertise from service providers. Since institutional organizations tend to employ professional foresters to manage their timber holdings, promoting assistance of forestry consultants on timber replanting would be an effective policy tool to prompt reforestation among institutional owners. Additionally, enhancing the understanding of timberland investment benefits in terms of financial and economic aspects is essential to drive TIMOs and REITs to undertake consistent replanting behavior. For example, timberland investment brings an attractive return into diversified portfolio for a long period with low correlation with traditional investment regarding a given level of risk (Binkley et al. 1996).

Recognizing the reality that change in timberland ownerships has major implications on sustainable forest management, brings scholars' interests in related studies concerning institutional owners. Future research can continue to move forward through examining the impact of forest species, government assistance programs, and other potentially influential factors on the behavior of reforestation on institutional timberland. Silvicultural treatments, such as fire management, fertilization and herbicide applications, are other potentially issues where the ownership would be relevant.

Table 21. Description and summary statistics with regard to different ownership categories.

	Variable	Sample Mean	Sample SD
All Ownerships	Cycle 8 sawtimber harvest volume (m^3/ hectare)	65.60	85.45
	Cycle 8 pulpwood harvest volume (m^3/ hectare)	103.22	98.35
	Dummy variable: 1 if horizontal distance to improved road was less than or equal to 0.5 mile	0.85	--
	Slope: the angle of slope of the site condition	3.50	6.85
	Coastal plain: 1 if coastal plain; 0 otherwise	0.64	--
	Dummy variable: 1 if industry landowner; 0 otherwise	0.23	--
	Dummy variable : 1 if institutional landowner; 0 otherwise	0.28	--
	Total population by county (thousand)	53.51	87.77
	Sawtimber real price (base = 1992) ($/ m^3)	66.34	10.01
	Pulpwood real price (base = 1992) ($/ m^3)	3.56	0.99
	Reforestation real cost (base = 1992) ($/ hectare)	338.34	33.74
	Reforestation probability	0.75	--
Forest Industry	Cycle 8 sawtimber harvest volume (m^3/ hectare)	69.14	82.69
	Cycle 8 pulpwood harvest volume (m^3/ hectare)	104.42	90.08
	Dummy variable: 1 if horizontal distance to improved road was less than or equal to 0.5 mile	0.83	--
	Slope: the angle of slope of the site condition	3.61	6.72
	Coastal plain: 1 if coastal plain; 0 otherwise	0.65	--
	Total population by county (thousand)	43.33	52.73
	Sawtimber real price (base = 1992) ($/ m^3)	65.25	9.10
	Pulpwood real price (base = 1992) ($/ m^3)	3.29	0.82
	Reforestation real cost (base = 1992) ($/ hectare)	332.40	37.01
	Reforestation probability	0.80	--
Institutional Entity	Cycle 8 sawtimber harvest volume (m^3/ hectare)	58.25	60.25
	Cycle 8 pulpwood harvest volume (m^3/ hectare)	101.58	97.22
	Dummy variable: 1 if horizontal distance to improved road was less than or equal to 0.5 mile	0.91	--
	Slope: the angle of slope of the site condition	2.38	5.00
	Coastal plain: 1 if coastal plain; 0 otherwise	0.57	--
	Total population by county (thousand)	40.37	57.40
	REITs: 1 if the landowner was REITs; 0 otherwise	0.65	--
	Sawtimber real price (base = 1992) ($/ m^3)	66.17	8.55
	Pulpwood real price (base = 1992) ($/ m^3)	3.57	0.88
	Reforestation real cost (base = 1992) ($/ hectare)	342.04	31.29
	Reforestation probability	0.83	--
NIPF	Cycle 8 sawtimber harvest volume (m^3/ hectare)	68.11	97.88
	Cycle 8 pulpwood harvest volume (m^3/ hectare)	103.60	102.85
	Dummy variable: 1 if horizontal distance to improved road was less than or equal to 0.5 mile	0.82	--
	Slope: the angle of slope of the site condition	4.07	7.70
	Coastal plain: 1 if coastal plain; 0 otherwise	0.68	--
	Total population by county (thousand)	65.60	110.46
	Sawtimber real price (base = 1992) ($/ hectare)	66.95	11.11
	Pulpwood real price (base = 1992) ($/ m^3)	3.68	1.10
	Reforestation real cost (base = 1992) ($/ acre)	339.00	33.24
	Reforestation probability	0.69	--

Table 22. A logit regression model estimating reforestation probabilities for ALL sampled stumpage stands located in the 9 southern states during the study period.

Variable	Coefficient	*z*-test	Marginal Effect
Constant	0.38	1.08	--
Net timber value ($/hectare)	1.27E-5	0.77	2.24E-6
Distance	-0.29	-1.00	-0.05
Slope	9.05E-5	0.01	1.60E-5
Forest industry	0.67**	2.54	0.12***
Institutional entity	0.94***	3.61	0.17***
Coastal plain	1.09***	4.69	0.19***
Population	-1.75E-3*	-1.63	-3.09E-4*
Log likelihood	-304.69		
Chi-square	42.44***		
Number of obs	583		

***, **, and * indicate statistical significance, different from zero at the 1%, 5%, and 10%, respectively.

Table 23. Separate logit regression models estimating reforestation probabilities with regard for three forest landowner categories in the 9 southern states during the study period.

Variable	Coefficient	*z*-test	Marginal Effect
Forest Industry			
Constant	2.03**	2.10	--
Net timber value ($/acre)	-4.93E-6	-0.12	-6.91E-7
Distance	-1.16	-1.41	-0.16
Slope	0.02	0.58	3.01E-3
Coastal plain	1.30**	2.52	0.18***
Population	-0.01**	-2.15	-1.22E-3**
Log likelihood	-59.74		
Chi-square	11.94**		
Number of obs	133		
Institutional Entity			
Constant	0.52	0.61	--
Net timber value ($/acre)	-3.92E-5	-0.79	-4.65E-6
Distance	1.69**	2.55	0.20**
Slope	-0.07*	-1.76	-0.01*
Coastal plain	0.94*	1.81	0.11*
Population	3.61E-3	0.58	4.28E-4
REITs	-0.87	-1.62	-0.10*
Log likelihood	-64.59		
Chi-square	19.97***		
Number of obs	162		
NIPF			
Constant	0.60	1.41	--
Net timber value ($/acre)	2.29E-5	1.15	4.81E-6
Distance	-0.65*	-1.76	-0.14*
Slope	4.47E-3	0.24	9.42E-4
Coastal plain	1.09***	3.38	0.23***
Population	-1.48E-3	-1.28	-3.12E-4
		1.41	
Log likelihood	-169.99		
Chi-square	17.77***		
Number of obs	288		

***, **, and * indicate statistical significance, different from zero at the 1%, 5%, and 10%, respectively.

Table 24. Estimated average probability of stumpage reforestation with respect to different ownership groups.

	All	Forest Industry	Institutional Entity	NIPF
Estimated average probability (Std. Dev.)	0.75 (0.12)	0.80 (0.01)	0.83 (0.01)	0.69 (0.01)
		FI vs. INSTI	FI vs. NIPF	INSTI vs. NIPF
Difference on averaged probabilities (*t* – test)		-0.02** (-2.42)	0.12*** (10.61)	0.14*** (14.16)

***, **, and * indicate statistical significance, different from zero at the 1%, 5%, and 10%, respectively.

Chapter 5. Conclusions

The impact of industrial timberland sale events, both announcements and actual sales, on shareholder values was analyzed by the method of event analysis. In Chapter 2, event analysis measured an abnormal rate of return to provide evidence of market efficiency following a timberland sale event. Also, we used a cross-sectional regression to analyze the market impact of abnormal rate of return and the characteristics of forest products firms and employed the CAPM to study the possible long-term cost associated with industrial timberland sales. Additionally, the Chow test proved that the viability of market rate of return relative to forest products firms and industry was influenced by the selection of width of event window following the event day.

Consequently, the 32 large industrial timberland sale events with the 11 announcements and the 21 sale events, were found. The Chow test statistics selected a 2-day (0, 1) event window for all three groups of events (i.e., the announcement and sale events, the announcement events, and the sale events). Nonetheless, the aggregated abnormal rates of return were reported for each event group in three windows, (0, 1), (0, 2), and (0, 3). For all the 32 events as a group, the aggregated abnormal rates of returns ranged from 1.46% to 1.78% and the largest one was in a 2-day window (0, 1). For the 21 sale event group, the aggregated abnormal rate of returns was the largest in a 4-day window (0, 3), however, the 11 announcement group was the largest in a 2-day window (0, 1). For the capitalization change analysis, the financial variable, *TD*, had a negative impact on capitalization change per transaction land acreage, while *TA* had a positive contribution towards capitalization change. For 100 days before and after the timberland sales, the systematic risk of two out of eleven announcement events significantly increased, while one announcement event decreased. For 150 days, the systematic risk of one firm increased and that of another firm decreased significantly out of the announcement event group. In terms of the sale event group, the changes in systematic risk were significantly related to Meadwestvaco Corp. and Weyerhaeuser Co.

Generally, we found that industrial timberland sales have positive impacts on shareholder values of major U.S. forest products firms. In addition, the change in market capitalization per unit of land sale of these firms is positively related to their size and negatively related to their total debt, as well as the time of sales. Finally, the systematic risk of firms that sold their timberlands did not change much or only increased slightly.

The study in Chapter 3 applied the two-period harvest choice model to institutional timberland investors to explore their behavior with regard to timber harvest and to compare their impact on timber supply in forest stands with other forest ownerships (i.e., forest industry and NIPF landowners). Results addressed that current timber value, stand volume, and net growth volume were significantly and positively related to timber harvest probability while the coefficients of future timber value and squared terms of stand volume and net growth volume were negative. Timber supply was positively associated with current stumpage prices and negatively with future stumpage prices. Additionally, industry and institutional owners were more likely to conduct a partial or final harvest than NIPF.

With 1% current stumpage price increases, forest industry firms acted more price elastic behavior on timber production, compared with both institutional entity and NIPF landowners. Also, institutional landowners increased the smallest amount of timber supply, with values of

1.02% for sawtimber and 0.11% for pulpwood on TIMO-managed stands and with values of 1.38% for sawtimber and 0.15% for pulpwood on REIT-managed stands. Stumpage prices generally affect less harvest quantities in institutional stand than in industry and NIPF stands.

In the study of addressing reforestation behavior, a binomial logit model was applied to estimate the occurrence probabilities of reforestation following harvest with regard to different land ownership categories. Of the 583 sampled stands, there were 437 stands which were replanted following harvest. Forest industry and institutional timberland investors were more likely to conduct reforestation than NIPF landowners. Across the three ownership groups, the variable *Coastal Plain* positively influenced the landowner's reforestation choice across all the three ownership categories. Distance to improved road, county population, and slope of the site condition demonstrated different degrees of influence on landowner reforestation behavior in a specific ownership group. Among these significant variables, *Coastal Plain* had the largest marginal effect at 0.18 for forest industry and 0.23 for NIPF landowners and *Distance* had the largest marginal effect at 0.20 for institutional entity.

Furthermore, the reforestation probability was 0.83 for institutional entity, 0.80 for forest industry, and 0.69 for NIPF landowners. The results show that TIMO and REITs undertake consistent silviculture management activities and institutional owners do not hinder their efforts on reforestation and stewardship in forest management.

As the trend of institutional investment in timberland appear to be continuing in the U.S and have growing impact of timberland ownership, this dissertation illustrated vital concerns regarding the rise of institutional timberland ownership and empirically explored the change of structure and conduct of the timber market and forest silvicultrual management activities. An important concern that future research may address relates to other unanswered issues about this emerging owner group. Particularly, extensive studies may include forest land use, biodiversity conservation, and carbon sequestration to build a comprehensive perception of the adaptive capacity of timberland owned and managed by institutional timberland investors.

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