EVALUATING THE FINANCIAL PERFORMANCE OF THE TIMBER SECTOR IN THE US

by

XIAORUI PIAO

(Under the Direction of Bin Mei)

ABSTRACT

In the past two decades, massive structural changes of timberland ownership occurred in the United States with almost 55 million acres of timberland changed hands. Forestry firms structured as C-Corporations (C-Corps) have either converted to timber real estate investment trusts (REITs) or divested most of their timberland holdings to REITs and timber investment management organizations (TIMOs). REIT, as a unique investment vehicle, is known to have better tax efficiency and liquidity and draws investors' attention. The first part of this dissertation evaluates the long-term financial performance of four publicly-traded timber REIT conversions by an event study using buy-and-hold and cumulative abnormal returns, a zero-investment portfolio approach, and pooled ordinary least squares (OLS) regression. The results show that on average, annualized abnormal returns of about 0.5% are identified before, and over 8.9% are identified after, the REIT conversions. Structural changes have added values to the timber firms in the long run. The second part compares the financial performance of publicly-traded timber REITs with other REITs using the intertemporal capital asset pricing model and multivariate generalized autoregressive conditional heteroscedasticity model. The results show that the conditional volatilities of REITs rise more after good news, and REITs as a whole respond positively to past shocks. Timber REITs, in particular, have large market capitalizations and no excess returns, and are insensitive to recessionary shocks. Timber REITs have the smallest unconditional variance and are most vulnerable to idiosyncratic shocks. The last part of this dissertation examines the determinants of timberland transaction prices in the US South during 2000-2015 using over 340 large transaction data provided by Timber Mart-South. The results show that pine sawtimber prices and the Federal funds rate have significantly positive impacts on transaction prices, while crude oil prices and the US dollar index have significantly negative impacts. Among the 11 Southern states, North Carolina and South Carolina have significantly positive effects on transaction prices, while Alabama, Arkansas, Tennessee, Texas, and Virginia have significantly negative effects. In regards to timberland ownership, C-Corps and TIMOs outperform firms outside the timber industry.

INDEX WORDS: Forest Investments, Economic Evaluation, Timber Industry, Linear Regression, Volatility

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XIAORUI PIAO

B.S., Tianjin University, China, 2008

M.S., Beijing Forestry University, China, 2012

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XIAORUI PIAO

Major Professor: Bin Mei
Committee: William D. Lastrapes
Puneet Dwivedi
Pete Bettinger

Electronic Version Approved:

Suzanne Barbour
Dean of the Graduate School
The University of Georgia
May 2017

DEDICATION

To my family – for the love and encouragement you give me.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

In the US timber sector, five types of landowners have participated in the massive structural changes of timberland ownership since the 1990s. Forest products firms have sold out most of their timberland holdings to privately owned TIMOs and publicly traded timber REITs. US Forest Services and local governments hold timberlands for conservation and recreation purposes, while firms outside the timber industry hold timberlands for land development and carbon sequestration incentives.

As for timber REITs specifically, Plum Creek converted from a Master Limited Partnership (MLP) in 1998. Then Rayonier, Potlatch, and Weyerhaeuser converted from C-Corps in 2003, 2005, and 2009, respectively. Catchmark, a former TIMO, went through initial public offering in 2013. Weyerhaeuser offered to acquire Plum Creek in 2015 and became the largest industry timberland owners in the US.

This dissertation evaluates the financial performance of the timber sector in the US with three independent journal articles. Chapter 2 analyzes the long-term structural changes of timber REIT conversions. Chapter 3 makes the performance comparisons between timber REITs and other REITs. Chapter 4 evaluates the determinants of large timberland transactions in the US South. The last Chapter summarizes the major findings of Chapters 2-4.

CHAPTER 2

LONG-TERM EVENT STUDY OF TIMBER REAL ESTATE INVESTMENT TRUST CONVERSIONS[1]

[1] Piao, X., Mei, B., Zhang, W. Accepted by *Forest Policy and Economics*.
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Abstract

The long-term financial performance of four timber real estate investment trust (REIT) conversions in the United States is evaluated by an event study with one-, two-, and three-year event windows. Three types of benchmarks are used in gauging the abnormal returns. The first benchmark is a portfolio of firms that are closest in size and book-to-market ratio to the timber REITs, the second is a portfolio of pre-conversion timber firms, and the third is an equal-weighted timber exchange traded fund (ETF) comprised of selected forest firms. Four approaches are used to calculate abnormal returns. Buy-and-hold abnormal returns and cumulative abnormal returns measure the preliminary abnormal returns; zero-investment portfolio approach with rolling regression evaluates the market-based risk premiums; and panel data analyses capture the relative advantages of REITs over their competitors within the timber industry. On average, annualized abnormal returns of about 0.5% and 8.9% are identified before and after the REIT conversions. There is no difference between variances of pre- and post-event annualized abnormal returns. Therefore, structural changes have added values to the timber firms in the long run.

Introduction

Real estate investment trust (REIT) is a widely-used corporate structure in the United States in owning and managing various kinds of investment properties such as offices, apartments, hotels, industrial properties, and retail properties (Pagliari et al., 2005). Among many considerations, tax efficiency and liquidity are two major ones. REITs are pass-through entities that pay no income taxes at the corporate level. Instead, corporate income is distributed to the owners and income taxes are only levied at the individual level. In addition, securitized real estate equities can be traded in shares rather than big chunks and thus partially eliminate the entry barrier of timberland investment. For a publicly-traded REIT, liquidity is more improved for the fact that stocks of real estate equities are listed and transacted in well-structured stock exchanges, just like any other financial securities. Currently, more than 200 REITs are publicly traded in the US (Mendell et al., 2008).

In the timberland sector, there were five publicly traded timber REITs: Plum Creek (PCL), Rayonier (RYN), Potlatch (PCH), Weyerhaeuser (WY), and Catchmark (CTT). Among them, PCL pioneered the conversion in June 1998, followed by RYN in August 2003, PCH in September 2005, and WY in December 2009. CTT went through initial public offering in December 2013 with 280,000 acres of timberland valued at $310 million.[2] In February 2016, WY acquired PCL with the new WY owning 13 million acres of industrial grade timberland in the US. PCL used to own and manage approximately 7.8 million acres of timberlands, produce a line of softwood lumber products, extract mineral, and receive royalties from coal bed methane, natural gas and oil production. RYN owns or leases approximately 2.3 million acres of

[2] CTT was previously recognized as Wells Timberland REIT. It is not included in the analysis due to data limitation.

timberlands in the US and New Zealand. RYN also has business segments in real estate, performance fiber, and logs trading. PCH owns about 1.42 million acres of land, and manufactures and sells lumber, panels and particleboard. In addition to US timberlands, WY leases another 14 million acres in Canada, manufactures wood and cellulose fiber products, and manages real estate.

Vertically integrated forest products firms, mostly structured as C-Corporations (C-Corps) and Master Limited Partnerships[3] (MLPs) are predecessors of timber REITs. Pressured by return-driven Wall Street investors and increasing competitions in the timber industry, a separate in business segments took place in the past two decades. Four timber firms converted to REITs, whereas the rest gradually stepped out of timberland management and sold out their timberland holdings (Hood et al., 2015). Such industry-wide segregation probably contributes to a higher level of economic efficiency and better performance of stock returns.

There are sound reasons behind these timber REIT conversions. One is double taxation under the C-Corp structure. C-Corp timber firms are considered separate legal entities from their shareholders. Hence, C-Corps pay taxes on their earnings, just as individuals do. However, when timber firms pay out dividends, those payments incur income tax liabilities for shareholders again. That is, one-dollar income is taxed twice before it is finally realized by shareholders. Income of timber REITs, on the contrary, is taxed only once at the shareholder's level. Therefore, after-tax gains are improved for timber REIT investors. Another reason for the conversions is the undervaluation of timberland assets by the market. Substantial timberland

[3] Master Limited Partnerships (MLP) are also pass-through entities. However, they have limitations in attracting institutional investors. Today, more than 70% of common equities of public timber REITs are controlled by institutional investors except for CTT, which has 20%.

ownership changes occurred over the last two decades, when timber REITs and timberland investment management organizations (TIMOs) acquired timberlands from vertically-integrated forest products firms and private timberland owners (Binkley, 2008). Under the generally accepted accounting principles that are adopted in the US, assets are recognized by their book values. This value recognition principle puts timber firms in a disadvantageous position because most timberland assets were acquired a long time ago with few subsequent transactions. As such, the book values of timberlands are way below their fair market values. Being converted to public REITs and focused solely on timberland management, more market information is incorporated and mispricing of timberlands is alleviated. Lastly, public timber REITs offer more liquidity and transparency than their counterparts, private-equity timberland assets. TIMOs typically have minimum investment criteria that are prohibitive to retail investors and require a commitment of 10-15 years, whereas shares of publicly traded timber REITs are more easily traded. In addition, financial information of TIMOs is not disclosed to the general public, whereas public timber REITs are subject to Securities and Exchange Commission filings and routinely covered by Wall Street analysts.

The structural changes being broadly recognized, a few studies have investigated their impacts on the financial performance (Mei and Sun, 2008; Mendell et al., 2008; Sun, 2013a). However, these studies are short-term analyses in nature. The long-term financial performance of publicly-traded timber REITs after conversions has not been inspected yet. This study aims to fill the knowledge gap by applying a long-term event study on timber REIT conversions with a null hypothesis being that there are no long-term abnormal returns after the conversions.

Literature Review

In finance, event studies have been prolific on a series of corporate topics such as mergers and acquisitions, earnings announcements, dividend payments, initial public offerings, seasoned equity offerings, share repurchases, proxy fights, stock splits, spinoffs, and so on. A brief review of the literature can be found in Fama (1998). Methodologies of long-term event studies evolve over decades. The measurement of abnormal returns is of great importance and leads to various ways in selecting benchmarks such as market return proxy, individual firms, and stock portfolios, all of which demonstrate certain merits and are chosen based on the purpose of a specific study (Abadie and Gardeazabal, 2003; Barber and Lyon, 1997; Fama, 1998).

Cumulative abnormal returns (CARs) are first used in short-term event studies and demonstrate conclusive favorable statistical properties over other methods (Fama, 1998). However, there remains an ongoing dispute between buy-and-hold abnormal returns (BHARs) and CARs in long-term event studies (Barber and Lyon, 1997; Fama, 1998). Hence, recent long-term event studies have adopted both for the sake of robustness. Fama (1998) argued the vulnerability of gauging long-term abnormal returns due to incorrectly measuring risks (i.e., the bad-model problem) so alternative asset pricing models should be used. Another approach that addresses abnormal returns is known as the zero-investment portfolio approach, in which an investor holds long positions in the target firms and short positions in benchmark firms (e.g., Eberhart et al., 2004; Ikenberry and Ramnath, 2002). Then, the return-risk relation of the portfolio across the stock market is explained by the Fama-French three-factor model (Fama and French, 1993) and the intercept from the regression is interpreted as a measure of abnormal returns. Rolling regression analyses are often used to further examine the stability of abnormal returns over time. Regarding idiosyncratic risks, the incentives of an event may be endogenously incorporated by the firm. This fact leads to additional analyses on the underlying causal effects and mechanisms of long-term financial performance. Hence, a panel data analysis can be used to deal with the endogeneity issues and reveal causal effects after controlling for other key financial variables (Donald and Lang, 2007).

In the forest products industry, Cascio (2006) identified nine major mergers and acquisitions during 1995-2002 that involve 15 publicly-traded, integrated forest firms, and found a significant 15% abnormal return or a net creation of $4.7 billion of market value attributable to the merger and acquisition announcements. Mei and Sun (2008) compiled a more complete database consisting of 70 mergers and acquisitions in the forest products industry from 1990 to 2004, evaluated their impact on the financial performance of forest firms, and found significant gains for the target firms. Sun and Zhang (2011) investigated the impact of vast industrial timberland sales over 1997-2007 and concluded that these sales create values for forest products firms involved without changing much on the systematic risk. Sun et al. (2013b) examined both abnormal returns and volatility of public timber firms induced by timberland ownership changes over 1997-2010 and found mixed results.

Looking at timber REITs specifically, Mendell et al. (2008) examined the market response in the short term and found significant abnormal returns. They concluded that investors are in favor of the REIT conversions. Sun (2013a) assessed the joint distribution between daily returns of public timber REITs and two market indices and asserted that each firm, except for PCL, had smaller volatility of tail dependence after the conversion. Sun et al. (2013b) found positive abnormal returns as well as increased volatility related to the REIT conversions.

Long-term event studies in the forest industry have been scarce. The only one is by Cascio (2006), who applied the calendar-time portfolio approach to estimate the long-run performance of forest firms after mergers and acquisitions. Insignificant three-year average abnormal returns of -5% and -11% were identified compared to benchmark portfolios based on size and risk, respectively. However, as aforementioned, results of long-term event studies largely depend on the selection of benchmarks. A common way to address it is to examine the robustness of the results to different measures (Eberhart et al., 2004).

Methodologies

Event study, introduced by Fama et al. (1969), is a common method to evaluate the responses of stock returns to new information. A key assumption underlying event studies is the market efficiency, which dictates that market reaction to new information should be both rapid and lasting. Short-term event studies test the quickness of the market, whereas long-term event studies test the lasting effect. Regardless, an event study starts by defining an event window, during which actual returns and benchmark returns are compared and the differences are recognized as abnormal returns. Both pre- and post-event abnormal returns should be computed to detect the influence of certain event. To examine the short-term anomaly, CARs are computed by summing up abnormal returns over the event window. Then, a *t*-test is conducted to test the null hypothesis of no cumulative abnormal returns. Different event windows may lead to different findings, so timing is crucial in a short-term event study (MacKinlay, 1997).

The long-term abnormal returns are not easy to detect because of investors' financial tactics, more uncertainties over a longer period, and bad-model problems (Andrade et al., 2001; Fama, 1998). The lengthy stock holding period makes it difficult to determine whether a 15% annual abnormal return, for example, is statistically larger than zero. Biases in test statistics introduced by the CAR method force researchers to seek new methods for long-term event analyses. This study uses multiple methods and benchmarks to generate robust measurement of abnormal returns.

Four Approaches to Compute Abnormal Returns

Buy-and-hold Abnormal Returns

Barber and Lyon (1997) claim that a benchmark firm with the closest size and book-to-market ratio to the target firm yields well-specified test statistics. Furthermore, buy-and-hold abnormal returns (BHARs) replace CARs to gauge the abnormal performance:

$$BHAR_{it} = \prod_{t=1}^{T}(1+R_{it}) - \prod_{t=1}^{T}(1+R_{bt}) \tag{2.1}$$

where R_{it} is return for the target firm, R_{bt} is return on the benchmark, and T is the length of the event window.

Cumulative Abnormal Returns

Despite Barber and Lyon's favor in BHARs, Fama (1998) insists on using CARs for abnormal returns. CARs can be constructed with a matching firm, a matching portfolio, or the CAPM. The CAPM relates the expected return on an asset to the risk-free rate and the market return in a linear function

$$E[R_i] = R_f + \beta_i[R_m - R_f] \tag{2.2}$$

where $E[R_i]$ is the expected return for the target asset, R_f is the risk-free return, β_i is known as the systematic risk of the target asset, and R_m is the return on a market proxy.

In the regression form, the CAPM can be expressed as (Jensen, 1968)

$$R_{it} - R_{ft} = \alpha_i + \beta_i(R_{mt} - R_{ft}) + \varepsilon_{it}\,. \tag{2.3}$$

Accordingly, CARs based on the CAPM are constructed by

$$\text{CAR}_{it} = \sum_{t=1}^{T} [R_{it} - (\hat{\alpha}_i + \hat{\beta}_i R_{mt})] \quad (2.4)$$

where $\hat{\alpha}$ and $\hat{\beta}$ are coefficient estimates from the CAPM regression, and T is the length of the event window.

Zero-investment Portfolio Approach with Rolling Regressions

Another method for long-term abnormal returns is the zero-investment portfolio approach based on the Fama-French three-factor model. The portfolio consists of longing the target asset and shorting the benchmark portfolio so that abnormal returns should not exist to prevent an arbitrage opportunity. Specifically, the following regression is used

$$R_{pt} - R_{ft} = \alpha + b(R_{mt} - R_{ft}) + sSMB_t + hHML_t + \varepsilon_{pt} \quad (2.5)$$

where $R_{pt} = R_{it} - R_{bt}$ is the return for zero-investment portfolio, R_{it} is return for the target firm, R_{bt} is the return for the benchmark, SMB_t represents the size factor defined as the return difference between portfolios of small and large stocks, HML_t represents the value factor defined as the return difference between portfolios of high and low book-to-market ratio stocks, and ε_{pt} is the error term. The intercept α indicates the abnormal return.

In this approach, rolling regression helps the initial zero-investment portfolio approach obtain stable estimated coefficients over time (Meese and Rogoff, 1988). Considering an event window of T months and a rolling window of t months ($T > t$), we conduct ($T - t + 1$) times of rolling regression and obtain ($T - t + 1$) alphas. The mean of alphas is the average monthly abnormal return, and annualized abnormal returns (AARs) are calculated as 12 times the mean. If alphas are truly constant across different event windows, we may conclude that abnormal returns are persistent regardless of the timing. The stability of the rolling analysis depends on the two-tailed *t*-statistics.

Panel Data Regression

Although both difference in difference and panel data approaches capture the relationship between abnormal returns and the occurrence of an event, the limited number of observations and possible adjustment of firms' books suggest panel data regression more suitable as to expand the time windows (Donald and Lang, 2007). The causal effects are expressed as the event dummies combined with lagged explanatory variables leading to current abnormal returns between timber REITs and their competitors. Three theoretical mechanisms behind the conversions, i.e., taxation, mark-to-market values of timberland assets, and liquidity, are captured by tax-to-size ratio, binary REIT dummy, [4] and turnover rate. The time-variant and time-invariant effects are tested to find the most appropriate panel data approaches. Pooled OLS regression is used (Padachi, 2006)

$$BHAR = f(Event, REIT, Tax, Turnover, ROE, EPS, Size) \quad (2.6)$$

where $BHAR$ is the annualized buy-and-hold abnormal returns of timber REITs and their competitors with the timber ETF as the benchmark, $Event$ is the binary dummy variable representing the occurrence of the event, $REIT$ is the binary dummy variable indicating timber REIT after the event. The rest of the independent variables are defined as numerical values two years before the event: Tax is the tax-to-size ratio, $Turnover$ is the turnover rate, ROE is the return on equity, EPS is earnings per share, and $Size$ is the natural logarithm of market cap. The

[4] Timber REITs focus on timberland management, while forest products firms have gradually sold out their timberlands. The comparison of these business behaviors, and thus the correction of undervalued timberland assets is captured by the REIT dummy.

sum of coefficients of *Event* and *REIT* dummies measures annualized abnormal returns of timber REITs over three years. Four models are used to examine robustness among different sets of explanatory variables.

Three Types of Benchmarks

Benchmark 1: Benchmark Portfolios Similar in Size and Book-to-market Ratio

A portfolio of firms with similar size and book-to-market ratio to the target firm is used. The advantage is evident by the modern portfolio theory: a portfolio is less risky than an individual firm. The benchmark portfolio enables a solid comparison as there is no "convenient coincidence" or "lucky guess" in this treatment (Barber and Lyon, 1997). This procedure can be further divided into four steps. First, sizes and book-to-market ratios are calculated and ranked during the fiscal year of the event. Second, firms are filtered by size first and then by book-to-market ratio to construct a valid portfolio. Third, abnormal returns (BHARs or CARs) are calculated using equal-weighted monthly returns over alternative event windows, and annualized to facilitate comparisons across different event windows. Last, one-tailed *t*-test is used to determine the significance of abnormal returns.

By filtering firms with market capitalization 70% - 130% of the target firm, the pool of potential candidate shrinks. The precise range, as defined by the lower and upper bounds in percentages of both filters, affects the number of firms remained in the portfolio. The goal is set to have 15-20 stocks for a diversified portfolio and any portfolio size narrower or wider will be undesirable. (Fama and French, 1993).

Benchmark 2: Pre-conversion Timber Firms as Benchmark Firms

Given that the similarities in their businesses outweigh the disparities, the four timber REITs are considered as their own competitors in benchmark 2. That is, firms converted later become benchmark firms for those converted earlier. Following the chronological sequence of REIT conversions, RYN, PCH, and WY are used as benchmark firms for PCL; PCH and WY are used as benchmark firms for RYN; WY is used as the benchmark firm for PCH. In the case of multiple benchmark firms, equal-weighted returns are used. Then, abnormal returns are calculated and tested.[5]

Benchmark 3: An Equal-weighted Timber ETF

A timber ETF index[6] is constructed with the help of standard industrial classification (SIC) codes, where all timber related firms (wood, paper, and chair) are averaged with equal-weighted returns. In total, 200 firms are included in this timber ETF.

Tests for Mean and Variance of Abnormal Returns

Significance of abnormal returns is tested as follows

$$t = \frac{\bar{R}}{\sigma / \sqrt{n}} \tag{2.7}$$

where t is the *t*-statistic, and $\bar{R}$ and σ are mean and standard deviation of abnormal returns across n firms.

The difference in variances of pre- and post-event annualized abnormal returns is tested using *F*-test with a null hypothesis of constant variances across two samples (Kandel and Stambaugh, 1987).

[5] BHARs of WY cannot be constructed since it is the fourth one to convert and has no benchmark.
[6] This ETF is a refinement of equal-weighted portfolio returns of wood, paper, and chair industries from Fama-French 38 industry portfolios. The list of SIC codes can be provided upon request.

Data

Monthly data are obtained from CRSP and Compustat in Wharton Research Data Services (WRDS, 2015). Specifically, stock prices and returns, number of shares outstanding, cumulative adjustment factors for price and shares come from CRSP. Other balance sheet items come from Compustat.

Market capitalization (market cap), book value of equity, book-to-market ratio, tax-to-size ratio, turnover rate, and return on equity are defined in Equations 2.8−2.13 (Daniel et al., 1997). [7] Annual market capitalization is obtained by averaging 12 monthly market capitalizations in a fiscal year. Preferred stock is captured by redemption value of preferred stock and can be replaced by liquidating value in the case of missing redemption value.

$$\textit{Market cap} = \textit{Price} \times \textit{Total number of shares} \tag{2.8}$$

$$\begin{aligned} &\textit{Book value of equity} = \textit{Stockholder's total equity} + \textit{Deferred taxes} \\ &+ \textit{Investment tax credit} - \textit{Preferred stock} \end{aligned} \tag{2.9}$$

$$\textit{Book-to-market ratio} = \textit{Book value of equity} / \textit{Market cap} \tag{2.10}$$

$$\textit{Tax-to-size ratio} = \textit{Income taxes paid} / \textit{Market cap} \tag{2.11}$$

$$\textit{Turnover rate} = \textit{Trading volume} / \textit{Total number of shares} \tag{2.12}$$

$$\textit{Return on equity} = \textit{Net income} / \textit{Stockholder's total equity} \tag{2.13}$$

Following Barber and Lyon (1997), we use equal-weighted CRSP market return including dividends, indexed as EWRETD to calculate CARs in the CAPM regression. Following Eberhart et al. (2004), we use value-weighted market return for the zero-investment

[7] The corresponding item numbers in Compustat are item 216 (SEQ) for stockholders' total equity, item 74 (TXDB) for deferred taxes, item 208 (ITCB) for investment tax credit, item 56 (PSTKRV) for preferred stock redemption value, item 10 (PSTKL) for preferred stock liquidating value, item 317 (TXPD) for income taxes paid, and item 172 (NI) for net income.

portfolio approach with rolling regression. Value-weighted market return, risk-free rate (one-month T-bill rate), size factor (*SMB*), and value factor (*HML*) are collected from the Kenneth French data library (French, 2014).

Pre- and post-event windows are defined as 1-3 years before and after the REIT conversions (Table 2.1). The first two benchmarks are used for the approaches of BHARs, CARs, zero investment portfolio with rolling regression. The third benchmark is used for panel data regression. Intermediate results in constructing the benchmark portfolios are demonstrated in Table 2.2. The scale of the filters is set to be 85% - 115% of the size and book-to-market ratio of timber REITs. The timber REIT itself is excluded from the benchmark portfolio. Accordingly, the number of stocks in the benchmark portfolio is 29 for PCL, 32 for RYN, 37 for PCH, and 6 for WY.[8]

After excluding firms with almost zero timberland holdings, penny stocks and persistent losers, four publicly traded forest firms are selected as the competitors of timber REITs, namely Pope Resources Limited Partnership (POPE), Universal Forest Products Inc. (UFPI), Deltic Timber Corp. (DEL), and Trex Co. Inc. (TREX).

Empirical Results

BHAR Results

Timber REITs have negative pre-event BHARs for benchmark 1 (except PCH) but mostly positive pre-event BHARs for benchmark 2 (Table 2.3). Despite discrepancy in BHARs among the two benchmarks, the average BHAR is -6.5% for the one-year period, 19.2% for the

[8] The relative smaller number of stocks in the benchmark portfolio for WY is due to its much larger market capitalization.

two-year period, and -4.4% for the three-year period. The average annualized BHAR is close to zero at 0.6%, indicating similar stock returns between timber REITs and their benchmarks before the conversions.[9]

Post-event timber REITs generally outperform their benchmarks in the long run, except that PCL has two slightly negative BHARs (Table 2.4). The average BHAR is 11.0% for the one-year period, 23.1% for the two-year period, and 48.3% for the three-year period. At the company level, RYN and WY have better performance than PCL and PCH. Of the 21 annualized post-event BHARs, 2 are slightly negative, 5 are between 0% and 5%, 4 are between 5% and 10%, 4 are between 10% and 20%, and 6 are larger than 20%. The average annualized BHAR is 11.0% for the one-year period, 11.6% for the two-year period, and 16.1% for the three-year period. Overall, the average annualized BHAR is more than 11%, indicating a significant extra economic gain for timber REIT investors.

CAR Results

Combined results of CARs with the CAPM regression, the average pre-event CARs is -5.0% for the one-year period, 10.6% for the two-year period, and 3.0% for the three-year period (Tables 2.3 and 2.5). Of the 33 annualized pre-event CARs, five are above 20%, 12 are between zero and 20%, 13 are between -20% and zero, and three are below -20%. The average annualized CAR is also close to zero at 0.4%. On the other hand, post-event CARs are generally positive (Tables 2.4 and 2.5). The average CAR is 8.5% for the one-year period, 15.5% for the two-year period, and 31.3% for the three-year period. The average annualized CAR is still economically significant at a level of 8.9% and the sample standard deviation of annualized CARs is 11.2%.

[9] Annualized returns are obtained by averaging BHARs over years.

Results from Zero-investment Portfolio Approach with Rolling Regressions

The intermediate regression results of both pre- and post-event abnormal returns from this approach are shown in Table 2.6. The AR columns demonstrate monthly abnormal returns, and two-tailed *t*-statistics indicate the stability of monthly ARs over time. We first run regressions on each individual timber REITs, and obtain the associated AARs. Then, we average R_{it}, R_{bt}, R_{mt}, R_{ft}, SMB_t, and HML_t across REITs by the event calendar, run the regression again and obtain the portfolio AARs. Considering the essential length of the rolling window, a trial-and-error process shows that the empirical results for the rolling regression are robust with respect to the choice of rolling windows (12 or 24). Thus, we choose a rolling window of 12 months and run 25 rolling regressions.

Realizing that heteroscedasticity and autocorrelation may affect the validity of the regression, we test for both but find evidence for neither (Eberhart et al., 2004). Again, the pre-event abnormal returns are generally negative for benchmark 1, and positive for benchmark 2 with an average pre-event AAR of 0.6% (Table 2.3). The rolling AARs for zero-investment portfolios are -7.0% for benchmark 1, and 15.1% for benchmark 2. On the contrary, most post-event AARs are positive except PCL for benchmark 1 with an average post-event AAR of 13.5% (Table 2.4). The rolling AARs for zero-investment portfolios are 9.8% for benchmark 1, and 10.2% for benchmark 2. Pre- and post-event monthly abnormal returns of the four timber REITs are plotted in Figure 2.1. WY exhibits the most volatility than the other three before the conversions, and PCL exhibits the most volatility after the conversions.

Results from Panel Data Regressions

Four timber REITs and four competitors are analyzed using a strongly balanced panel data over a three-year event window. The abnormal return is the intercept of panel data regression after controlling for three mechanisms, market capitalization, and profit. The correlations of these variables are reported in Table 2.7. BHAR has significant positive relation with turnover rate and negative relation with return on equity. The REIT dummy has a significant positive correlation with turnover rate, earnings per share, return on equity and size, and negative relation with tax ratio.

Based on the Hausman test and the Breusch-Pagan Lagrange multiplier test, a robust pooled OLS procedure is used (Table 2.8), which not only triples the sample size, but also treats heteroscedasticity with robust standard errors. The estimated coefficients and test results are robust regardless of the model used (Equation 2.6). For the full set model (model 1), the coefficients of Event and REIT dummies are 4.3% and 11.7%, respectively. Both coefficients are positive with the latter being significant at the 10% level. The post-event AAR measure (sum of both coefficients) is 15.9%, indicating outperformance of timber REITs against their competitors. The estimated coefficients of the three mechanisms are -0.007 for tax-to-size ratio, 0.117 for REIT dummy, and 0.021 for turnover rate. Combined this with the significance of the REIT dummy, the undervalued assets are found to be the most influential mechanism, while the taxation is the least influential. The negative coefficient of tax ratio is as expected, implying the negative relation between abnormal returns and income taxes paid. The liquidity measure (turnover rate) is positive, with more liquidity implying larger abnormal returns. The coefficients of profit measurements are -0.006 for earnings per share, and -0.314 for return on equity, suggesting return on equity be more influential than earnings per share. The coefficient for market capitalization is close to zero.

Comparison of Results from the Four Approaches

The signs of pre-event abnormal returns are generally negative for benchmark 1, and mostly positive for benchmark 2. Regardless, the pre-event average AARs are 0.6% for BHARs, 0.4% for CARs, and 0.6% for zero-investment portfolio approach with rolling regression, implying no significant difference between timber REITs and their benchmarks before the conversions (Figure 2.2). The post-event average AARs are 12.9% for BHARs, 8.9% for CARs, and 13.5% for zero-investment portfolio approach with rolling regression. Within the timber industry, the post-event AAR from pooled OLS regression is around 15.9%, which are slightly higher than previous approaches. The panel data estimation induced causal effects, which show evidence of explanatory power of the three mechanisms. As shown in Figure 2.2, the signs of post-event abnormal returns are mostly positive, and the magnitudes are economically significant for all approaches. Hence, timber REITs outperformed their benchmarks in stock market and forest industry after the conversions.

Results of t- and F-tests

Pre- and post-event *t*-test results are demonstrated in Table 2.9. The degrees of freedom of both BHARs and CARs are 11 for benchmark 1, and 8 for benchmark 2. The negative pre-event *t*-statistics of BHARs and CARs pass the 10% level of significance for benchmark 1, while the positive pre-event *t*-statistics pass the 1% level of significance for benchmark 2. These mixed results suggest the sign of pre-event AARs undetermined. All post-event *t*-statistics of BHARs and CARs pass the 1% level of significance for two benchmarks. With degrees of freedom at 12, the *t*-statistics of CARs with the CAPM regression are -0.1 for pre-event study, and 1.6 for post-event study, which passes the 10% significance level. The pre- and post-event *t*-statistics of AARs from the zero-investment portfolio approach with rolling regression are conducted on timber REITs portfolio with degrees of freedom of 24. The associated *t*-statistics are significant at 1% significance level.

The *F*-statistics of benchmark 1 are 2.46 for BHARs, 2.39 for CARs, and 1.33 for zero-investment portfolio approach with rolling regression, all fail to pass 5% significance level (Table 2.9). The *F*-statistics of benchmark 2 are 1.38 for BHARs, 1.65 for CARs, and 7.07 for zero-investment portfolio approach with rolling regression, all of which also fail to pass 5% significant level. We cannot reject the hypothesis of constant variances of pre- and post-annualized abnormal returns. Hence, the standard errors are not downward biased and the *t*-statistics are not upward biased.

Results from Short-term Event Analyses

Post-event BHARs and CARs with 1-month, 3-month, and 6-month event windows are reported in Table 2.10. Except those for PCH, the abnormal returns for both methods are similar and mostly positive. The average abnormal returns are 1.9% for 1-month period, 1.5% for 3-month period, and 3.1% for 6-month period. Of the 42 annualized abnormal returns, fifteen are above 30%, 11 are between zero and 30%, and 16 are below zero. The average AAR is economically significant at 11.7%, which are consistent with previous findings of Mendell et al. (2008).

Discussion and Conclusions

The long-term financial performance of four timber REIT conversions in the US is evaluated by an event study with 1-3 year event windows. The systematic and idiosyncratic risk premiums of this event are examined with different benchmarks and approaches. Results show that abnormal returns are significantly larger than zero after the REIT conversions. On average, annualized abnormal returns of about 0.5% and over 8.9% are identified before and after the REIT conversions. There is no difference between variances of pre- and post-event annualized abnormal returns. Therefore, REIT conversions have added values to the timber firms in the long run.

Despite some debate between the use of BHARs and CARs in measuring long-term returns, we use four approaches and find robust outcomes (Barber and Lyon, 1997; Fama, 1998). The signs of post-event abnormal returns of timber REITs for both measure remain consistent and the magnitudes of them are slightly higher for BHARs. With the zero-investment portfolio approach with rolling regressions, post-event abnormal returns are robust regardless their measurements. Assuming constant variances across the event windows, the standard errors of all approaches are not underestimated, and thus *t*-test results are not upward biased. The signs of pre-event AARs are affected by the selected benchmarks and thus undetermined, whereas those of post-event AARs are significantly positive.

Within the timber industry, negative correlations between tax-to-size ratio and event dummies are consistent with tax efficiency rationale of REITs (Mei and Clutter, 2010; Mendell et al., 2008). This reduced profit, as revealed by negative coefficient estimates in the pooled OLS, may be attributed to the costs associated with the process of REIT conversions. Positive coefficient estimates for liquidity and mark-to-market values justify the intention of REIT conversions. These results are clear indications that REIT conversions are viewed by the market as positive structural changes. Thus, there is a causal relation between the three mechanisms of REIT conversions and long-term abnormal returns.

Given the small sample size, statistical propensities of the *t*-test might be biased. Nonetheless, an excess return of 8.9% per year makes economic sense. Combined with findings from short-term event studies, market reaction to timber REITs conversions is proven both quick and lasting (Mendell et al., 2008). Therefore, REIT conversions have turned out to be sound decisions for those public timber firms. The short-term anomaly, well recognized by investors, is possibly due to a swift market reaction to conversion announcements. The long-term anomaly, incorporating with broad timberland ownership shifts and corporate structural changes, might need more time for the investors to digest. It is worth noting that our results should not be interpreted as evidence against the efficient market hypothesis because this study is conducted on a small group of firms within a particular industry. At a more aggregate level, anomaly might be chance events, and positive and negative abnormal returns might cancel each other out.

Favorable market reactions in the past may stimulate more structural changes within the timber industry in the future. The initial public offering of CTT in 2013 and the merger between WY and PCL in 2015 are two recent examples of such kind. Although timber REITs own or manage 18 million acres of commercial timberland in total, their holdings represent less than 20% of the total and their market capitalization only represents 4% of all publicly traded REITs in the US. Looking forward, more restructuring activities are likely to take place in the timber industry to enhance synergy and reduce risk. Timber investors ought to make use of these opportunities for potential long-term rewards.

Table 2.1. Important dates of timber REIT conversions, and pre- and post-event windows

	REIT conversion date		Pre-event window				Post-event window			
	Announcement	Completion	Start			End	Start	End		
PCL	06/08/98	07/01/99	06/97	06/96	06/95	05/98	06/98	05/99	05/00	05/01
RYN	08/19/03	01/01/04	08/02	08/01	08/00	07/03	08/03	07/04	07/05	07/06
PCH	09/19/05	01/01/06	09/04	09/03	09/02	08/05	09/05	08/06	08/07	08/08
WY	12/15/09	01/01/10	12/08	12/07	12/06	11/09	12/09	11/10	11/11	11/12

Table 2.2. Construction of benchmark portfolios

	Pool	Size filter			Book-to-market ratio filter		
		85%	115%	Firm #	85%	115%	Firm #
PCL	380	1,156.63	1,564.85	168	0.2532	0.3426	29
RYN	366	1,301.63	1,761.04	165	0.4623	0.6255	32
PCH	497	1,059.67	1,433.67	225	0.6154	0.8325	37
WY	124	6,075.19	8,219.38	59	0.6638	0.8981	6

Note: Size in millions of dollars. Same benchmark portfolios are used both for pre- and post-event analyses. Pool indicates number of firms left after filtering on 70% - 130% of the size of the target firm using CRSP / Compustat merged dataset. After filtering on the size and book-to-market ratio, firms with less similarities with the timber REITs are dropped. Timber REITs themselves are also excluded from the benchmark portfolio. The smaller total number of firms of WY's benchmark portfolio is due to the fact that the market capitalization of WY is relatively larger and it has fewer matches initially in the pool.

Table 2.3. Summary of pre-event abnormal returns of timber REIT conversions

	Benchmark 1			Benchmark 2		
	1-year	2-year	3-year	1-year	2-year	3-year
BHARs						
PCL	-20.2	-16.0	-98.0	-1.9	18.8	22.3
RYN	-14.9	-7.6	-39.2	15.4	27.3	31.4
PCH	11.8	60.0	8.7	26.7	82.1	62.2
WY	-62.1	-30.2	-18.3	--	--	--
CARs						
PCL	-18.0	-11.3	-50.3	-3.4	13.6	15.1
RYN	-12.7	-6.3	-24.8	14.5	25.4	24.5
PCH	11.1	40.2	11.8	23.4	56.0	42.7
WY	-41.8	-32.9	-11.3	--	--	--
Zero-investment portfolio with rolling regression						
PCL	-24.7	-49.4	-74.2	6.1	12.2	18.3
RYN	-18.0	-36.0	-54.0	1.7	3.3	5.0
PCH	12.8	25.6	38.4	19.1	38.2	57.2
WY	0.5	1.0	1.6	--	--	--
Portfolio	-7.0	-14.1	-21.1	15.1	30.2	45.4
Annualized BHARs						
PCL	-20.2	-8.0	-32.7	-1.9	9.4	7.4
RYN	-14.9	-3.8	-13.1	15.4	13.7	10.5
PCH	11.8	30.0	2.9	26.7	41.1	20.7
WY	-62.1	-15.1	-6.1	--	--	--
Annualized CARs						
PCL	-18.0	-5.7	-16.8	-3.4	6.8	5.0
RYN	-12.7	-3.1	-8.3	14.5	12.7	8.2
PCH	11.1	20.1	3.9	23.4	28.0	14.2
WY	-41.8	-16.5	-3.8	--	--	--
Annualized zero-investment portfolio with rolling regression						
PCL	-24.7	-24.7	-24.7	6.1	6.1	6.1
RYN	-18.0	-18.0	-18.0	1.7	1.7	1.7
PCH	12.8	12.8	12.8	19.1	19.1	19.1
WY	0.5	0.5	0.5	--	--	--
Portfolio	-7.0	-7.0	-7.0	15.1	15.1	15.1

Note: Abnormal returns are reported in percentages.

Table 2.4. Summary of post-event abnormal returns of timber REIT conversions

	Benchmark 1			Benchmark 2		
	1-year	2-year	3-year	1-year	2-year	3-year
BHARs						
PCL	3.8	-3.1	1.0	-5.5	4.9	9.8
RYN	39.6	68.3	78.8	23.8	37	78.7
PCH	1.1	13.2	31.6	6.2	16.6	44.8
WY	8.2	25	93.5	--	--	--
CARs						
PCL	0.9	-2.9	1.1	-6.4	3.9	7.7
RYN	31.9	41.7	45.3	18.1	20.5	42.8
PCH	5.0	15.5	30.6	8.9	14.5	37.5
WY	11.6	31.8	72.3	--	--	--
Zero-investment portfolio with rolling regression						
PCL	-1.0	-2.1	-3.1	12.6	25.3	37.9
RYN	6.9	13.8	20.7	13.4	26.7	40.1
PCH	19.0	37.9	56.9	6.7	13.5	20.2
WY	43.5	87.0	130.5	--	--	--
Portfolio	9.8	19.6	29.5	10.2	20.4	30.6
Annualized BHARs						
PCL	3.8	-1.6	0.4	-5.5	2.5	3.3
RYN	39.6	34.2	26.3	23.8	18.5	26.2
PCH	1.1	6.6	10.5	6.2	8.3	14.9
WY	8.2	12.5	31.2	--	--	--
Annualized CARs						
PCL	0.9	-1.4	0.4	-6.4	2.0	2.6
RYN	31.9	20.9	15.1	18.1	10.2	14.3
PCH	5.0	7.7	10.2	8.9	7.2	12.5
WY	11.6	15.9	24.1	--	--	--
Annualized zero-investment portfolio with rolling regression						
PCL	-1.0	-1.0	-1.0	12.6	12.6	12.6
RYN	6.9	6.9	6.9	13.4	13.4	13.4
PCH	19.0	19.0	19.0	6.7	6.7	6.7
WY	43.5	43.5	43.5	--	--	--
Portfolio	9.8	9.8	9.8	10.2	10.2	10.2

Note: Abnormal returns are reported in percentages.

Table 2.5. Pre- and post-event CARs of timber REIT conversions from the CAPM regression

	Regression window		CAPM regression statistics				Percentage annualized CARs		
	Start	End	*α*	*β*	Std. Err.	R^2	1-year	2-year	3-year
Pre-event CARs									
PCL	06/90	05/95	0.018	0.739	0.064	0.203	-29.9	-11.4	-20.3
RYN	08/95	07/00	0.000	0.411	0.073	0.084	-4.8	5.6	9.5
PCH	09/97	08/02	-0.003	0.407	0.069	0.146	26.3	32.0	18.0
WY	12/01	11/06	-0.004	0.758	0.051	0.328	-19.6	-10.2	1.4
Post-event CARs									
PCL	06/93	05/98	0.007	0.775	0.064	0.155	-6.8	-12.7	-8.5
RYN	08/98	07/03	0.004	0.474	0.072	0.191	31.5	24.0	17.0
PCH	09/00	08/05	0.006	0.582	0.066	0.246	-4.4	1.6	4.6
WY	12/04	11/09	-0.005	0.973	0.076	0.381	3.1	10.1	22.6

Note: We calculate CARs using the CAPM with a 5-year regression window prior to REIT conversions. Std. Err. is the standard error of the regression.

Table 2.6. Abnormal returns of timber REIT conversions from zero-investment portfolio approach with rolling regressions

	Benchmark 1							Benchmark 2						
	b	*s*	*h*	AR	*t*-stat	*BP*-stat	*DW*-stat	*b*	*s*	*h*	AR	*t*-stat	*BP*-stat	*DW*-stat
Pre-event														
PCL	-0.153	-0.469	0.780	-0.021	-9.675	3.32	2.179	-0.136	-0.014	0.223	0.005	3.968	1.26	2.069
RYN	-0.438	0.237	-0.087	-0.015	-6.491	0.12	1.952	-0.423	0.549	-0.459	0.001	0.563	0.89	2.237
PCH	0.408	-0.061	1.192	0.011	2.866	0.11	2.062	0.071	0.924	0.817	0.016	3.787	0.00	1.766
WY	-0.234	-1.151	1.383	0.000	0.098	0.41	2.741	-	-	-	-	-	-	-
Portfolio	-0.140	-0.289	-0.102	-0.006	-3.179	0.83	2.524	-0.323	0.384	-0.477	0.013	5.972	0.61	1.775
Post-event														
PCL	-0.868	-0.190	-0.228	-0.001	-0.387	0.36	2.323	-0.916	0.003	-0.610	0.011	1.695	0.09	1.902
RYN	0.226	-0.725	0.231	0.006	4.443	1.54	2.057	-0.219	-0.360	-0.265	0.011	7.265	0.57	2.376
PCH	-0.094	0.477	-1.330	0.016	3.424	0.11	2.353	-0.516	0.442	-1.025	0.006	1.014	0.18	2.406
WY	0.131	-0.455	2.320	0.036	14.207	0.77	2.162	-	-	-	-	-	-	-
Portfolio	0.128	0.639	0.635	0.008	5.570	0.20	1.774	-0.483	-0.096	-0.197	0.009	4.835	0.22	2.147

Note: We use Fama-French three-factor model with a 3-year sample period. *b*, *s*, and *h* are coefficients of $R_m - R_f$, SMB, and HML. R_m is CRSP value-weighted market return. The data for R_m, SMB, HML, and R_f are collected from the Kenneth R. French data library. Regarding rolling regression analyses, we use a rolling window of 12 months and obtain 25 monthly abnormal returns (ARs). The *t*-statistics for abnormal returns are of two tails. *BP*-stat is Breusch-Pagan test statistics for heteroscedasticity. *DW*-stat is Durbin-Watson statistics for serial correlation. Results from both tests indicate evidence of neither of them.

Table 2.7. Correlation coefficients for panel data: four timber REITs and four competitors, 1998-2012

	BHAR	Event	REIT	Tax ratio	Turnover	ROE	EPS	Size
BHAR	1							
Event	0.049	1						
REIT	0.159	−0.113	1					
Tax ratio	−0.117	−0.089	−0.176*	1				
Turnover rate	0.174*	0.066	0.394**	0.028	1			
ROE	−0.197*	−0.067	0.286**	0.098	−0.032	1		
EPS	−0.166	−0.094	0.185*	−0.239*	−0.192*	0.708**	1	
Size	−0.012	0.011	0.177*	0.071	0.151	0.053	0.010	1

Note: Pearson correlation coefficients are reported. ROE is return on equity, and EPS is earnings per share. Single and double asterisks indicate 10% and 1% significance level, respectively. REIT dummy has significant correlation with all the other explanatory variables.

Table 2.8. Post-event abnormal returns of timber REIT conversions from pooled OLS regressions

Dependent variable	BHAR			
Regression model	(1)	(2)	(3)	(4)
Constant	1.028	1.024	1.021	1.015
	(21.26)	(22.00)	(22.93)	(24.90)
Event	0.043	0.040	0.046	0.044
	(0.50)	(0.48)	(0.54)	(0.53)
REIT	0.117*	0.111*	0.118*	0.112*
	(1.75)	(1.66)	(1.80)	(1.70)
Tax-to-size ratio	-0.007	-0.008	-0.005	-0.006
	(-0.62)	(-0.72)	(-0.60)	(-0.67)
Turnover rate	0.021	0.020	0.023	0.022
	(0.76)	(0.72)	(0.84)	(0.81)
ROE	-0.314	-0.295	-0.374**	-0.369**
	(-1.30)	(-1.28)	(-2.30)	(-2.32)
EPS	-0.006	-0.008		
	(-0.37)	(-0.50)		
Size	0.000		0.000	
	(-0.58)		(-0.68)	
AAR	15.9%	15.1%	16.4%	15.6%
R^2	0.105	0.103	0.104	0.101
Hausman test	7.95	10.32	6.30	5.42
Breusch-Pagan LM test	0.85	0.93	1.07	1.24
F-test	1.58	1.62	1.45	1.48
Time fixed effect test	0.11	0.11	0.06	0.08
Heteroscedasticity test	9266	9456	31981	53159

Note: Robust pooled OLS is used to address the heteroscedasticity in the panel data. Model (1) ~ (4) correspond to nested models of Equation 2.6. Return on equity (ROE) and earnings per share (EPS) are profit measures. AAR is post-event annualized abnormal return. Two-tailed *t*-statistics are in brackets. The OLS estimation generally has an AAR of 15% and R-squared of 0.10. Breusch-Pagan LM test is Breusch-Pagan Lagrange multiplier test for random effects. *F*-test is to compare fixed effects with pooled OLS. Regardless of the estimated model, results from these tests favor pooled OLS regression over fixed effects and random effects approaches. All the constant terms and heteroscedasticity tests pass the 1% significance level. Single and double asterisks indicate the 10% and 5% significance levels, respectively.

Table 2.9. Mean, variance, and *t*-test and *F*-test results for annualized abnormal returns of timber REIT conversions

	Benchmark 1			Benchmark 2		
	Mean	Variance	*t*-stat	Mean	Variance	*t*-stat
Pre-event						
BHARs	-10.9	22.7	-1.66*	15.9	12.5	3.82
CARs	-7.6	15.8	-1.67*	12.2	9.5	3.85
Zero-investment portfolio with rolling regression	-7.0	10.8	-3.18	15.1	12.0	5.97
Post-event						
BHARs	14.4	14.5	3.44	10.9	10.6	3.08
CARs	11.9	10.2	4.04	7.7	7.4	3.12
Zero-investment portfolio with rolling regression	9.8	8.4	5.57	10.2	10.8	4.84
F-test: two-sample for variances	*F*-stat	*F*-critical	*p*-val	*F*-stat	*F*-critical	*p*-val
BHARs	2.46	2.82	0.076	1.38	3.44	0.331
CARs	2.39	2.82	0.082	1.65	3.44	0.248
Zero-investment portfolio with rolling regression	1.33	6.39	0.394	7.07	9.28	0.071

Note: One-tailed *t*-statistics are calculated within benchmarks using annualized BHARs and CARs. Two-tailed *t*-statistics are calculated for zero-investment portfolio approach with rolling regression. The mean and variance of AARs are in percentage. The variance is the sample standard deviation of AARs. Single asterisk denotes the 10% significance level. Pre-event BHARs and CARs for benchmark 1 pass the 10% significance level, and the rest of AARs pass the 1% significance level. The *t*-statistics for pre- and post-event CARs with the CAPM regression are -0.1 and 1.6, respectively. *F*-test examines the difference of variances of AARs before and after the conversions. *F*-stat is the *F*-statistics, and *F*-critical and *p*-val are the critical value and the *p*-value of *F*-test, respectively. When *F*-stat is smaller than *F*-critical, we cannot reject the null hypothesis that there is no difference between variances of pre- and post-event AARs.

Table 2.10. Summary of short-term abnormal returns of timber REIT conversions

	Benchmark 1			Benchmark 2		
	1-month	3-month	6-month	1-month	3-month	6-month
BHARs						
PCL	1.2	9.0	-0.5	3.4	4.1	-0.4
RYN	8.6	9.4	17.4	5.5	9.8	11.2
PCH	-4.2	-13.0	-7.8	-9.2	-13.0	-9.6
WY	8.1	3.2	12.2	--	--	--
CARs						
PCL	1.2	9.7	-2.5	3.4	4.9	-0.3
RYN	8.6	8.5	14.9	5.5	8.9	9.5
PCH	-4.2	-12.2	-6.5	-9.2	-12.6	-8.5
WY	8.1	3.8	14.4	--	--	--
Annualized BHARs						
PCL	14.4	36.0	-1.0	40.8	16.4	-0.8
RYN	103.2	37.6	34.8	66.0	39.2	22.4
PCH	-50.4	-52.0	-15.6	-110.4	-52.0	-19.2
WY	97.2	12.8	24.4	--	--	--
Annualized CARs						
PCL	14.4	38.8	-5.0	40.8	19.6	-0.6
RYN	103.2	34.0	29.8	66.0	35.6	19.0
PCH	-50.4	-48.8	-13.0	-110.4	-50.4	-17.0
WY	97.2	15.2	28.8	--	--	--

Note: Abnormal returns are reported in percentages.

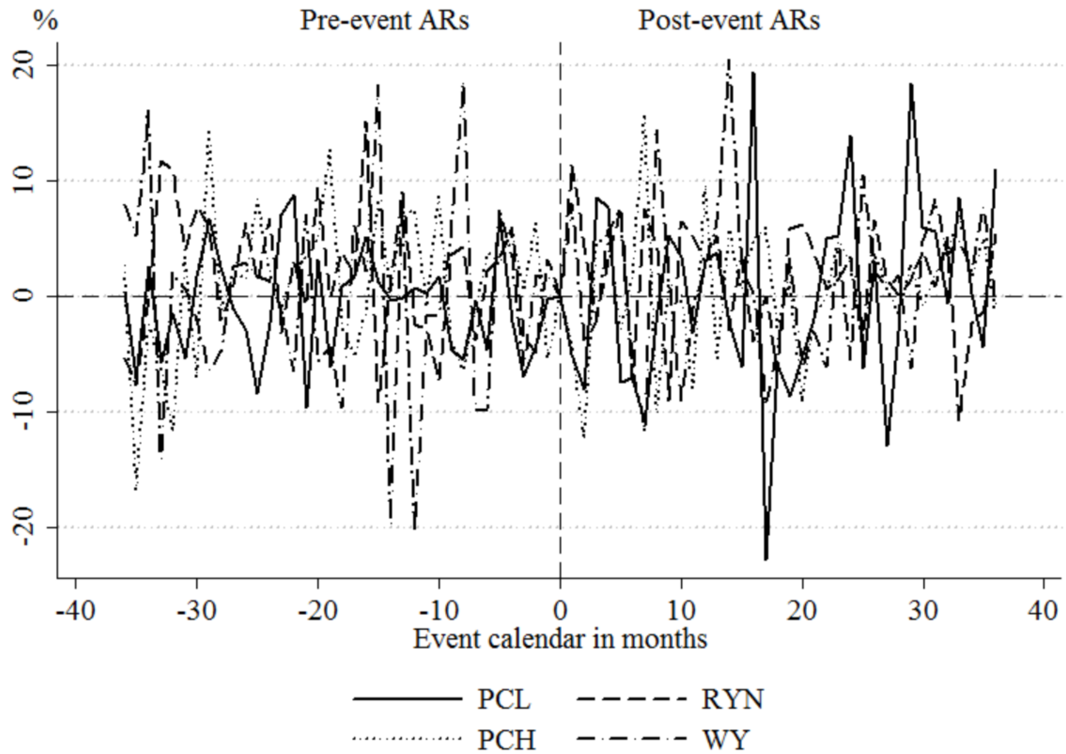

Figure 2.1. Zero-investment portfolio approach: Pre- and post-event monthly abnormal returns of timber REITs over time.

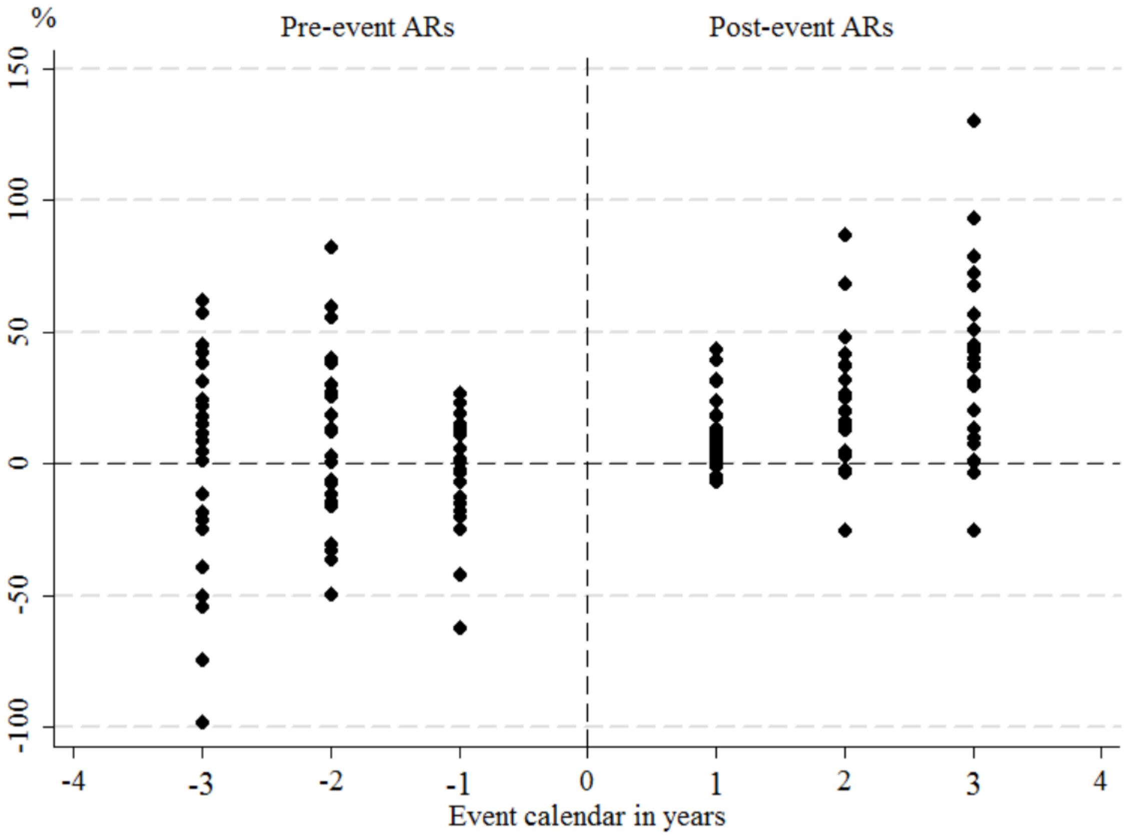

Figure 2.2. BHARs, CARs, and zero-investment portfolio approach: Pre- and post-event abnormal returns of timber REITs over time.

CHAPTER 3

COMPARING THE FINANCIAL PERFORMANCE OF TIMBER REITS AND OTHER REITS[10]

[10] Piao, X., Mei, B., Xue, Y. Published by *Forest Policy and Economics*. Reprinted here with permission of publisher, 04/14/2017.

Abstract

The return and risk characteristics of three types of real estate investment trusts (REITs) in the United States are evaluated by the intertemporal capital asset pricing model (CAPM) and the multivariate generalized autoregressive conditional heteroscedasticity (GARCH) model. The three types of REITs are timber REITs, which focus on timberland management; specialized REITs, which focus on properties that are specialized in a single use; and common REITs, which consist of all REITs except specialized REITs. Results from the intertemporal CAPM demonstrate that REITs behave like procyclical small and value stocks. Results from multivariate GARCH model show that the conditional volatilities of REITs rise more after good news and REITs as a whole respond positively to past shocks. Despite being a part of specialized REITs, timber REITs have large market capitalizations and no excess returns, and are insensitive to recessionary shocks. Timber REITs have the smallest unconditional variance and are most vulnerable to idiosyncratic shocks.

Introduction

Real estate investment trust (REIT) is an investment vehicle in owning and managing real properties and is exempt from corporate income taxes. Since its establishment in 1960 under the Real Estate Investment Trust Act, REIT has become an attractive asset type and served as risk diversifiers in portfolio management. The Real Estate Investment Trust Act requires companies to distribute 90% of their income to investors, which leaves only 10% to internal fund growth opportunities. To raise enough capital, REITs tend to issue secondary offerings in the stock market. In empirical research, REIT returns are found to behave like small and value stocks, and are different from private real estate investments (Corgel et al., 1995; Han and Liang, 1995). Since the 1960s, REITs have slowly developed into three traditional categories: equity REITs, mortgage REITs, and hybrid REITs.[11] The total market value of REITs accounted for 1-2% of the total US real estate wealth in 1993, a critical time when the market depth of REITs increased dramatically (Corgel et al., 1995). Thereafter, the total market capitalization of REITs went up correspondingly from $8.7 billion in 1990 to $57 billion in 1995, $224 billion in 2003, and $907 billion in 2014 (Cotter and Stevenson, 2006; NAREIT, 2014).

In the United States, more than 200 REITs are publicly traded, which manage different types of properties (Mendell et al., 2008). REITs are not just related to the housing market. Since the 1990s, according to the GICS,[12] REITs have evolved from traditional categories to nine sub-industries: diversified, industrial, mortgage, hotel and resort, office, health care, residential, retail, and specialized REITs. Among them, specialized REITs are newly founded and attract a

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[11] Hybrid REITs are a mixture of equity and mortgage REITs. This concept belongs to a traditional way to categorize REITs and is considered outdated in the 21st century.

[12] The Global Industry Classification Standard (GICS) is published by Morgan Stanley Capital International Indexes (MSCI). MSCI Inc. is a US-based provider of equity, fixed income, and hedge fund stock market indices, and equity portfolio analysis tools.

lot of market attention. This type of REITs own properties that are specialized in a single use such as lodging or storage. Specialization gives access to private information, which enables property managers to obtain persistent outperformance (Eichholtz et al., 1997). Specialized REITs tend to engage in more development activities, which leads to higher return and risk (Benefield et al., 2009). Thus, investors favor specialized REITs and the weight of specialized REITs has remained the largest in the MSCI REIT index (around 31 %) in recent years.

Timber REITs, as a part of the specialized REITs, have evolved since 1998[13] and drawn investors' attention in the forestry sector. Unlike other types of real estate whose value generally depreciates over time, trees keep growing and timberland value appreciates accordingly. Biological growth is independent of business cycles and contributes more than 60% of total timberland investment returns (Mei et al., 2013). Timberland owners can apply flexible harvesting schedules of trees and sell timber at the appropriate time (Caulfield and Flick, 1999). By concentrating on managing timberland, timber REITs exhibit outperformance over other forest firms (Mendell et al., 2008). Since 1997, almost all large public forest products companies, most of which were structured as C-corporations, have either sold their timberlands, or converted themselves to timber REITs. This trend corresponds to massive structural changes of timberland ownership in United States. Between 1996 and 2009, $28 billion of industrial timberlands were sold, and many of them had been securitized[14] (Sun, 2013b). As of 2014, timber REITs and timber investment management organizations (TIMOs) controlled 4.2% and 4.3% of total timberlands in United States (Hood et al., 2015).

[13] The first launched timber REIT is Plum Creek., which announced its decision to convert from a Master Limited Partnership (MLP) to a REIT in December 1998.
[14] Timberland securitization is an indirect way of owning and managing timberlands. In history, there have been three forms of timberland securitization: MLP, letter stock, and REIT. In recent years, REIT has become the dominant form.

Since the 1980s, financial analyses about REITs have been common, and the risk features and volatility clustering of REITs have been examined. The comparison between specialized and diversified REITs[15] remains a hot topic. Comparisons of timber REITs versus other forest firms have been conducted. However, to our best knowledge, there is no study comparing timber REITs with other REITs. The purpose of this paper is to fill this knowledge gap and examine the cross-sectional return and risk characteristics and the conditional volatilities for the three types of REITs using the intertemporal CAPM and multivariate GARCH models. The null hypothesis is that there is no difference between timber REIT and other REIT returns in terms of mean and volatility characteristics. This study can provide investors and managers some guidance of the financial performance of various types of REITs, and in particular, how REIT returns react to market, macroeconomic, and idiosyncratic risks.

Literature Review

Research on REITs

In the early stage (1960-1993), REITs were considered to be a brand new investment vehicle. Corgel et al. (1995) concluded that REITs' performance highly depends on the sample period and the selected benchmark portfolio.[16] After 1993, REITs moved into the mature stage. Cotter and Stevenson (2006) found that REIT returns have strong performance verses S&P 500 and other related benchmarks[17] during 1990-2003, which leads to increased investments into the

[15] The diversified REITs do not focus their businesses on a single industry, rather they have multiple types of businesses across different industries.
[16] In the case where there exist excess returns, these excess returns move closely with those of the small stocks. The January effect accounts for 5% of the excess returns per year for equity REITs.
[17] These benchmarks include the Wilshire small and mild capitalization growth and value indices, and the Wilshire micro-capitalization index.

REIT sector especially after the collapse of the technology bubble. Jirasakuldech et al. (2009) used the GARCH approach to examine the equity REITs pre- and post-1993, and found an increase in the unconditional volatility and a less persistent conditional volatility during 1993-2006. They also tested the predictability of REIT volatility with four fundamental macroeconomic variables, [18] and found these variables explain more than one third of the variations in future REIT volatility. In addition, good news and bad news have no different impacts on equity REIT volatility. Considering increased daily trading and a reduction in the bid-ask spread after 1993, Cotter and Stevenson (2006) suggested using daily return series and multivariate GARCH models.

The mainstream corporate finance literature indicates that firms with specializations have higher returns than diversified firms. Regarding REITs, Eichholtz et al. (1997) and Capozza and Seguin (1999) examined the excess returns of specialized REITs during 1990-1996 and found that property specialization leads to an outperformance, [19] whereas geographical specialization does not. On the contrary, Benefield et al. (2009) claimed diversified equity REITs perform better in economic expansions. [20] Ro and Ziobrowski (2011) found that diversified REITs outperform specialized REITs during 1997-2006 despite the insignificance. Possible explanations for the mixed findings can be owed to the discrepancies in the definitions of specialized REITs and selections of sample periods.

[18] These fundamental macroeconomic variables are the consumer price index, the industrial production, the federal funds rate, and the default premium.
[19] Specialized REITs outperform the S&P 500 index and all REITs by 0.83% and 0.65% per month, respectively.
[20] Their comparison may be sensitive to the sample period selection and the overall market condition.

Research on Timber REITs

Compared to private-equity assets (i.e., TIMOs), Sun (2013a) indicated that publicly-traded timber REITs have better liquidity and tax efficiency, more exposure to market risk, and higher return volatility. Mei and Clutter (2010) compared public- and private-equity timberland returns during1987-2008, and found that both equities outperform the market although only private-equity timberlands have significant abnormal returns. Yao et al. (2014) used the arbitrary pricing theory and found that timber REITs have higher excess returns, whereas their private-equity counterparts barely earn expected returns.

Mendell et al. (2008) used event analysis to evaluate timber REIT conversions and found at least 2.5% of abnormal returns on the day of conversion. Sun et al. (2013a) also found that REIT conversions increase returns and asset volatility, but timberland sales and acquisitions generate negative abnormal returns. Sun (2013a) used the Copula modeling and concluded that the REIT structure has introduced non-diversifiable market risk into its ownership, and its diversification potential in a portfolio may be limited. Sun (2013b) found the return and volatility series of securitized timberlands demonstrate non-normality, serial correlation, and heteroscedasticity, and discovered a positive return-volatility relation. Using the cointegration analysis, La and Mei (2015) found that timber REITs are not cointegrated with the S&P 500 index and that there exists no long-term common trend among them.

Methodologies

Sharpe Ratio

A rudimentary approach to evaluate the return and risk relation is the Sharpe ratio, which explains how well the return of an asset compensates for the risk taken. The higher the ratio, the better the performance of an asset.

$$Sharpe = \frac{E[R_i - R_f]}{SD[R_i]} \tag{3.1}$$

where *Sharpe* is the Sharpe ratio, R_i is the return for an asset, R_f is risk-free rate, and $SD[R_i]$ is the standard deviation of R_i.

Intertemporal CAPM

The CAPM is a widely used asset pricing model, which relates the expected return on an asset to the risk-free rate and the market risk premium (Treynor, 1961). Fama-French three-factor model adds size and value factors into the CAPM, given the fact that firms with small market capitalizations and high book-to-market ratios generally outperform those with large market capitalizations and low book-to-market ratios (Fama and French, 1993). In contrast to the traditional single-period CAPM which assumes that investors share a homogeneous expectation across time, the intertemporal CAPM is a multi-period asset pricing model which assumes that investors trade continuously and maximize the expected utility of lifetime consumption (Merton, 1973). This model enhances the explanatory power of previous models by including state variables and therefore is used in this study. Stock return series are known to display non-normality, non-stationarity, heteroscedasticity, and serial correlation. Innovations of the state variables capture the time-varying trend of the return series and hence alleviate the non-stationary issues (Maio and Santa-Clara, 2012). Robust regression with White standard errors is used to deal with heteroscedasticity (White, 1980).

$$R_{it} - R_{ft} = \alpha_i + b_1(R_{mt} - R_{ft}) + b_2\Delta SMB_t + b_3\Delta HML_t + b_4\Delta DEF_t + b_5\Delta DIV_t + b_6\Delta TERM_t + \varepsilon_{it} \tag{3.2}$$

where α_i is the excess return of the asset; b_1 is known as the systematic risk of the target asset; and R_{mt} is the return on a market proxy. Small-minus-big (SMB) represents the market capitalization factor defined as the return difference between portfolios of small and large stocks, and high-minus-low (HML) represents the book-to-market ratio factor defined as the return difference between portfolios of high and low book-to-market ratio stocks. Default premium DEF is the additional amount a borrower must pay to compensate the lender for the default risk; dividend yield DIV is the average return on dividend distributions; and term premium $TERM$ is the difference between yields on bonds of the same credit quality but different maturities. Parameters b_2 and b_3 represent the coefficients of the innovations of two financial factors (*SMB* and *HML*), and $b_4 - b_6$ represent the coefficients of the innovations of three state variables (default premium, dividend yield, and term premium), respectively. Symbol Δ denotes innovations, which are defined as the difference between actual and fitted values of the state variables under the GARCH framework as described in Yao and Mei (2015). Variable ε_i is the error term.

If α_i is positive, then the asset has excess returns and outperforms the market; if α_i is negative, then the asset underperforms the market. If b_1 is positive, then the asset is procyclical; if b_1 is negative, then the asset is countercyclical. If b_2 is positive, then the asset behaves like firms with small market capitalizations. If b_2 is negative, then the asset behaves like firms with large market capitalizations. If b_3 is positive, then the asset behaves like value stocks. If b_3 is negative, then the asset behaves like growth stocks. If coefficients of the state variables are relatively large and significant in absolute value, then the asset is sensitive to macroeconomic shocks.

Multivariate GARCH

Stock returns are often not normally distributed in that the volatility associated with returns is usually non-stationary with serial correlations. These characteristics call for a volatility modeling and the GARCH model with the maximum likelihood estimator is commonly used. Our objective, comparison of the three REIT groups, suggests multivariate GARCH instead of univariate one. Three procedures of multivariate GARCH approach are widely discussed: the direct generalization of univariate model, the linear combination of univariate model with orthogonal and latent factors, and the constant and dynamic matrices of the conditional correlations (Bauwens et al., 2006; Bollerslev, 1986). Among them, the conditional correlation procedure stands out as a nonlinear combination of univariate GARCH, which allows the specifications of individual conditional variance and the conditional correlation matrices separately.

Two stages are involved to estimate this approach. In the first stage, constraints for each individual series and the univariate GARCH process are set. Among various model specifications of the GARCH process, a prominent one is the exponential GARCH model (EGARCH), which often provides superior fits compared to standard GARCH models (Lee and Hansen, 1994). The EGARCH has an additional asymmetric term that captures the leverage effect. We use EGARCH (1, 1, 1) to evaluate the heteroscedasticity in REITs' daily returns,

$$\begin{aligned} & r_t = \mu_t + \varepsilon_t \\ & \ln(\sigma_t^2) = \omega + \alpha_1\left(\left|\frac{\varepsilon_{t-1}}{\sigma_{t-1}}\right| - \sqrt{\frac{2}{\pi}}\right) + \gamma_1 \frac{\varepsilon_{t-1}}{\sigma_{t-1}} + \beta_1 \ln(\sigma_{t-1}^2) \\ & \varepsilon_t = \sigma_t e_t \\ & e_t \sim N(0,1) \end{aligned} \tag{3.3}$$

where r_t is a random walk time series with a mean μ_t, ε_t is the heterogeneous error term, σ_t^2 is the conditional variance of ε_t, and e_t is a white noise with a standard normal distribution. Constant term ω represents the unconditional volatility, the ARCH coefficient α_1 measures the adjustment to past shocks, and the volatility asymmetric term γ_1 captures the leverage effect. The GARCH coefficient β_1 is the persistence parameter for conditional variance σ_t^2, and is usually close to 1. If γ_1 is negative, then the conditional volatility of the asset rises more after bad news; if γ_1 is positive, then the conditional volatility of rises more after good news. The closer β_1 to 1, the higher the conditional volatility. In addition to the conventional parameter estimates, the shape and asymmetric effects are also reported. The shape parameter states the conditional distribution of the variance, implying excess kurtosis of the estimated series. The asymmetric effect ($\frac{\gamma_1}{\alpha_1}$) illustrates the skewness of the time series.

In the second stage, model is estimated and evaluated. In practice, the dynamic conditional correlation (DCC) procedure is more often used because it allows the conditional correlation matrix to be time dependent and guaranteed to be positive definite (Bauwens et al., 2006). Engle (2002) introduces this approach,

$$
\begin{aligned}
& r_t \mid I_{t-1} \sim M(\mu, \Sigma_t) \\
& \Sigma_t = D_t R_t D_t \\
& \eta_t = D_t^{-1}(r_t - \mu) \\
& E\left[\eta_t \eta_t' \mid I_{t-1}\right] = R_t \\
& Q_t = (1-\alpha-\beta)\overline{Q} + \alpha \eta_{t-1}\eta_{t-1}' + \beta Q_{t-1} \\
& R_t = diag(dg(Q_t))^{-0.5} Q_t diag(dg(Q_t))^{-0.5}
\end{aligned}
\tag{3.4}
$$

where I_{t-1} represents the information set at time $t-1$, Σ_t is the dynamic conditional covariance matrix, M denotes multivariate density function, D_t is the diagonal matrix, R_t is the dynamic correlation matrix, and η_t is defined as the standardized residuals of the DCC. Q_t is the outer cross-products of η_t, $\overline{Q}$ is assumed to be positive definite, scalar parameters α and β satisfy $\alpha + \beta < 1$, and matrix operator $dg(Q_t)$ returns a vector equal to the main diagonal of matrix Q_t. Due to the time-dependent conditional correlation specification, the DCC estimators in the second stage may be different from those of the first stage (Caporin and McAleer, 2013). In addition, constant term ω and volatility asymmetric term γ_1 are suppressed for the joint return series.

Data

Daily data are used for all the analyses and all returns are value-weighted based on market capitalizations. Stock returns come from the CRSP (WRDS, 2015). Data for market return, risk-free rate as represented by 1-month US Treasury bill rate, size factor, and value factor are collected from the Kenneth French data library (French, 2014). Default premium, dividend yield, and term premium are defined in line with Petkova and Zhang (2005). Specifically, default premium equals the Baa corporate bond return minus the Aaa corporate bond return; dividend yield is the difference between value-weighted market returns with and without dividend; and term premium equals 10-year Treasury bill rate minus 1-year Treasury bill rate. Treasury bill rates and corporate bond returns are collected from the Board of Governors of the Federal Reserve System.

A total of 329 REITs are identified and used.[21] According to the classification of industry categories, 69 REITs are specialized REITs and the rest 260 REITs are defined as common

[21] In CRSP, REITs are separated from common stocks with a unique share code of 18. The list of companies in each REIT category can be provided upon request.

REITs. Timber REITs belong to specialized REITs and share certain common features. Currently, there are five public timber REITs in the United States: Plum Creek, Rayonier, Potlatch, Weyerhaeuser, and CatchMark. CatchMark went through the initial public offering (IPO) from a private TIMO in December 2013. Considering the widely recognized negative impact on returns of REIT IPOs, it is excluded from the timber REIT portfolio. To examine their unique features, the four timber REITs are excluded from specialized REITs. As such, the three REIT groups have 4, 64, and 260 firms, respectively (Table 3.1). Given the fact that the first timber REIT (Plum Creek) conversion completion date is in January 1999, our sample is set as from January 4, 1999 to December 31, 2014.

There are 4,025 of daily portfolio returns for each REIT group. The mean daily returns are 0.058% for timber REITs, 0.084% for specialized REITs, and 0.079% for common REITs. The standard deviation for timber REITs is 0.019, whereas the standard deviations for specialized and common REITs are lower at 0.016 and 0.018. The Sharpe ratio is 0.026 for timber REITs, 0.047 for specialized REITs, and 0.040 for common REITs. Test results suggest portfolio returns for the three REIT groups display features of non-normality, stationarity, heteroscedasticity, and not serial correlation. No autocorrelation is different from the findings for securitized timberlands in Sun (2013b), probably due to different firms and sample periods. [22] From Table 3.2, portfolio returns for the three REIT groups are positively correlated at the 1% significance level.

Within each group, timber REITs are all significantly positively correlated with large correlation coefficients, whereas specialized and common REITs have much smaller and

[22] Sun (2013b) analyzed three timber REITs and three master limited partnerships (MLPs) during 1989-2010.

sometimes negative correlation coefficients (Table 3.3 and Figure 3.1). The market capitalizations of timber REITs are larger than the other two groups (Figure 3.2). Regarding risk levels, the standard deviations and Sharpe ratios are concentrated for timber REITs and widespread for specialized and common REITs (Figure 3.3). These statistics suggest lack of diversification for timber REITs and more diversification potential for specialized and common REITs, despite the fact that both are in a single industry.

Empirical Results

Results from the Robust Intertemporal CAPM

As shown in Table 3.4, the intertemporal CAPM alphas are 0.001% for timber REITs, 0.036% for specialized REITs, and 0.046% for common REITs. The alphas for specialized and common REITs are significant at the 1% level, whereas that of timber REITs is insignificant and not different from zero. The annualized alphas (AAR) are 0.35% for timber REITs, 9.15% for specialized REITs, and 11.64% for common REITs, implying timber REIT returns are adequate for the risks taken. The market betas are positive and statistically significant at the 1% level, among which the market beta for timber REITs is close to 1. The ΔSMB coefficients are 0.129, 0.408, and 0.496, and the ΔHML coefficients are 0.792, 0.577, and 0.939, respectively. All coefficients of the two financial factors are positive and significant at the 1% level. The coefficients of innovations of default premium and dividend yield are all insignificant and not different from zero. The coefficients of innovations of term premium are all negative (-0.557, -2.364, and -1.318). The $\Delta TERM$ coefficients for specialized and common REITs are significant at the 1% level, whereas that of timber REITs is insignificant with a p-value of 0.142. The R^2 are 0.577, 0.659, and 0.668.

The intertemporal CAPM alphas and the loadings of market risk premium, ΔSMB, and ΔHML indicate the three REIT groups behave like procyclical small and value stocks. The insignificant ΔDEF and ΔDIV indicate REITs are insensitive to default and dividend yield risks. The *t*-statistics of $\Delta TERM$ are relatively large in absolute value. The innovation of term premium is closely related to business cycles (Nyberg, 2012). Negative loadings of $\Delta TERM$ serve as a recession predictor, suggesting the term structure of interest rates is downward sloping. Although positive and significant, the coefficients and *t*-statistics of ΔSMB for timber REITs are much smaller than those of specialized and common REITs, probably because of their relatively large market capitalizations (Figure 3.2). The insignificant $\Delta TERM$ coefficient for timber REITs implies insensitivity to recessionary shocks.

Results from Multivariate EGARCH Model

The return series for the three REIT groups are stationary and thus suitable for multivariate GARCH approach. In the first stage, the individual series is assumed to follow student *t*-distribution with univariate EGARCH (1, 1, 1) specification. In Table 3.5, all estimated coefficients (ω, α_1, β_1, γ_1, and shape) are significant. The ω's are -0.051 for timber REITs, -0.103 for specialized REITs, and -0.089 for common REITs. The adjustment to past shocks parameters α_1's are all negative (-0.047, -0.082, and -0.054). The persistent parameters β_1's are all positive and close to one (0.994, 0.988, and 0.990). The leverage effect parameters γ_1's are 0.112, 0.174, and 0.236. The excess kurtosis indicators shape's are 9.22, 8.31, and 9.96, respectively. The asymmetric effect parameters are -2.38, -2.12, and -4.37.

Parameter γ_1's are often negative for common stocks, which implies the volatility rises more after bad news (Nelson, 1991). However, all three REIT groups have significant positive

γ_1's, suggesting their daily volatilities rise more after good news. Compared to other REIT groups, timber REITs have the smallest ω and γ_1, meaning that timber REITs have the smallest unconditional volatility and leverage effect. Also, timber REITs have the smallest α_1 in absolute value, indicating the smallest adjustment to past shocks. Timber REITs exhibit the largest β_1, meaning the highest conditional volatility, whereas specialized REITs have the lowest. The graph for daily volatility estimates of three REIT groups is shown in Figure 3.4. Three volatility plots demonstrate similar patterns with slight differences. In response to shocks, all exhibit persistent volatility that lasts a couple of months and reached the peak in 2008.

In the intertemporal CAPM, the R^2 is 0.67 at best, implying weaker explanatory power compared to an autoregressive process. Hence, the ARMA (1, 1) is used in the second stage as the mean equation. To achieve the estimation efficiency, we adopt multivariate EGARCH (1, 1, 1) model with a DCC that follows a multivariate *t*-distribution (Engle and Sheppard, 2001). The order of the DCC approach is DCC (1, 1), a total of 27 parameters are estimated, and all coefficients are significant at the 1% level. The joint estimates for α_1, β_1 and shape are 0.032, 0.966 and 7.78. The multivariate α_1 is significantly positive and the multivariate shape is relatively small. Considering the strong positive correlation among the three REIT groups, synergistic effect might change the sign of α_1, leading positive response to past shocks.

Discussion and Conclusions

Using the intertemporal CAPM and multivariate GARCH models, we evaluate the return and risk characteristics of three types of REITs, i.e., timber REITs, specialized REITs, and common REITs, in the United States. Results from the intertemporal CAPM demonstrate that

REITs behave like procyclical small and value stocks. Specialized and common REITs have excess returns and are sensitive to recessionary shocks. Results from the exponential GARCH model show that the conditional volatilities of REITs rise more after good news, which is consistent with those of previous studies (Chandrashekaran, 1999; Kuhle, 1987; La and Mei, 2015). The volatility of common stocks, on the contrary, rises more after bad news. Thus, investing in REITs represents a well-established diversification strategy. Multivariate GARCH model suggests that REITs as a whole respond positively to past shocks. In spite of being a part of specialized REITs, timber REITs have large market capitalizations and no excess returns, and are insensitive to recessionary shocks. Timber REITs have the smallest unconditional variance and are most vulnerable to idiosyncratic shocks. Thus, we reject the null hypothesis that timber REIT returns are indifferent to other REIT returns regarding mean and variance features.

From the intertemporal CAPM, the total risk as measured by the standard deviation of asset returns can be divided into portions explained by the systematic risk (R^2) and the idiosyncratic risk ($1-R^2$). Timber REITs have both the highest total risk and idiosyncratic risk. Furthermore, timber REITs have the highest market beta, which implies the least diversification potential. In finance, the higher the risk an asset carries, the higher the returns are expected. However, the highest total risk and the smallest returns for timber REITs contradict this principle. One plausible cause might be the portfolio construction process. There are only four firms in the timber REIT portfolio in contrast to at least twenty firms for a diversified portfolio, so that any interpretation regarding timber REITs should be taken with caveat. The fact that these four firms all come from the same industry worsens the scenario. Moreover, the significant positive correlations and concentrated standard deviations and Sharpe ratios imply a lack of diversification and a higher total risk. Thus, the timber REIT group may not be representative of the general principle between return and risk. Using daily returns, this study focuses on short-term effects that last for a few months. In the long run, however, the timber REIT portfolio tends to be more diversified because timber REIT returns do not share a common trend (La and Mei, 2015).

From univariate EGARCH model, timber REITs have the smallest unconditional variance. Hence, timber REITs should have the lowest risk were there no external shocks. Given that timber REITs have the highest total risk and conditional volatility as measured by the persistence parameter in GARCH, external shocks might explain the discrepancy between the smallest unconditional volatility and the highest conditional volatility. External shocks generally involve a large category of shocks, including macroeconomic shocks, natural disasters, outbreaks of wars, policy and regulation changes, and so forth. From the intertemporal CAPM, timber REITs are least sensitive to recessionary shocks, which leaves idiosyncratic shocks to be considered. Again, the lack of diversification may cause timber REITs vulnerable to idiosyncratic shocks. Further research is needed to explore the causal relationship between diversification and risk features of timber REITs. Both the investors and managers of timber REITs should focus more on monitoring the idiosyncratic risks within the timber industry.

The negative term premium estimate for timber REITs is consistent with the finding of Yao and Mei (2015). Our new finding is that timber REITs exhibit the least sensitivity to recessionary shocks, which may be related to the unique features of timberland. Timber is a long-term biological asset and the yield function is independent of business cycles. Timber REITs can time their harvesting schedules based on market conditions to some extent, and can divest non-strategic timberlands or explore higher and better uses to generate cash flows. Regarding other management aspects, timber REITs often employ timber harvest contracts and long-term leases, which help limit their risks. Contrary to other types of REITs which are usually dependent on monthly rents, these long-term features could make timber REITs least sensitive to recessionary shocks.

Timber REITs' underperformance and more exposure to risk are consistent with previous studies (Binkley, March 20, 2008; Sun, 2013a). Although timber REITs own or manage 18 million acres of commercial timberland in total, their holdings represent less than 20% of the total and their market capitalization only represents 4% of all publicly traded REITs in the United States. Looking forward, more restructuring activities are likely to take place in the timber industry to enhance synergy and reduce risk. For instance, in 2015 Weyerhaeuser offered to acquire Plum Creek. Managers should be prepared for this continuing wave of timberland structural changes.

Table 3.1. Descriptive statistics: Daily value-weighted portfolio returns of three REIT groups

	Firm #	Mean	Std. Dev.	Min	Max	*Sharpe*	*ADF*	Hettest	*DW*-stat
Timber REITs	4	0.058	0.019	-0.148	0.188	0.026	-70.2	26.3	2.07
Specialized REITs	64	0.084	0.016	-0.129	0.159	0.047	-70.4	411.5	2.12
Common REITs	260	0.079	0.018	-0.186	0.198	0.040	-75.0	272.0	2.16

Note: Daily portfolios have identical number of observations (4025) in the time series. Firm # indicates the number of firms in the portfolio. Mean returns are in percentage. *Sharpe* indicates the Sharpe ratio in the portfolio. *ADF* shows test statistics for augmented Dickey-Fuller test for non-stationarity, Hettest indicates Breusch-Pagan test statistics for heteroscedasticity, and *DW*-stat are results of Durbin-Watson test for serial correlation. The Jarque-Bera tests for normality reject the null hypothesis that the time series is normally distributed for all the three groups. These results reject the null hypothesis of a unit root and constant variance at the 1% significance level, but cannot reject the null hypothesis of no serial correlation.

Table 3.2. Correlation matrix of daily portfolio returns of three REIT groups during 1999-2014

	Timber REITs	Specialized REITs	Common REITs
Timber REITs	1		
Specialized REITs	0.692	1	
Common REITs	0.725	0.882	1

Note: All the Pearson correlation coefficients are significant at the 1% level.

Table 3.3. Correlation matrix of daily returns of the market and four timber REITs during 1999-2014

	MKT	PCL	RYN	PCH	WY
MKT	1				
PCL	0.621	1			
RYN	0.730	0.798	1		
PCH	0.749	0.825	0.800	1	
WY	0.729	0.719	0.566	0.673	1

Note: Market (MKT) return is defined as the value-weighted market return including distributions. All the Pearson correlation coefficients are significant at the 1% level.

Table 3.4. Robust regression results from the intertemporal CAPM model

	α	b_1	b_2	b_3	b_4	b_5	b_6	AAR	R^2
Timber	0.001	1.066	0.129	0.792	0.976	-0.002	-0.557	0.35	0.577
REITs	(0.08)	(51.52)	(3.35)	(20.98)	(0.99)	(-0.35)	(-1.47)		
Specialized	0.036	0.897	0.408	0.577	-0.604	-0.004	-2.364	9.15	0.659
REITs	(2.87)	(50.28)	(15.19)	(16.06)	(-0.76)	(-0.70)	(-6.66)		
Common	0.046	0.894	0.496	0.939	-0.422	-0.007	-1.318	11.64	0.668
REITs	(3.44)	(45.98)	(20.23)	(29.14)	(-0.47)	(-0.86)	(-3.62)		

Note: *t*-statistics, in parentheses, are calculated from White standard errors. b_1 represents the market risk beta; b_2 and b_3 represent the coefficients of the innovations of two financial factors (*SMB* and *HML*); and b_4 ~ b_6 represent the coefficients of the innovations of three state variables (default premium, dividend yield, and term premium), respectively. AAR indicates annualized abnormal returns, which are defined as α times 252 (trading days). The intertemporal CAPM alpha and AAR are in percentage.

Table 3.5. Results from multivariate EGARCH model

	ω	α_1	β_1	γ_1	*Shape*	*AE*	*LL*
First stage							
Timber REITs	-0.051	-0.047	0.994	0.112	9.22	-2.38	11110
	(-7.65)	(-5.80)	(1117)	(6.01)	(3.25)		
Specialized REITs	-0.103	-0.082	0.988	0.174	8.31	-2.12	12259
	(-5.97)	(-6.86)	(483)	(7.14)	(13.7)		
Common REITs	-0.089	-0.054	0.990	0.236	9.96	-4.37	12551
	(-9.13)	(-4.91)	(866)	(65.1)	(7.18)		
Second stage							
Joint	−	0.032	0.966	−	7.78	−	40283
		(9.92)	(270)		(19.9)		

Note: *t*-statistics in parentheses. *AE* is the asymmetric effect and *LL* is the log-likelihood ratio. In the first stage, we generate GARCH estimates for the three REIT portfolios. In the second stage, the conditional correlation among the three groups is considered and GARCH estimates of the joint series are evaluated.

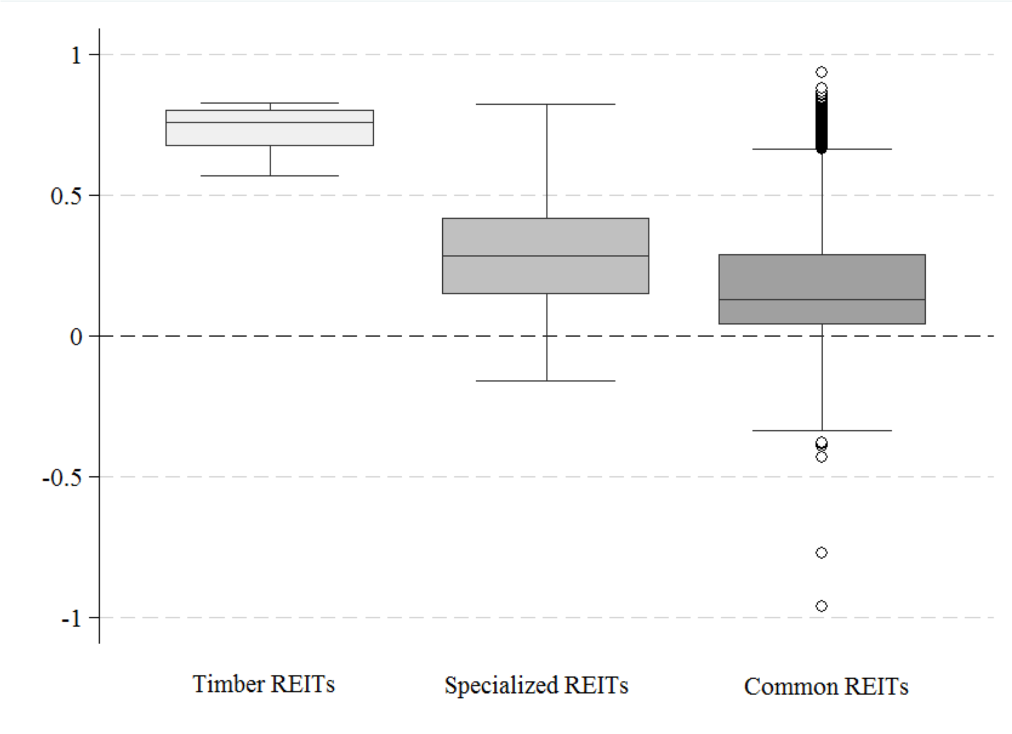

Figure 3.1. Pairwise correlation coefficients of the three REIT groups during 1999-2014.

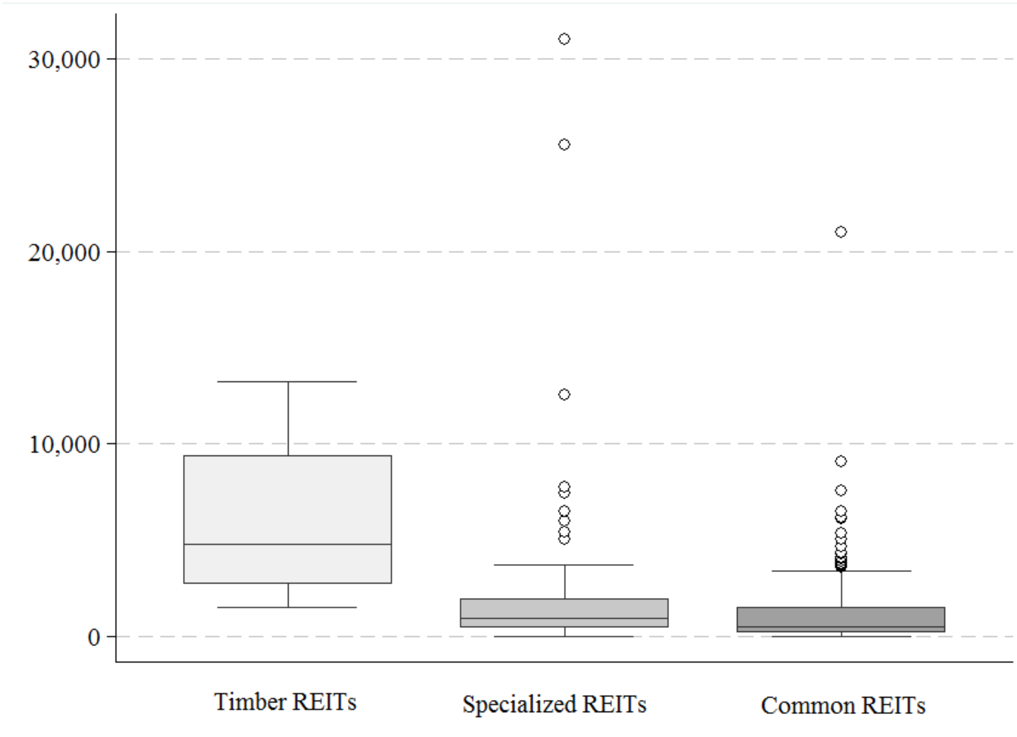

Figure 3.2. Firm size (million dollars) of the three REIT groups during 1999-2014.

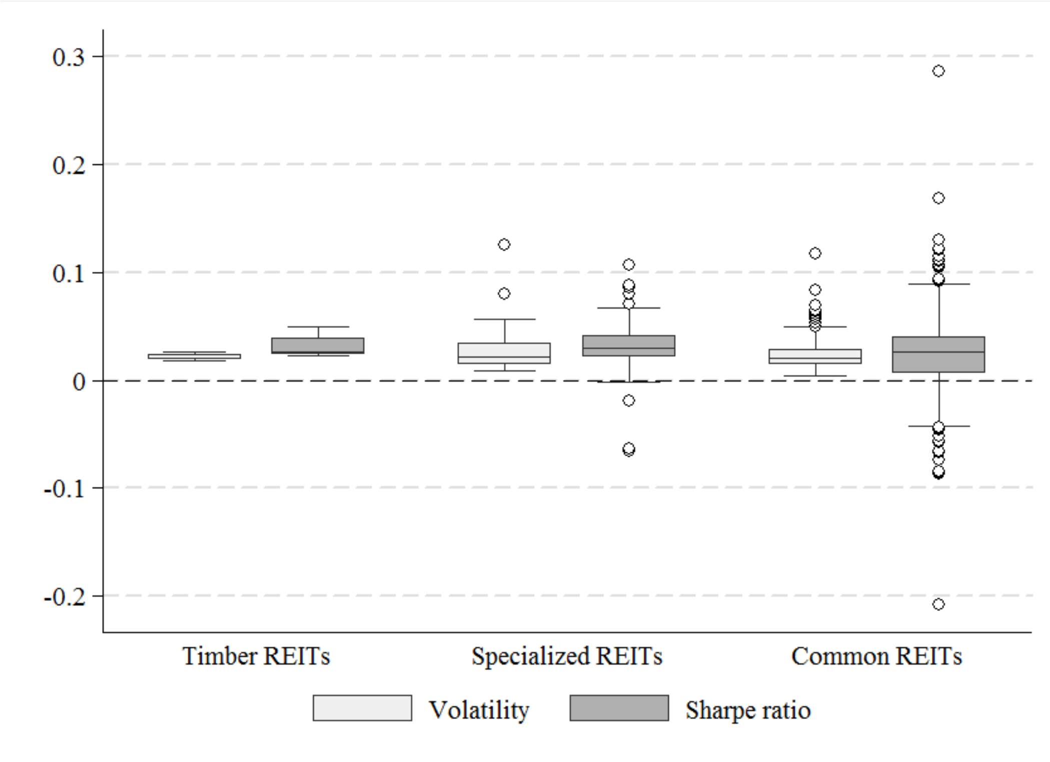

Figure 3.3. Volatilities and Sharpe ratios of the three REIT groups during 1999-2014.

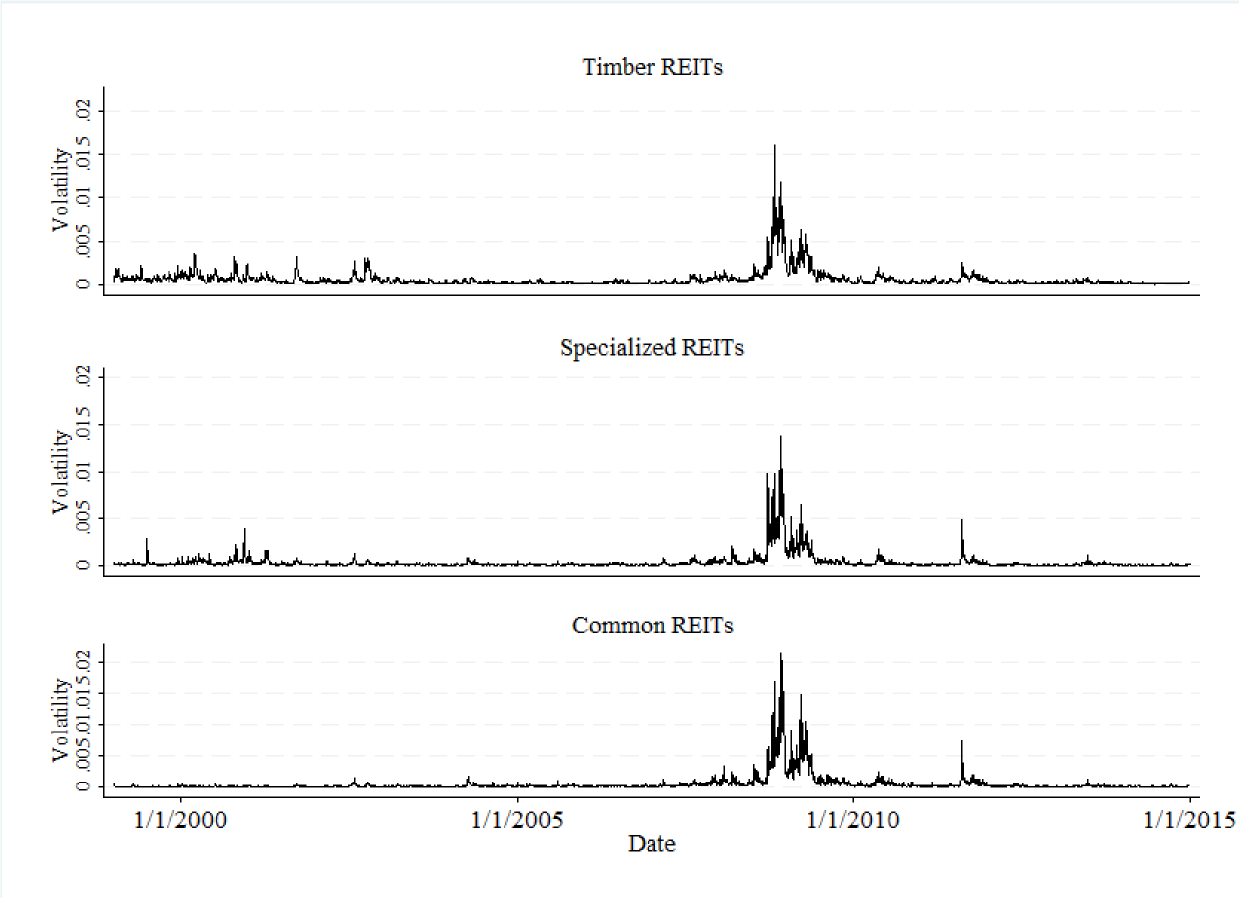

Figure 3.4. Daily volatility estimates of the three REIT groups from the univariate EGARCH(1, 1, 1) model.

CHAPTER 4

ON THE DETERMINANTS OF TIMBERLAND TRANSACTION PRICES IN THE US SOUTH[23]

[23] Piao, X., Mei, B. Submitted to *Forest Products Journal*, September 2016.

Abstract

Over 340 large timberland transactions that occurred in the US South during 2000-2015 are examined with robust regressions to discover the influence of timber prices, locations, timberland ownership types, and macroeconomic variables on per acre transaction prices. Results show that important determinants include pine price and some of the location and seller/buyer dummies. Pine sawtimber prices and the Federal funds rate have significantly positive impacts on transaction prices, while crude oil prices and the US dollar index have significantly negative impacts. Among the 11 Southern states, North Carolina and South Carolina have significantly positive effects on timberland prices, while Alabama, Arkansas, Tennessee, Texas, and Virginia have significantly negative effects. In regards to timberland ownership, separate seller or buyer types have no impact on timberland prices, but the combination of seller and buyer types suggests otherwise. Of the 12 seller/buyer combinations, seven of them have significantly negative impacts. Vertically integrated forest products firms and timber investment management organizations outperform firms outside the timber industry.

Introduction

Since 2000, the total value of large timberland transactions[24] in the United States has been over $64 billion, and almost 55 million acres of timberland have changed hands (Hood et al., 2015). This coincides with massive structural changes of timberland ownership: Forestry firms structured as C-Corps have either converted to timber real estate investment trusts (REITs) or divested most of their timberland holdings, and REITs and timber investment management organizations (TIMOs) acquired timberlands from industry firms as well as private timberland owners (Binkley, 2008).[25] In particular, three very large transactions with over 4 million acres transacted: International Paper acquired Champion International in 2000; Plum Creek acquired The Timber Co. in 2001; and Weyerhaeuser acquired Plum Creek in 2016.[26]

In the meantime, average timberland transaction prices per acre increased from $1,250 to $2,045. Although transaction prices have an overall upward trend, prices decreased during 2010-2014 because of the financial crisis. Simultaneously, timber prices have changed drastically. For example, hardwood sawtimber stumpage prices increased from $17 per ton in 2000 to $32 per ton in 2014. Framing lumber composite prices exceeded $390 per mbf in 2005, decreased to $250 per mbf in 2009, and increased to $400 per mbf in 2014. With such high volatility in the timber market, investor sentiment and valuation of timberland may change accordingly (Mei et al., 2013).[27]

[24] Large timberland transaction is defined as of size over 1000 acres.
[25] TIMOs typically have minimum investment criteria and require a long holding period (i.e., 10-15 years), whereas shares of public REITs are more easily traded via stock exchanges.
[26] International Paper is a C-Corp, and Plum Creek and Weyerhaeuser are timber REITs. The Weyerhaeuser-Plum Creek merger represented 13 million acres of timberland and was completed in February 2016.
[27] During 1995-2010, timber price changes contribute -106% of total timberland investment returns, while the other two return drivers are biological growth (183%) and land appreciation (23%).

The positive linkage between timberland transaction and timber prices has been well recognized by theoretical analyses (i.e., discounted cash flow) (Straka and Bullard, 1996). However, to our best knowledge, there is no empirical study directly examining this relation. In practice, timberland owners rely on case by case appraisals to price timberlands, whereas a general to specific approach are hardly seen. With a new timberland transaction dataset provided by Timber Mart-South, we would like to fill this knowledge gap and quantify the impact of timber price, location, and ownership on timberland transaction prices in the US South[28] using the robust ordinary least squares (OLS) estimations. The null hypothesis is that timber prices have positive impacts on per acre transaction prices after controlling for market information. This study can provide investors and managers some guidance of the pattern of large timberland transactions in the US South, and in particular, how transaction prices react to market signals including timber prices, locations, ownership types, and macroeconomic variables.

Literature Review

In land economics, the valuation of real estate plays a major role, and various models have been developed to investigate the relation between land price and a set of influential variables, such as parcel size, zoning, ownership types, and liquidity. McMillen and McDonald (1991) used a multinomial logit model to explain zoning effect in Chicago during 1961-1981, and found that land values and land uses were correlated and that there were significant impacts of location and zoning on land values. King and Sinden (1994) used price formation models to discover search and bargaining abilities in Australian farmland market, and found that market

[28] Among the four major timber regions (i.e., Pacific Northwest, Lake States, Northeast, and South), the South is the leading region with 30 million acres of timberland transacted. Thus, this study focuses on transactions in the US South.

information had a positive impact on farmland prices and that buyers had more bargaining power than sellers. Isakson (1997) introduced seller/buyer combinations to the land pricing model, and found significant impacts of seller/buyer combinations on land values. Krainer (2001) discussed the liquidity theory in residential real estate market and found that investor sentiment affected the liquidity of real estate transactions and that a “cold” market often led to an exposure to default risks.

Focusing on timberland valuation, a couple of empirical studies have examined the pricing of timberland transactions indirectly. Aronow et al. (2004) used NCREIF timberland index to examine the determinants of timberland values in the South and Pacific Northwest during 1987-2003, and found a significant effect of timber prices on timberland values through their influence on operating revenues. Clements et al. (2011) used OLS regression and the cointegration analyses to price timberland values over 20 years and found that unanticipated shocks on lumber futures led to a permanent change on timberland prices. Kennedy et al. (2002) used hedonic modeling techniques and geographic information system procedures to examine influential factors in the timberland market in Northern Louisiana during 1993-1998 and found that location and tract development potential had impacts on timberland valuation. The purpose of this study is to identify influential factors in pricing timberland in the US South, and provide investors and managers some insights on future timberland transactions.

Methodologies

The plattage model is a widely used land economics model, which relates the land selling price to the parcel size, zoning, and location (Colwell and Sirmans, 1978). Plottage and plattage describe the relation between land value and size, specifically, the increment in value that comes from the assembly and the subdivision of land. Urban land in populous areas tends to have a plottage effect, while vacant and large lands tend to have a plattage effect. Other determinants of land value include the time of sale and land location. Land value is assumed to be an increasing exponential function of time. Location, i.e., the distance from downtown, is known to have negative relation with land value. An OLS regression is used to estimate the plattage model,

$$log(Price) = \alpha + \beta_1 Time + \beta_2 DistC + \beta_3 (Size - s)^{1/3} + \varepsilon \tag{4.1}$$

where $Price$ is the transaction price per acre, $Time$ is the time of sale, and $DistC$ is the distance from the central business district in miles, $Size$ is the parcel size transacted, and ε is the error term. Parameter s represents a turning point at which the land valuation function shifts from plottage to plattage, the magnitude of which is selected so as to maximize R^2 in the regression.

Isakson (1997) extended the standard plattage model with ownership types (e.g., individual, partnership, government, and corporation) and investigated the impact of separate seller and buyer types as well as the combination of seller/buyer types. Individual tends to pay the lowest prices, while the government tends to pay the highest prices. In regards to seller/buyer combinations, the lowest prices paid are in individual/individual transactions, and the highest prices paid are in partnership/corporation transactions. The seller/buyer combinations have better prediction power than the separate seller and buyer types.

$$log(Price) = \alpha + \beta_1 log(Size) + \beta_2 log(Size)Time + \beta_3 DistH + \delta Zone + \eta SLR / BYR + \varepsilon \tag{4.2}$$

where $DistH$ is the distance to a highway in miles, $Zone$ is a vector of zoning dummy variables (i.e., commercial, industrial, and residential), and SLR / BYR is a vector of dummy variables representing the seller/buyer combinations. Variable $log(Size)Time$ represents the interaction effect between parcel size and the time of sale, which captures information regarding subdivision potential.

In contrast to these traditional land economics models, characteristics of the timberland market are captured by timber prices and related macroeconomic variables. Time trend is used to alleviate the seasonal effect of the time series. Business cycle dummy coincides with investor sentiment, and thus serves as an indirect measure of real estate liquidity. Given inflation is a primary cause of the appreciation of land prices, the Producer Price Index (PPI) is used to deflate transaction and timber prices. The general model is analyzed by the OLS regression,

$$log(Price') = f(Time, Crisis, log(Size), log(Pine'), log(HW'), State, SLR/BYR, Macro) \quad (4.3)$$

where $Crisis$ is the binary recession dummy, and $Pine$ and HW are timber prices for pine and hardwood. $State$ is a vector of state dummy variables, and $Macro$ is a vector of related macroeconomic variables including oil and gold prices, the US dollar index, housing starts, market return, and the Federal funds rate (FFR). Symbol $'$ denotes the inflation adjustment, which is accomplished by dividing the time series by the Producer Price Index (PPI). Positive coefficient suggests positive impact on transaction prices, and negative coefficient suggests negative impact on transaction prices. Five models are used to examine robustness among different sets of independent variables.

Data

Quarterly data from 2000Q1 to 2015Q2 are used for all the analyses. Large timberland transaction data for per acre transaction prices, size transacted, location, and seller and buyer firms are collected from Timber Mart-South (Hood et al., 2015). Ownership types, i.e., C-Corp, TIMO, REIT, Public (i.e., US Forest Service, local governments, and non-profit organization), and firms outside the timber industry (Other), are derived from their profiles. South-wide sawtimber stumpage prices for pine and hardwood also come from Timber Mart-South. The crisis dummy captures two recessions[29] (2001Q2-2001Q4 and 2008Q1-2009Q2) as determined by the National Bureau of Economic Research. Data for oil price, gold price, the US dollar index, housing starts, and the Producer Price Index (PPI) come from the Federal Reserve Bank of St. Louis. The Federal funds rate (FFR) is collected from the Board of Governors of the Federal Reserve System, and market return is collected from the CRSP (WRDS, 2015). Specifically, oil price is the global price of simple average of three spot prices crude oil; gold price is the gold fixing price in London Bullion market converted from British pounds to US dollars; the US dollar index is the trade weighted US dollar index; the PPI is PPI for all commodities with 2000=1; the FFR is the monthly Federal funds effective rate converted to quarterly series; and market return is monthly value-weighted market return including dividends converted to quarterly series.

A total of 347 large timberland transactions in the US South are used. The mean and standard deviation of size transacted are 65.70 and 189.93 thousand acres (Table 4.1). Per acre transaction prices have a mean of $1,488.91 and a standard deviation of $725.45. Figure 4.1 plots transaction prices and size, both of which reached their peaks during the financial crisis. Mean sawtimber prices are $31.34/ton for pine and $22.26/ton for hardwood, and the standard deviations are $6.01/ton for pine and $3.35/ton for hardwood. From Figure 4.2, pine price is negatively related to hardwood price. The former decreased over time, while the latter slightly increased. In regards to location, Figure 4.3 displays the geographic map for the 11 Southern

[29] The first recession in 2001 is the collapse of technology bubble, and the second one during 2008-2009 is the financial crisis that is closely related to the investments in the real estate market.

states used in this analysis. Among them, GA and AR have the most transactions (38 and 37), SC and NC have the highest average transaction prices per acre ($2,091.5 and $2,028.3), and TX and AL have the largest average transaction size (69.7 and 52.0 thousand acres), as shown in Table 4.2.

For ownership types, the top seller types are C-Corps and TIMOs with 144 and 106 transactions, and the top buyer types are TIMOs and Other with 161 and 85 transactions (Table 4.3 and Figure 4.4). Obviously, TIMOs are the most active player in the timberland market. The top seller/buyer combinations are C-Corp/TIMO, TIMO/TIMO, and C-Corp/Other with 60, 58, and 39 transactions, respectively. The seller/buyer combinations with the highest average transaction prices are TIMO/REIT, REIT/Other, and C-Corp/Other with $1,694.7, $1,659.7, and $1,659.5, respectively. Thus, when timberland is sold to firms outside the timber industry, the average transaction prices tend to be higher. The seller/buyer combinations with the largest average size transacted are C-Corp/TIMO, C-Corp/C-Corp, and Other/TIMO with 170.1, 83.2, and 79.5 thousand acres, respectively. The size transacted is larger when timberland is sold from C-Corps or sold to TIMOs.

Summary statistics of the six macroeconomic variables are reported in Table 4.1 and their trends are plotted in Figure 4.5. Oil and gold prices show similar ascending trend; the US dollar index, housing starts, and the FFR experienced cyclical pattern; and market return has the most volatile trend. From Table 4.4, all of the macroeconomic variables except market return are significantly correlated at the 1% level, which can cause multicollinearity that affects the accuracy of estimated coefficients in the regression model (Farrar and Glauber, 1967). Using the variance inflation factor (VIF) approach, we find severe multicollinearity for the six macroeconomic variables (Table 4.5). The problem is alleviated once we eliminate gold price, housing starts, and market return.

Empirical Results

Based on the Breusch-Pagan test, a robust OLS procedure is used to treat heteroscedasticity with White standard errors (Table 4.6). Regardless the model used, the estimated coefficients and test results are robust. For the full set model excluding outliers,[30] the time trend coefficient is significantly positive (0.016) at the 1% level, and the coefficient of the financial crisis dummy is significantly positive (0.082) at the 10% level (model 5 and Figure 4.6). The significantly positive estimate of the time trend suggests a positive relation between transaction prices and the time trend. Given transaction prices are deflated by the PPI, this suggests timberland appreciates at a faster rate than inflation. The positive financial crisis dummy coefficient implies a positive effect of market liquidity on timberland prices. The size estimate is significantly negative (-0.091) at the 1% level, suggesting the smaller the parcel size, the higher the transaction prices. The coefficients of timber prices are 0.698 for pine sawtimber and -0.193 for hardwood sawtimber, with only the former significant at the 5% level. Among the two timber prices, only pine prices have a positive relation with transaction prices.

For location dummies, the coefficients of North Carolina and South Carolina are 0.274 and 0.133, and are significantly positive at the 10% level. On the other hand, the coefficients of Alabama, Arkansas, Tennessee, Texas, and Virginia are -0.189, -0.187, -0.597, -0.206, and -0.172, and are significantly negative at the 5% level. All the coefficients of seller/buyer

[30] Four outliers are marked based on extreme leverage and normalized residual squared.

combinations are negative.[31] Among them, the coefficients of CT, TT, TO, RC, RT, and RO are ranging from -0.327 to -0.191 and are significant at the 5% level, and that of OT is -0.201 and significant at the 10% level. Figure 4.7 highlights these significantly negative seller/buyer combinations.

The coefficients of macroeconomic variables are -0.009 for oil price, -0.016 for the US dollar index, and 0.044 for the FFR, all of which are significant at the 5% level. As an indirect measure of logging cost, oil price is expected to have a negative relation with transaction prices. A strong US dollar would decrease the realized earnings for foreign investors, thus a negative estimate of the US dollar index is as expected. The FFR is associated with discount rate of timberland valuation. The positive FFR estimate suggests the higher the FFR, the higher the transaction prices.

In sum, important determinants with significant coefficients larger than 0.1 include pine price and some of the location and seller/buyer dummies, whereas those of time and crisis dummies, size, and macroeconomic variables have smaller magnitudes. The R^2 is 0.440, and the F-statistic is 7.8. Results from the Breusch-Pagan and the Shapiro-Wilk tests are 15.48 and 1.80, respectively. Both are significant at the 5% level, indicating heteroscedasticity and non-normality for the regression model. Plots for normality, homoscedasticity, and independence in Figure 4.6 suggest that residuals are independent of time. Using augmented partial residual plots, we find no sign of non-linearity, asserting that the linear OLS regression is adequate (Figure 4.8).

[31] Separation of seller and buyer types have insignificant impacts on transaction prices.

Discussion and Conclusions

We evaluate the influence of timber prices, locations, timberland ownership types, and macroeconomic variables on per acre transaction prices in the US South during 2000-2015. Results show that important determinants include pine sawtimber price and some of the location and seller/buyer dummies. Parcel size has a significantly negative impact on transaction prices, which is consistent with those of previous studies (King and Sinden, 1994; McMillen and McDonald, 1991). Only pine sawtimber prices have a significantly positive impact on transaction prices. Among the 11 Southern states, North Carolina and South Carolina have significantly positive effects on timberland prices, while Alabama, Arkansas, Tennessee, Texas, and Virginia have significantly negative effects. In regards to timberland ownership, combination but not separation of seller or buyer types have impact on timberland prices. Of the 12 seller/buyer combinations, seven of them have significantly negative impacts. Crude oil prices and the US dollar index have significantly negative impacts on timberland prices, while the Federal funds rate has significantly positive impact. Thus, we cannot reject the null hypothesis that timber prices have positive influence on per acre transaction prices.

The positive time trend estimate indicates the transaction prices increased over time. Given the PPI adjustment for transaction prices, timberland assets appreciate at a faster speed than inflation and serve as an inflation hedge, which is consistent with the finding of Wan et al. (2013). Serving as a liquidity measure, the positive estimate of the financial crisis dummy implies a positive effect of liquidity on transaction prices, which is consistent with the finding of Amihud et al. (2006). This positive relation provides an incentive of holding timberland assets during market contractions.

The negative size premium combined with increasing land development and high and best use practices in the timber market, can lead to forest fragmentation and sometimes deforestation. Similar concerns are described in previous studies (Clutter et al., 2005; Harris and DeForest, 1993). In regards to timber prices, the coefficients for pine and hardwood prices have opposite signs, probably due to their negative correlations. In the timber market, pine and hardwood are complementary goods with a negative cross elasticity of demand (Nagubadi and Zhang, 2005; Yue et al., 2006). The significant and larger coefficient of pine price indicates pine is the dominant product in the joint demand equilibrium.

Among the 11 Southern states, only North Carolina and South Carolina have positive impacts on transaction prices, partly because they have the highest average price per acre, partly because they have smaller average size transacted. State economy as measured by gross state products per capita (GSPC) is found to be not as relevant to transaction prices as local timber market conditions. North Carolina and South Carolina are known to have better timber inventory than the other states (Cubbage et al., 1995).

Regarding ownership types, sellers often reserve higher prices than buyers. C-Corps are the top seller, as is found in previous studies (Binkley, 2008; Mei and Sun, 2008). TIMOs are identified as the most active player in the timberland market. The size transacted tends to be larger when timberland is sold from C-Corps or sold to TIMOs. Given the negative relation between transaction prices and size, TIMOs tend to pay less per acre when purchasing timberlands. Three seller/buyer combinations (TIMO/REIT, REIT/Other, and C-Corp/Other) have the highest average transaction prices, indicating higher purchasing prices for firms outside the timber industry (i.e., bank, oil company, steel company). Compared to the seven significantly negative seller/buyer types, the five insignificant ones primarily include C-Corps as sellers, suggesting superior bargaining power of C-Corps during timberland transactions. Thus, C-Corps and TIMOs may have taken advantage of their industry knowledge against firms outside the timber industry in consummating timberland sales.

Timber is known for its low value to weight ratio (Baker and Greene, 2008). In order to transport timber from distant timberland to processing facilities, timberland owners may have to pay extensive logging fees. Oil price being an indirect measure of logging costs, its negative impact on timberland values is expected. Some timberlands in the US South are owned by foreign investors. When converting their earnings from US dollars to their home currencies, they are exposed to exchange rate risks and may suffer losses if the US dollar appreciates. The negative estimate for the US dollar index is consistent with this rationale.

Besides pine and hardwood sawtimber prices, the relation between timberland and timber prices can be further examined by adding more prices of timber products, such as chip-n-saw and pulpwood. In addition, Hood et al. (2015) simply compile a new timberland transaction dataset. The stories behind large timberland transactions are not disclosed, especially the transmission channels that might lie behind the positive or negative effect. Future research might check the effect of adding more timber prices into the model, and dive into the details of timberland transactions.

Table 4.1. Descriptive statistics: Timberland transactions, timber prices, and macroeconomic variables in the US South from 2000 to mid-2015

Variable	Unit	Mean	Std. Dev.	Min	Max
Size	000 acres	65.70	189.93	0.70	2,593.70
Price per acre	$	1,488.91	725.45	250	5,571
Pine price	$/ton	31.34	6.01	22.59	41.96
Hardwood price	$/ton	22.26	3.35	16.30	32.06
Oil price	$/bbl	68.38	31.44	19.31	121.11
Gold price	$/oz	889.80	488.13	263.36	1,722.73
US dollar index	—	108.33	9.54	95.31	129.12
Housing starts	000 units	1,247.39	533.66	526	2,120
Market return	%	0.65	2.90	-8.24	5.80
Federal funds rate	%	1.65	1.89	0.07	6.52

Note*:* Market return is defined as the value-weighted market return including distributions.

Table 4.2. Descriptive statistics: Large timberland transactions in the 11 Southern states from 2000 to mid-2015

	Frequency	Percent	Avg price	Avg size	GSP	GSPC
AL	24	6.9	1,310.1	52.0	207.3	42,663
AR	37	10.7	1,366.1	15.7	122.5	41,129
FL	32	9.2	1,769.5	29.7	883.7	42,595
GA	38	11.0	1,567.7	24.1	496.2	48,574
LA	12	3.5	1,379.3	48.2	253.0	54,159
MS	10	2.9	1,221.7	25.1	106.9	35,717
NC	6	1.7	2,028.3	16.3	503.7	50,159
SC	22	6.3	2,091.5	13.2	196.9	40,212
TN	20	5.8	861.4	46.1	307.1	46,531
TX	27	7.8	1,200.0	69.7	1648.0	59,994
VA	16	4.6	1,347.8	22.3	477.0	56,891
Other	103	29.7	1,556.6	143.0	—	—

Note: Avg price and size are average transaction price per acre and parcel size transacted. GSP and GSPC are gross state product and gross state product per capita in 2015. GSP is in billion US$, and GSPC is in US$. Other denotes timberland transactions happened across states or in undisclosed location.

Table 4.3. Descriptive statistics: Timberland transactions by ownership type from 2000 to mid-2015

Seller	Buyer	Abbreviation	Frequency	Percent	Avg price	Avg size
Separate seller						
C-Corp			144	41.5	1,434.1	98.6
TIMO			106	30.5	1,534.6	47.4
REIT			73	21.0	1,595.4	28.9
Other			24	6.9	1,291.9	61.1
Separate buyer						
	C-Corp		30	8.6	1,426.8	43.1
	TIMO		161	46.4	1,345.1	100.3
	REIT		40	11.5	1,618.9	57.5
	Public		31	8.9	1,885.5	19.4
	Other		85	24.5	1,577.4	28.9
Seller/buyer combination						
C-Corp	C-Corp	CC	11	3.2	1,318.1	83.2
C-Corp	TIMO	CT	60	17.3	1,309.1	170.1
C-Corp	REIT	CR	15	4.3	1,348.5	80.0
C-Corp	Public	CP	19	5.5	1,501.2	24.5
C-Corp	Other	CO	39	11.2	1,659.5	36.2
TIMO	TIMO	TT	58	16.7	1,492.6	56.4
TIMO	REIT	TR	18	5.2	1,694.7	53.6
TIMO	Other	TO	20	5.8	1,411.1	30.5
REIT	C-Corp	RC	11	3.2	1,341.8	13.9
REIT	TIMO	RT	29	8.4	1,205.1	53.7
REIT	Other	RO	24	6.9	1,659.7	10.5
Other	TIMO	OT	14	4.0	1,178.4	79.5
—	—	—	29	8.4	2,027.6	23.2

Note: Avg price and size are average transaction price per acre and parcel size transacted. The last row represents all the transactions excluding the above 12 seller/buyer combinations.

Table 4.4. Correlation matrix of 6 macroeconomic variables from 2000 to mid-2015

	Oil	Gold	Dollar	Housing	Market	FFR
Oil	1					
Gold	0.875	1				
Dollar	-0.930	-0.822	1			
Housing	-0.722	-0.836	0.705	1		
Market	-0.053	0.024	-0.019	0.013	1	
FFR	-0.368	-0.618	0.323	0.577	-0.184	1

Note: Except those of market return, all the Pearson correlation coefficients are significant at the 1% level. These large and significant correlation coefficients might cause multicollinearity in the linear regression.

Table 4.5. Multicollinearity tests: Southern states, ownership types, and macroeconomic variables

Variable	VIF	SVIF	Tolerance	R^2
Southern states				
AL	1.15	1.07	0.87	0.13
AR	1.21	1.10	0.82	0.18
FL	1.19	1.09	0.84	0.16
GA	1.22	1.10	0.82	0.18
LA	1.08	1.04	0.93	0.07
MS	1.07	1.03	0.94	0.06
NC	1.03	1.02	0.97	0.03
SC	1.13	1.06	0.88	0.12
TN	1.12	1.06	0.89	0.11
TX	1.16	1.08	0.86	0.14
VA	1.10	1.05	0.91	0.09
Seller/buyer combinations				
CC	1.35	1.16	0.74	0.26
CT	2.59	1.61	0.39	0.61
CR	1.47	1.21	0.68	0.32
CP	1.53	1.24	0.65	0.35
CO	2.12	1.46	0.47	0.53
TT	2.55	1.60	0.39	0.61
TR	1.56	1.25	0.64	0.36
TO	1.61	1.27	0.62	0.38
RC	1.35	1.16	0.74	0.26
RT	1.86	1.37	0.54	0.46
RO	1.73	1.31	0.58	0.42
OT	1.41	1.19	0.71	0.29
Six macroeconomic variables				
Oil	10.62	3.26	0.09	0.91
Dollar	10.93	3.31	0.09	0.91
FFR	2.27	1.51	0.44	0.56
Gold	7.89	2.81	0.13	0.87
Housing	3.75	1.94	0.27	0.73
Market	1.10	1.05	0.91	0.09
Three macroeconomic variables				
Oil	9.47	3.08	0.11	0.89
Dollar	9.73	3.12	0.10	0.90
FFR	1.13	1.06	0.89	0.11

Note: The variance inflation factor (VIF) quantifies the severity of multicollinearity in an OLS regression analysis. SVIF is the square root of VIF. If VIF>10, there might be multicollinearity issue. Southern states and seller/buyer combinations exhibit no sign of multicollinearity, while 6 macroeconomic variables demonstrate this problem. After eliminating three of them, the issue is alleviated.

Table 4.6. Robust regression results for large timberland transactions in the US South from 2000 to mid-2015

	(1)		(2)		(3)		(4)		(5)	
	Coef.	*t*-stat	*Coef.*	*t*-stat	*Coef.*	*t*-stat	*Coef.*	*t*-stat	*Coef.*	*t*-stat
Intercept	4.256	6.59	4.382	6.88	4.651	7.33	7.290	6.85	7.354	7.08
Time	0.019	3.91	0.021	5.09	0.022	5.20	0.016	3.05	0.016	3.29
Crisis	0.101	1.99	0.078	1.68	0.081	1.79	0.089	1.98	0.082	1.81
Size	-0.105	-6.27	-0.105	-6.30	-0.098	-5.43	-0.100	-5.55	-0.091	-5.33
Pine	1.023	3.78	1.233	5.23	1.226	5.14	0.680	2.36	0.698	2.47
Hardwood	-0.306	-1.20	-0.580	-2.52	-0.632	-2.62	-0.137	-0.40	-0.193	-0.59
AL			-0.212	-3.16	-0.205	-2.78	-0.190	-2.66	-0.189	-2.65
AR			-0.235	-3.57	-0.219	-3.09	-0.197	-2.79	-0.187	-2.62
FL			0.010	0.12	-0.016	-0.20	-0.017	-0.21	-0.011	-0.14
GA			-0.053	-0.74	-0.019	-0.27	-0.018	-0.26	-0.009	-0.13
LA			-0.001	-0.01	-0.049	-0.49	-0.061	-0.68	-0.060	-0.69
MS			-0.210	-2.43	-0.195	-1.80	-0.171	-1.51	-0.166	-1.45
NC			0.134	0.82	0.089	0.51	0.159	0.98	0.274	1.87
SC			0.158	1.80	0.157	1.73	0.160	1.80	0.133	1.69
TN			-0.661	-7.30	-0.671	-6.90	-0.670	-6.86	-0.597	-8.68
TX			-0.221	-3.42	-0.224	-3.43	-0.207	-3.34	-0.206	-3.46
VA			-0.238	-2.78	-0.247	-3.00	-0.242	-2.75	-0.172	-2.42
CC					-0.123	-0.89	-0.124	-0.96	-0.172	-1.38
CT					-0.155	-1.51	-0.143	-1.39	-0.191	-2.06
CR					-0.110	-0.99	-0.083	-0.75	-0.142	-1.39
CP					-0.079	-0.56	-0.090	-0.66	-0.148	-1.23
CO					-0.046	-0.46	-0.028	-0.28	-0.075	-0.81
TT					-0.147	-1.54	-0.142	-1.44	-0.194	-2.25
TR					-0.052	-0.43	-0.052	-0.43	-0.100	-0.89
TO					-0.228	-2.04	-0.223	-1.96	-0.274	-2.79
RC					-0.204	-1.53	-0.226	-1.67	-0.268	-2.04
RT					-0.283	-2.83	-0.279	-2.69	-0.327	-3.51
RO					-0.299	-2.33	-0.276	-2.16	-0.313	-2.55
OT					-0.247	-1.79	-0.213	-1.54	-0.201	-1.75
Oil							-0.009	-2.52	-0.009	-2.63
Dollar							-0.016	-2.47	-0.016	-2.71
FFR							0.042	2.62	0.044	2.82
# Obs	347		347		347		347		343	
R^2	0.167		0.367		0.411		0.431		0.440	
F-test	11.7		9.4		7.1		7.1		7.8	
B-P test	13.74		12.82		7.23		5.81		15.48	
S-W test	3.99		2.66		3.00		3.39		1.80	

Note*:* The dependent variable is log transaction price per acre. Model 5 has the same independent variables as model 4 but excludes 4 outliers in the sample. *Coef.* and *t*-stat are estimated coefficients and *t*-statistics. # Obs is number of observations. *B-P* test is the Breusch-Pagan test for heteroscedasticity, and *S-W* test is the Shapiro-Wilk test for normality. Model 5 displays features of heteroscedasticity and non-normality.

Table 4.7. Pairwise Wald tests: Regression diagnostic for 11 Southern states

	AL	AR	FL	GA	LA	MS	NC	SC	TN	TX	VA
AL	-										
AR	0.00	-									
FL	3.70	3.78	-								
GA	4.38	4.61	0.00	-							
LA	1.68	1.58	0.22	0.28	-						
MS	0.03	0.03	1.50	1.70	0.66	-					
NC	9.56	9.60	3.31	3.57	4.22	6.50	-				
SC	12.59	12.51	1.98	2.49	3.19	5.62	0.86	-			
TN	22.52	23.97	40.87	48.56	27.82	12.13	35.24	60.34	-		
TX	0.05	0.06	5.12	6.46	2.41	0.12	10.69	17.81	25.01	-	
VA	0.04	0.03	2.89	3.87	1.24	0.00	8.56	11.25	23.64	0.19	-

Note: The *F*-statistics for Wald tests are displayed with null hypothesis that one state dummy equals to another. The threshold for these tests is 3.8 at the 5% significance level. More than half of the *F*-statistics pass the test, implying some of the state dummies are significantly different from others.

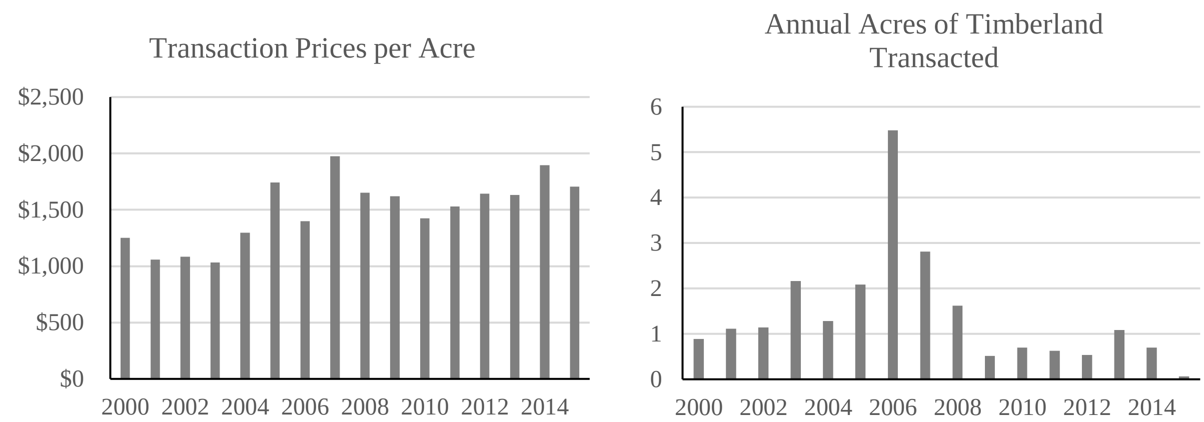

Figure 4.1. Large timberland transactions in the US South from 2000 to mid-2015.

Note*:* The size in the right plot is in million acres.

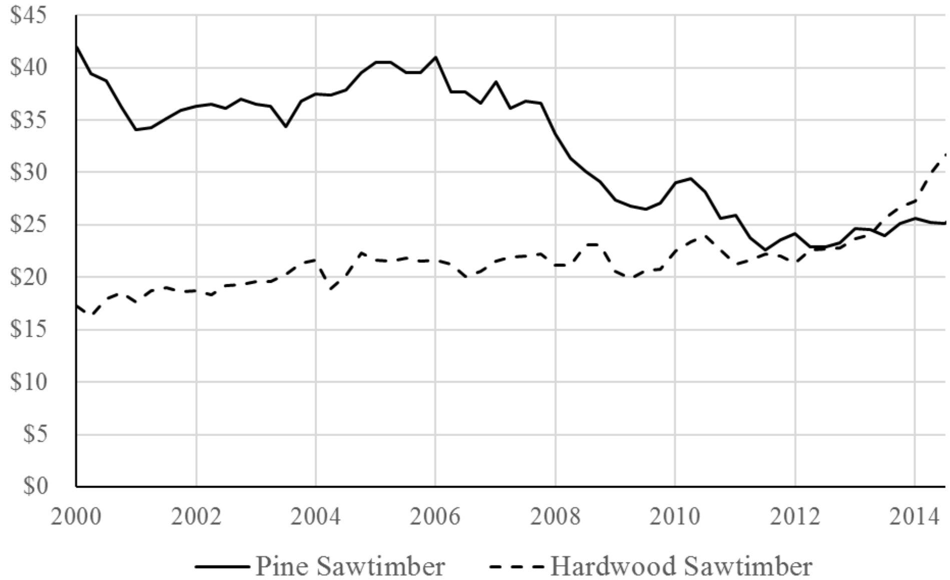

Figure 4.2. South-wide sawtimber stumpage prices from 2000 to mid-2015.

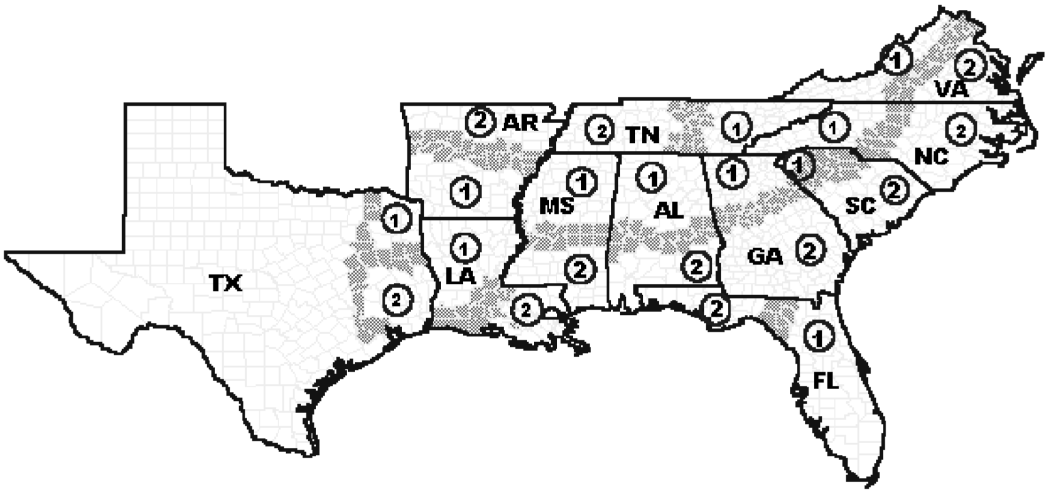

Figure 4.3. Timber Mart-South reporting areas in the US South.

Source: Timber Mart-South.

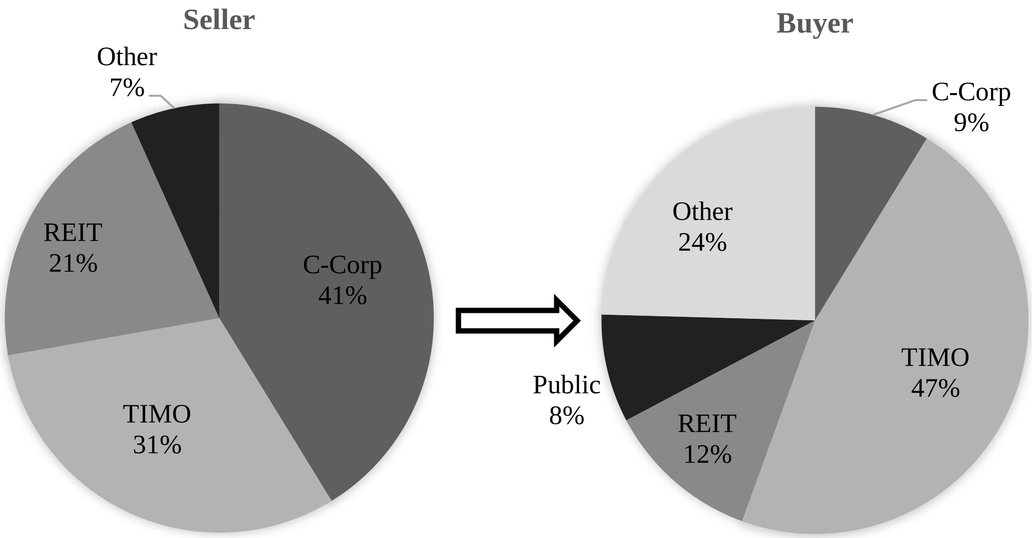

Figure 4.4. Pie charts: Number of large timberland transactions in the US South by ownership type.

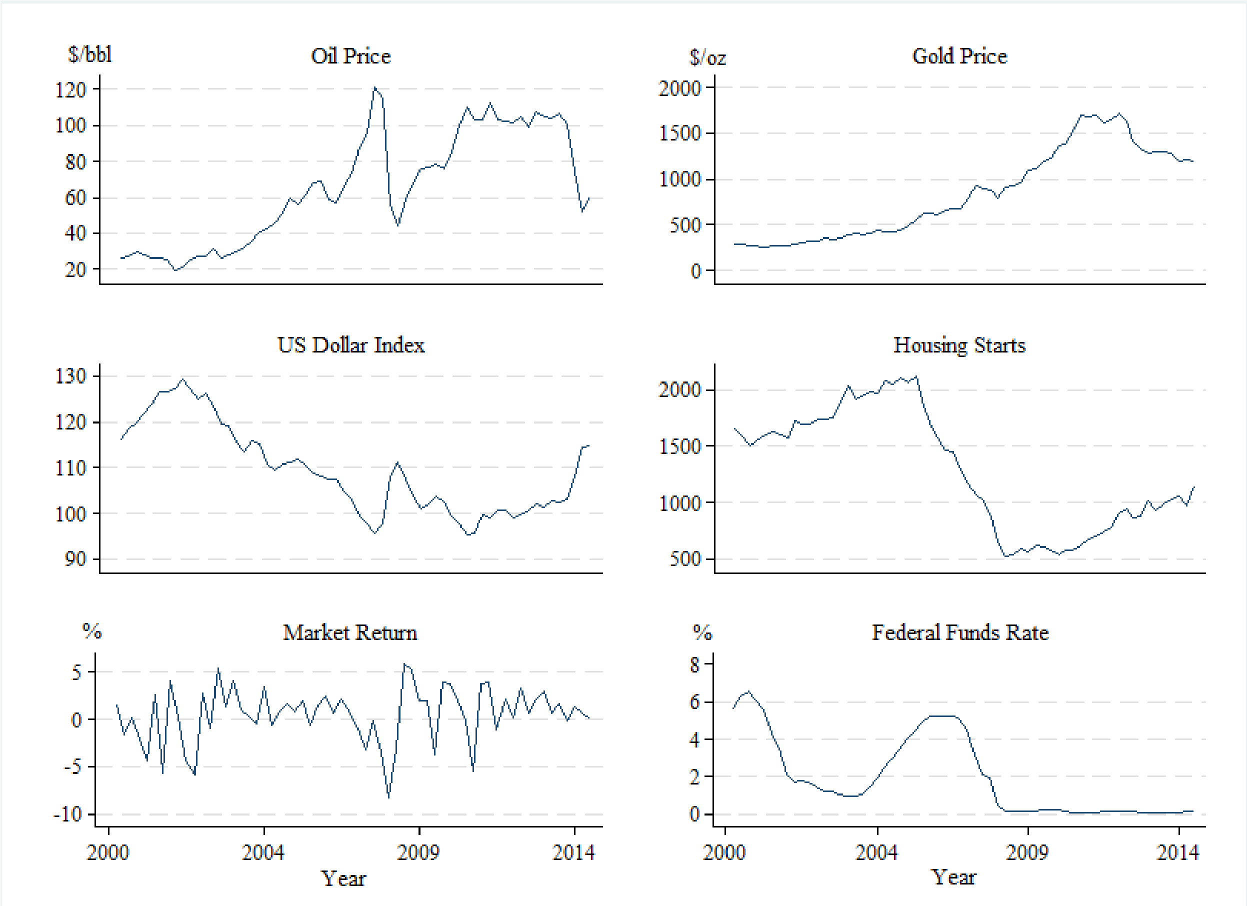

Figure 4.5. The trends of the 6 macroeconomic variables from 2000 to mid-2015.

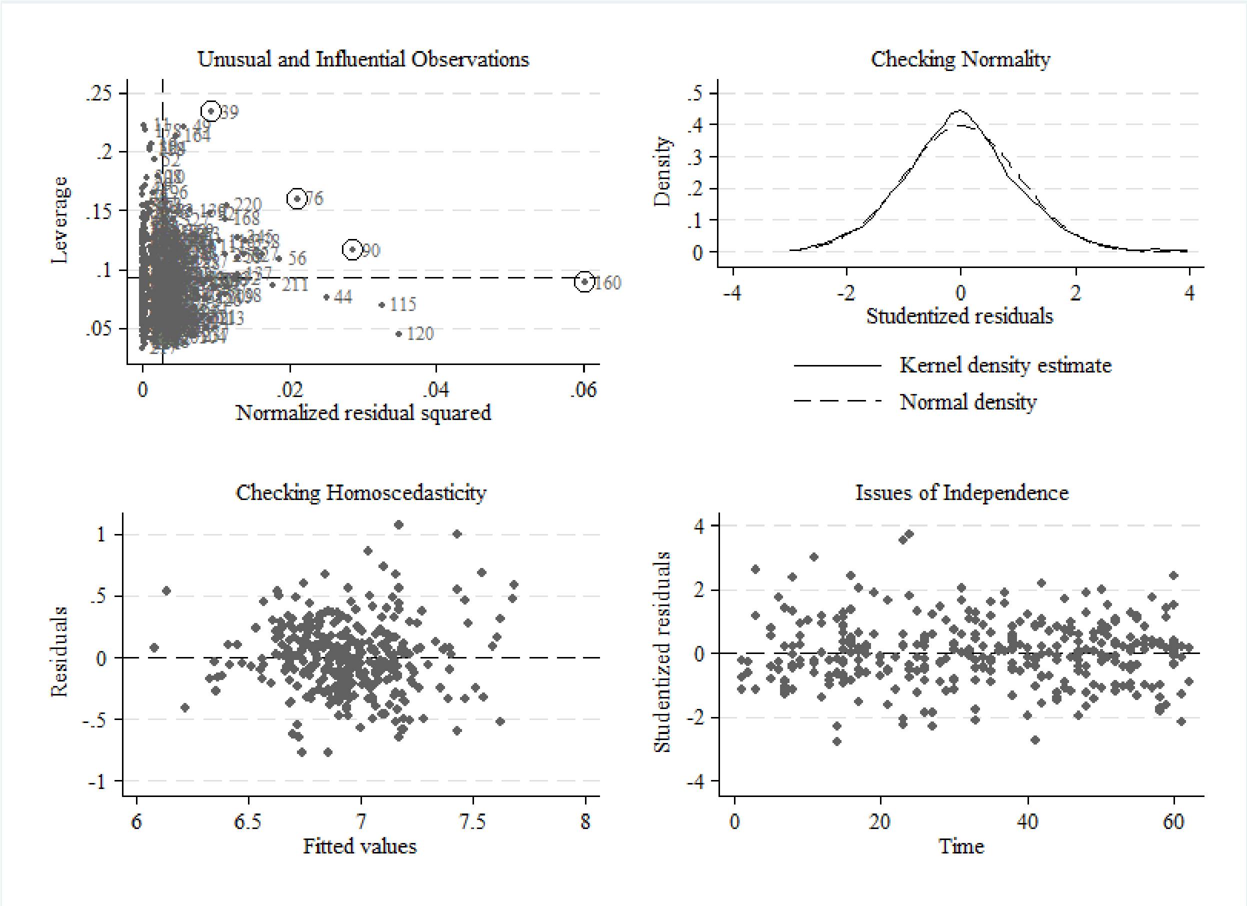

Figure 4.6. Multiple regression diagnostics for the robust regression model.

Note: In the upper-left plot, two reference lines denote the mean of leverage and normalized residual squared, and four outliers are discovered. The lower-right plot indicates residuals independent of time.

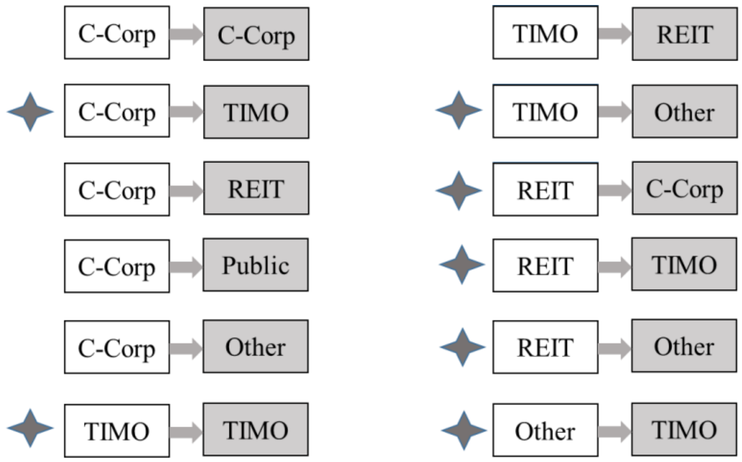

Figure 4.7. The 12 seller/buyer combinations.

Note: Four-point star represents significantly negative impact on transaction prices. Of the 12 seller/buyer combinations, seven of them have significantly negative impacts.

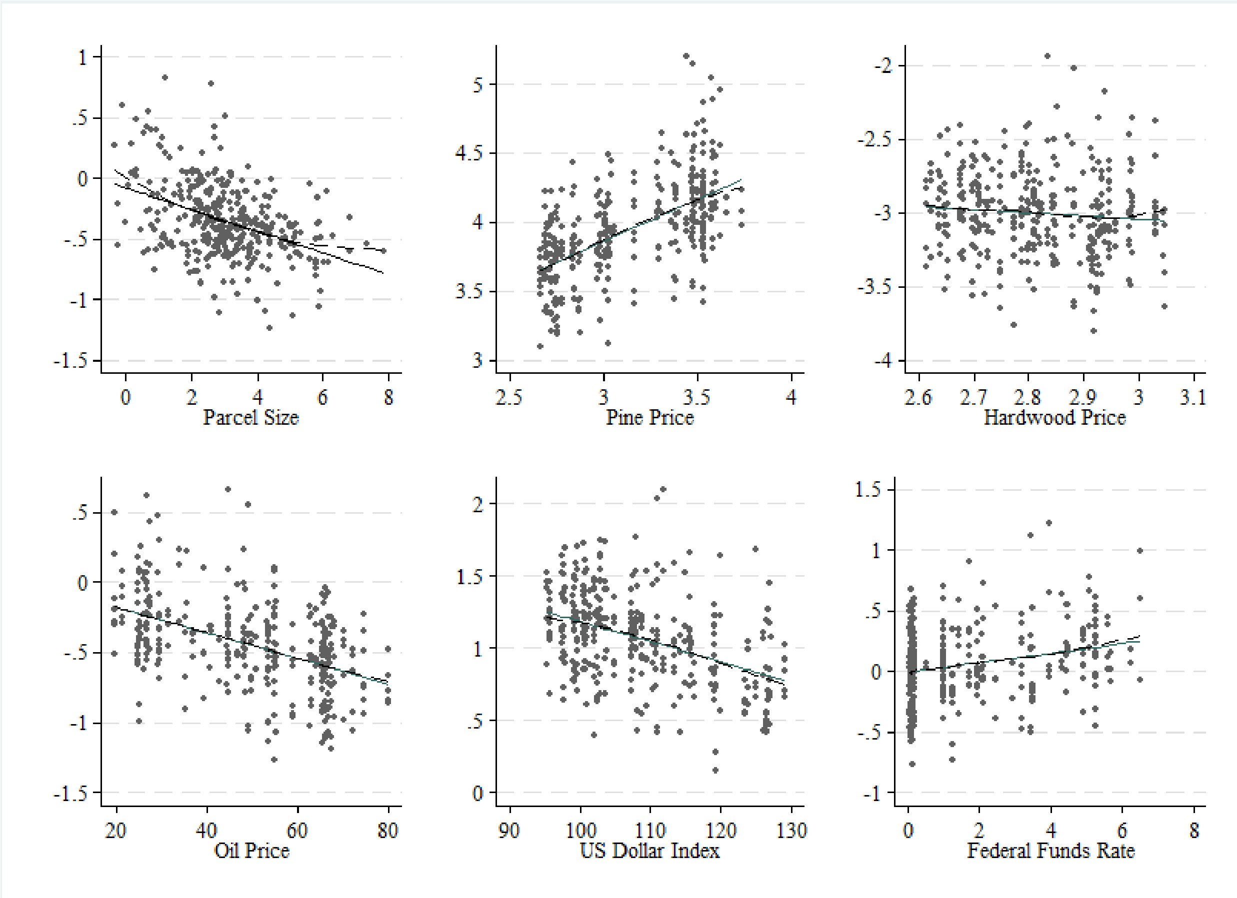

Figure 4.8. Linearity analyses: Augmented partial residual plots for the robust regression model.

CHAPTER 5

CONCLUSIONS

Massive structural changes of timberland ownership being well recognized, Chapter 2 finds that timber REITs, converted from MLP and C-Corps, added values to timber firms in the long run. In Chapter 3, we find that timber REITs underperform other REITs in terms of mean and variance characteristics. Chapter 4 concludes that TIMOs and C-Corps outperform firms outside the timber industry in consummating timberland sales.

The timber sector in the US mainly deals with real assets, including timberland investments and timber related productions. Pressured by Wall Street investors and rising competitions, Chapter 2 shows integrated timber firms chose to convert to timber REITs and thereby raised firm values in the long run. As a long-term biological asset independent of business cycles, Chapter 3 finds that timber REITs are insensitive to recessionary shocks. In Chapter 4, we relate drastic changes in timber prices with timberland appreciations, and find positive relation between them.

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