THREE ESSAYS ON THE PERFORMANCE OF TIMBERLAND ASSETS AND FOREST PRODUCTS INDUSTRY IN THE UNITED STATES

by

YANG WAN

(Under the Direction of Michael L. Clutter and Jacek P. Siry)

ABSTRACT

Timberland assets have become a popular alternative investment vehicle for institutional investors since the 1980s in the United States. Currently, private- and public-equity timberland investments exist together in the United States. Chapter 2 employs the Fisher hypothesis and CAPMUI to analyze how effectively private- and public-equity timberland assets hedge actual, expected, and unexpected inflation in the U.S. during 1987 – 2009. Empirical results suggest that private-equity timberland assets do hedge actual, expected, and unexpected inflation, whereas public-equity timberland assets are not consistent in hedging actual, expected, or unexpected inflation. Private-equity timberland assets are effective in hedging inflation during the expansion and less effective during the recession. Investment horizon also plays a significant role in timberland inflation hedging. The longer people invest in the private-equity timberland assets, the stronger and more consistent the hedging ability holds. Chapter 3 uses the M-CVaR optimization approach to formulate asset allocation strategies and to examine the role of timberland assets in a mixed portfolio from the risk perspective. The M-CVaR efficient frontier of the mixed portfolio is dramatically improved after adding timberland assets in comparison of the mean-variance (M-V) efficient frontier. Timberland assets are preferred for high target returns, indicating its ability to generate high returns. It is found that large-cap stocks and small-cap stocks are generally risk intensifiers, whereas treasury bonds, treasury bills, and timberland assets are risk diversifiers. Chapter 4 examines what role macroeconomic news plays in the U.S. forest products industry portfolios across business cycles. Using ARMA-EGARCH models, we examine the impact of consumer price index (CPI), industrial production (IP), and unemployment (UNEMP) on the returns and volatilities of the lumber and paper industry portfolios over 1963 – 2010. Leverage effects of positive and negative shocks on the forest products industry have been detected. The impact of macroeconomic news on industry portfolio returns and volatilities vary across business cycles. Negative shocks have greater impact on portfolio volatilities in recessions than in expansions.

INDEX WORDS: Forest Products Industry, Inflation Hedging, Macroeconomic News, Mean-Conditional Value at Risk, Timberland Assets, Time Series Modeling

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INTRODUCTION AND LITERATURE REVIEW

Timberland Investments in the United States

Timberland assets have become a popular alternative investment vehicle for institutional investors since the 1980s in the United States. Traditionally, timberland investors buy relatively large tracts of timberlands and hold them for long time periods, usually in private ownership with separate accounts. Currently, private- and public-equity timberland investments exist together in the United States. Wealthy individuals, families and smaller institutional investors can invest in timberlands through commingled funds, while larger investors can invest through separate accounts or individually managed accounts. Public-equity timberland investment provides an easy access for individual investors who would like to diversify their portfolios with timberland assets. One way is to buy stocks of publicly traded forest products companies with timberland holdings. Another way is to invest through public timber Real Estate Investment Trusts (REITs), which are not only liquid but also tax efficient (Mendell et al., 2008).

Structure Ownership Changes

The industrial timberlands were primarily owned by the vertically integrated forest products firms in the last century. However, the ownership of timberlands has experienced a dramatic change over the past three decades. Among the 70 million acres timberlands under the management of the forest products industry, there were more than 40 million acres of timberlands change hands (Clutter et al., 2005). There are two major structural ownership changes. One way is for the forest products firms to convert from a C-corporation to a timber REIT in order to avoid double taxation. This requires firms to have at least 75% of total asset in real estates and to distribute at least 90% of taxable income as dividends to shareholders. At present, there are four publicly traded timber REITs in the United States: Plum Creek, Potlatch, Rayonier, and Weyerhaeuser. By the end of 2010, these four REITs owned 17.4 million acres of timberlands across the country. Another way is to sell the timberlands to individual and institutional investors, including pension funds, university endowments, foundations and other institutional investors. Timberland Investment Management Organizations (TIMOs) emerged to manage private timberlands on behalf of individual and institutional investors. Currently, the top 19 TIMOs manage 20.78 million acres timberland assets in the United States.

Previous Studies on Timberland Investments

Previous timberland investment studies have examined forest investment return and risk (Mills and Hoover, 1982; Redmond and Cubbage, 1988; Lonnstedt and Svensson, 2000). The market model, capital asset pricing model (CAPM), arbitrage pricing theory (APT), and Fama-French three-factor model have been used as benchmarks to examine the performance of timberland assets (Heikkinen and Kanto, 2000; Sun and Zhang, 2001; Cascio and Clutter, 2008; Mei and Clutter, 2010; Niquidet, 2010). Various time series techniques such as cointegration and error correction model (ECM) have been introduced to detect the correlation between timberland assets and financial markets in both long-run and short-run views (Heikkinen, 2002; Liao et al., 2009). A recent study has compared the financial performance of private- and public-equity timberland assets (Mei and Clutter, 2010).

Meanwhile, a number of studies have been conducted to evaluate the performance of portfolios with timberland assets (Thomson, 1997; Healey et al., 2005). Several studies have employed the modern portfolio theory to analyze the diversification effects of timberland assets (Mills and Hoover, 1982; Zinkhan et al., 1992; Caulfield, 1998a; Scholtens and Spierdijk, 2010). Thomson (1997) employed the multiperiod portfolio optimization approach and showed that timber (e.g., Douglas Fir and Southern Pine) had been valuable either as a single asset or as an addition in a financial portoflio. Waggle and Johnson (2009) adopted the mean-variance approach to examine the effects of including timberlands, farmlands, and commercial real estates in a mixed asset portfolio with stocks and bonds. They found that timberlands entered all portfolios, whereas farmlands entered only low risk portfolios.

The Characteristic Features of Timberland Assets

Timberland assets are attractive to institutional investors due to its several characteristic features compared with other investment assets. First, timberland assets are dynamic, growing in both volume and value. In other words, the biological grow contribute to the timberland value all the time. Second, timberland is a real asset. Unlike financial assets such as stocks and bonds, timberlands always have intrinsic values due to the utility. From the financial performance perspective, private-equity timberland investments can generate high risk-adjusted returns (Cascio and Clutter, 2008; Mei and Clutter, 2010). Due to its low or negative correlations with other assets, timberland asset is able to diversify portfolios (Caulfield, 1998c). More importantly, timberland assets can protect investors against the inflation (Washburn and Binkley, 1993). From the environmental perspectives, timber and timberland are renewable and protect environments. Nevertheless, timberlands are not perfect and bear the risk from illiquidity and natural disasters. For example, it is typical to invest in timberlands for 10 – 15 years, so the capital is locked in during this time period. On the other hand, the natural disasters such as insects, hurricanes, and fire are hard to predict and avoid. Hence, investors need to prepare for the losses and diversify their portfolios to minimize risks.

Motivations of the Dissertation

Essay I: Inflation risk is of great concern for investors because it has a great impact on the real rate of return, and therefore, a key consideration in investment decisions. If the real return is constant, then higher inflation requires a higher nominal return. Therefore, whether an asset can hedge inflation is crucial for investment decisions. This is particularly relevant for the pension fund managers and institutional investors who have long-term investment horizons. In addition to real estates, timberland has been traditionally viewed as one of the best inflation hedging assets. To the best of our knowledge, few rigorous studies have examined the relationship between timberland assets and inflation in the U.S.

Essay II: Under the mean-variance framework, variance or standard deviation (SD) of asset returns is used to measure the portfolio risk under a multivariate normal distributional assumption. The SD can help us understand how asset returns vary around the mean value. However, investors are more concerned about potential losses or negative returns from the extreme events such as financial crises, and therefore, more attention have been paid to downside risks in practice. Additionally, it is well documented that returns of financial assets such as stocks and bonds are not normally distributed (Sheikh and Qiao, 2010). It is also observed that timberland returns depart from normality to some degree (Petrasek et al., 2011). These asset returns generally exhibit non-normality properties such as skewness and kurtosis in the real world. To address the risk measure and non-normality issues, the mean-conditional value at risk (M-CVaR) optimization method is introduced in this essay.

Essay III: The financial performance of the forest products industry has been volatile in recent decades (Mei and Sun, 2008). It is the fact that the forest products industry is affected by the states of the economy to a great extent. Security markets reflect expectations in an economy because the value of an investment is determined by its expected cash flows and discount rates, both of which are affected by the expected aggregate economic condition. This condition can be measured by the macroeconomic indicators such as CPI and UNEMP, and business cycles. Therefore, macroeconomic news is usually viewed as the source for systematic risk. Examination of the relationship between macroeconomic news and asset returns can help us understand how investors are compensated for bearing the systematic risk. Given that few rigorous studies have been conducted on the relationship between macroeconomic news and the forest products industry, the overall objective of this essay is to investigate the impact of macroeconomic news on the U.S. forest products industry portfolios across business cycles over 1963 – 2010. This essay aims help market participants make decisions across business cycles as well as assist academic researchers to identify some sources of the systematic risk.

Objectives of the Dissertation

The overall purpose of this dissertation is to examine the performance of timberland assets and the forest products industry in the United States. Specific objectives are: (1) to evaluate the inflation hedging abilities of private- and public-equity timberland assets; (2) to examine the role of timberland assets in a mixed portfolio from the risk perspective; and (3) to assess the impacts of macroeconomic news on the forest products industry portfolios across business cycles.

To address the issues discussed earlier, three relatively independent papers in journal article style are included. Each paper includes its own introduction, literature review, methodology, data source and variables, empirical results, and conclusions. The dissertation is organized as follows. Chapter 2 contains the first article, entitled "*Assessing the Inflation Hedging Ability of Timberland Assets in the United States*." The static and dynamic inflation hedging abilities of private- and public-equity timberland assets are evaluated by rolling regression and state space model. Chapter 3 contains the second article, entitled "*Assessing the Role of U.S. Timberland Assets in a Mixed Portfolio under the Mean-Conditional Value at Risk Framework*." Under the mean-conditional value at risk framework, the role of timberland assets in a mixed portfolio is examined from static and dynamic portfolio construction and backtesting. Chapter 4 contains the third article, entitled "*Assessing the Impact of Macroeconomic News on the U.S. Forest Products Industry Portfolio across Business Cycles: 1963 – 2010*." Using ARMA-EGARCH models, the impact of macroeconomic news on the forest products industry portfolios is simultaneously examined across business cycles over 1963 ─ 2010. Finally, Chapter 5 summarizes the conclusions for this dissertation and provides the discussion for future studies.

CHAPTER 2

ASSESSING THE INFLATION HEDGING ABILITY OF TIMBERLAND ASSETS IN THE UNITED STATES[1]

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Abstract

Inflation hedging is one of the unique features of timberland assets that attract timberland investors. This study employs Fisher hypothesis and capital asset pricing model under inflation (CAPMUI) to analyze how effectively private- and public-equity timberland assets hedge actual, expected, and unexpected inflation in the United States over 1987 – 2009. Rolling regression is used to evaluate whether timberland assets can persistently hedge inflation, while state space model is employed to capture the shocks on the system. Empirical results suggest that private-equity timberland assets do hedge actual, expected, and unexpected inflation, whereas public-equity timberland assets are not consistent in hedging actual, expected, or unexpected inflation. Hedging effectiveness depends on the states of the economy. We find that private-equity timberland assets are effective in hedging inflation during the expansion and less effective during the recession. Investment horizon also plays a significant role in timberland inflation hedging. The longer people invest in the private-equity timberland assets, the stronger and more consistent the hedging ability holds.

Introduction

Timberland has become an alternative investment class since the middle of 1980s in the United States. It is attractive to pension funds, university endowments, and other institutional investors due to its several unique features compared to other investment vehicles. It contributes to investors in the following aspects: (1) high risk adjusted return (Cascio and Clutter, 2008; Newell and Eves, 2009); (2) low or negative correlation with other financial assets (Lundgren, 2005); (3) portfolio diversification (Caulfield, 1998b); (4) inflation hedging (Washburn and Binkley, 1993; Lausti, 2004); (5) biological growth (Healey et al., 2005; Mei et al., 2010); and (6) land value appreciation (Caulfield, 1998c).

The options for timberland investment can be categorized by its ownership. Traditionally, timberland investors buy relatively large tracts of timberland and hold them for long time periods, usually in private ownership with separate accounts. This is a typical investment for large investors such as pension funds and university endowments. Timberland ownership has experienced a huge structural change. Traditional vertically integrated forest products companies have merged, been acquired by other firms, or sold their timberlands to improve their balance sheets, or realign their business strategies (Clutter et al., 2005; Healey et al., 2005). At the same time, institutional investors started investing in timberland assets in the 1970s. Timberland Investment Management Organizations (TIMOs) emerged to manage private timberlands on behalf of individual and institutional investors.

Currently, private- and public-equity timberland investments exist together in the United States. Wealthy individuals, families and smaller institutional investors can invest in timberland through commingled funds, while larger investors can invest through separate accounts or individually managed accounts. Public-equity timberland investment provides an easy access for individual investors who would like to diversify their portfolios with timberland assets. One way is to buy stock of publicly traded forest products companies with timberland holdings. Another way is to invest through public timber Real Estate Investment Trusts (REITs), which are not only liquid but also tax efficient (Mendell et al., 2008). A previous study indicates that private- and public-equity timberland assets perform differently (Mei and Clutter, 2010). Therefore, it is necessary to investigate their inflation hedging abilities separately.

Inflation risk is of great concern for investors because it has a great impact on the real rate of return, and therefore, a key consideration in investment decisions. If the real return is constant, then higher inflation requires a higher nominal return. In other words, if investors want to maintain the same level of real returns or purchasing power, they will demand higher nominal returns in the periods of higher inflation. Therefore, whether an asset can hedge inflation plays a significant role in investment decisions. This is particularly relevant for the pension fund managers and institutional investors who have long-term investment horizons. In addition to real estate, timberland has been traditionally viewed as one of the best inflation hedging assets.

Previous timberland investment studies have examined forest investment return and risk (Mills and Hoover, 1982; Redmond and Cubbage, 1988; Lonnstedt and Svensson, 2000). The market model, capital asset pricing model (CAPM), arbitrage pricing theory (APT), and Fama-French three-factor model have been used as benchmarks to examine the performance of timberland assets (Heikkinen and Kanto, 2000; Sun and Zhang, 2001; Cascio and Clutter, 2008; Mei and Clutter, 2010; Niquidet, 2010). Moreover, various time series techniques such as cointegration and error correction model (ECM) have been introduced to detect the correlation between timberland assets and financial markets in both long-run and short-run views (Heikkinen, 2002; Liao et al., 2009). Meanwhile, several studies have been conducted to evaluate the performance of portfolios with timberland assets (Thomson, 1997; Healey et al., 2005). Caulfield (1998b) used an asset-based benchmark to examine whether timberland would play a persistent role in portfolio optimization. He generated dynamic efficient frontiers over rolling time periods varying from 5 to 15 years and concluded that timberland maintained a persistent role in efficient portfolios as constructed using portfolio optimization.

To the best of our knowledge, few rigorous studies have examined the relationship between timberland assets and inflation in the U.S. The overall goal of this study is to assess the inflation hedging ability of private- and public-equity timberland assets in the U.S. from 1987 to 2009. To achieve this goal, several specific objectives are pursued in this study. First, inflation hedging ability of private- and public-equity timberland assets is examined. The Fisher hypothesis is used to test whether timberland assets can hedge actual, expected, and unexpected inflation. We further employ the capital asset pricing model under inflation (CAPMUI) to test inflation hedging ability in the context of portfolio. Second, the persistence of inflation hedging performance is evaluated over the same time period. Although timberland has become a more popular investment vehicle, it is still unclear whether timberland performance persists over longer time periods (Caulfield, 1998b). Hence the rolling regression is employed to examine whether timberland assets perform persistently over time and compare their performance in different time periods. Third, the state space model is used to evaluate the time-varying inflation hedging ability of timberland assets. It not only provides a convenient way to analyze the shock on the system but also examines the extent to which timberland assets can hedge inflation.

The rest of this study is organized as follows. Literature related to inflation hedging of both financial and physical assets is reviewed first. Empirical models and econometric methods used to test inflation hedging ability are introduced next. Following the methodology section, the data source and variable definition are explained. Finally, the empirical results are reported and discussed.

Literature Review

Inflation plays an important role in a country's economy since it reflects the extent to which the general price level increases. Investors care about inflation because it affects the real asset returns and high inflation rate can reduce real rates of return. Specifically speaking, inflation impacts on asset return in two ways. The first impact is from expected inflation, which is essentially the market's consensus on the future inflation. Expected inflation is usually priced into an asset and not viewed as risk. Hence, investigating the relationship between asset returns and expected inflation can help us understand the degree to which expected inflation has been priced into asset values. The second impact is from unexpected inflation, which is believed to stimulate a market response. Thus, unexpected inflation is a source of market volatility and also a real concern of the investors since it affects their wealth. To gain further insight into inflation hedging ability of different assets, the actual inflation is usually decomposed into expected and unexpected inflation.

Due to its importance, a lot of efforts have been put on the studies about inflation hedging ability of different assets. Fisher (1930) first proposed the theoretical foundation for inflation known as the "Fisher hypothesis" and concluded that expected nominal return of an asset comprises expected real return and expected inflation. It has been widely accepted that an asset is a good inflation hedging instrument if the Fisher hypothesis holds. Thereafter, Fama and Schwert (1977) established a classic framework to test the effect above, which has been commonly used in examining inflation hedging ability of different assets. They firstly examined the degree to which financial assets such as stocks and U.S. government bonds hedge inflation. They found that U.S. government bonds and bills were good hedge against expected inflation, and U.S. stocks did not serve well as an inflation hedge over 1953 – 1971. In addition, the private real estate was effective in hedging both expected and unexpected inflation during the same period of time.

In addition to financial assets, the impacts of inflation on physical assets such as real estate and gold have been empirically investigated over the past several decades (Brueggeman et al., 1984; Ghosh et al., 1993; Hoesli et al., 2008; Wang et al., 2010). The findings indicate that, unlike most other assets, real estate hedges inflation, especially expected inflation. However, whether real estate can hedge unexpected inflation is still inconclusive. Unlike real estate, gold is an asset that is durable, transportable, and widely acceptable. Whether gold can hedge inflation depends on the market and time selection (Wang et al., 2010). For example, gold was a complete hedge against inflation in the U.S. but partially effective in Japan during 1971 – 2010. Meanwhile, empirical studies have been conducted across different countries and regions including the United Kingdom (Hoesli et al., 2008), Switzerland (Liu et al., 1997), Australia (Newell, 1996), and Asia (Ganesan and Chiang, 1998; Chen and Foo, 2006). Previous research suggests that inflation has different impacts on different assets, across different countries, and over different time periods.

The key study on the inflation hedging ability of forest assets is by Washburn and Binkley (1993). In their study, timberland returns were proxied by the change of stumpage prices in the U.S. They examined whether the forest assets hedge against unexpected inflation regionally and nationally over 1955 – 1987 and the inflation hedging ability varied regionally. The Western and Southern forest investments were more effective in hedging unexpected inflation than Northeastern forest investments. Lausti (2004) investigated the extent to which forests hedge expected and unexpected inflation in Finland from1973 to 2003. He found that the Finnish forest asset did not hedge actual inflation but did hedge unexpected inflation. He also concluded that the longer the investment period is, the more forest assets hedge against inflation. Lundgren (2005) employed both nominal and real versions of CAPM to examine the investment performance of Swedish timberland. He concluded that Swedish timberland investment can diversify the portfolio and hedge actual inflation.

In summary, financial and physical assets have different inflation hedging performance in different countries or markets or time periods. We believe that time period selection, investment horizon, and market conditions play different roles in the asset performance. Few studies have been conducted to investigate inflation hedging ability of timberland assets in the United States, so we are motivated to conduct this study to provide more information for timberland investors.

Methodology

Fisher Hypothesis

The Fisher hypothesis states that expected nominal return of an asset can be decomposed theoretically into an expected real rate of return and an expected rate of inflation (Fisher, 1930). This proposition can be applied to all assets. We are first interested in the direct relationship between assets and actual inflation. The following equation can be used to test the hedging ability against actual inflation.

$$R_{it} = r_i + \delta_i^a \pi_t^a + \varepsilon_{it} \tag{2.1}$$

Where R is realized return of asset, π^a is actual inflation rate, and ε is the error term. Subscript i indices the asset and t indices the time. Parameter δ^a tests the hedging ability of actual inflation. If $\delta^a < 0$, then the asset is classified as an inferior inflation hedge; if $0 < \delta^a < 1$, then the asset is characterized as a partial inflation hedge; and if $\delta^a \geq 1$, the asset serves as a superior inflation hedge. Since inflation can generate two impacts on asset returns through expected and unexpected inflation, we are further interested in an asset's hedging ability against both of them. Actual inflation can be decomposed into expected and unexpected inflation and empirically estimated by the following equation (Fama and Schwert, 1977).

$$R_{it} = r_i + \delta_i^e \pi_t^e + \delta_i^u \pi_t^u + \varepsilon_{it} \tag{2.2}$$

where π^e and π^u are defined as expected inflation and unexpected inflation, respectively. Parameters δ^e and δ^u are to be estimated and similar hypothesis of inflation hedging ability can be tested against the critical values.

Inflation Hedging in the Context of Portfolio

The approach outlined above is used to test the direct relationship between asset returns and inflation rates. However, timberland assets are often combined with other financial assets to diversify the portfolio. The CAPM built on the modern portfolio theory is capable of examining the relationship between return and risk and evaluating the performance of portfolios. The traditional CAPM is derived without considering uncertain inflation, and therefore, parameters are generally estimated and explained in terms of the nominal rate of return (Chen and Boness, 1975). In other words, the effects of inflation have not been analyzed in the context of the equilibrium model. It is evident that inflation significantly affects returns for different assets such as stocks, bonds, and real estate (Hartzell et al., 1987). As a result, the traditional CAPM fails to explain the asset returns in real terms. On the other hand, the excess return on the market is the only priced factor in the CAPM. Given the empirical studies, the market factor alone may not fully explain the return, so models with more factors allow for multiple risks such as inflation risk. Hence, the CAPM under inflation (CAPMUI) is a suitable choice in this study. A good example of its application to timberland assets is provided by Lundgren (2005). He evaluated the performance of Swedish timberland assets by the following CAPMUI formula:

$$R_{it} - R_{ft} = \alpha_i + \beta_i (R_{mt} - R_{ft}) + \gamma_i^a \pi_t^a + \varepsilon_{it} \qquad (2.3)$$

where R_f and R_m are nominal risk-free rate and return on market portfolio, $R_i - R_f$ is realized excess return for asset i, and $R_m - R_f$ is risk premium of the market portfolio. Parameter α measures abnormal return and β measures systematic risk. Parameter γ^a measures the ability of hedging actual inflation in the context of portfolio. Variable π^a is the actual inflation rate and ε is the disturbance term. Furthermore, γ^a can be used to test the performance of nominal CAPM, or in other words, as an indicator of market efficiency. If $\gamma^a > 0$, the asset is underpriced by nominal CAPM, and vice versa. We further examine whether timberland assets hedge expected and unexpected inflation in the context of portfolio by the following equation.

$$R_{it} - R_{ft} = \alpha_i + \beta_i (R_{mt} - R_{ft}) + \gamma_i^e \pi_t^e + \gamma_i^u \pi_t^u + \varepsilon_{it} \qquad (2.4)$$

where γ^e and γ^u measure the hedging ability against expected and unexpected inflation. All the other variables are defined the same as above.

All the equations above are estimated by ordinary least square (OLS) to examine the static inflation hedging ability of both private- and public-equity timberland assets. Moreover, the model specification is examined by two diagnostic tests. The Breusch-Godfrey (BG) test is used to test the null hypothesis of no serial correlation, whereas the Breusch-Pagan (BP) test is adopted to test the null hypothesis of no heteroscedasticity [2].

Rolling Regression

Traditional regression analysis (e.g., OLS) makes an assumption of stable parameters over time. However, this assumption is not realistic because parameters may change with time periods of different duration. A common approach to assess a model's stability over time is the rolling regression. This technique is used to estimate the parameters over rolling windows through the entire sample. If the parameters are truly stable over time, then estimates should not show big differences. For a linear regression model, the general rolling regression model can be expressed as (Zivot and Wang, 2006):

$$y_t(n) = x_t(n)\beta_t(n) + \varepsilon_t(n) \tag{2.5}$$

where $y_t(n)$ is $n \times 1$ vector of dependent variables, $x_t(n)$ is a $n \times k$ matrix of independent variables, $\beta_t(n)$ is a $k \times 1$ vector of parameters and $\varepsilon_t(n)$ is a $k \times 1$ vector of error terms. Subscript t ranges from n to T, where the width of window n is less than the sample length T. In addition, the n most recent observations from $t - n + 1$ to t are used to estimate $\beta_t(n)$.

State Space Model

In this study, the state space model is also employed to examine the time-varying inflation hedging ability of private- and public-equity timberland assets from 1987 to 2009. The state space model allows for changes of parameters, and therefore, captures external shocks such as a policy change or a financial crisis on the system (Sun, 2007). This approach has been applied in the field of forestry in recent years. For example, Sun (2007) examines the time-varying effects of federal cost-share programs in the U.S. Recently, Mei and Clutter (2010) evaluate the financial performance of timberland investment in the U.S. under the state space framework. The general state space model can be expressed by the system of equations as follows (Hamilton, 1994; Durbin and Koopman, 2001):

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[2] Both BG and BP tests fail to reject the null hypothesis at the 5% level, indicating that the coefficients are unbiased and efficient in our study.

$$y_t = x_t\beta_t + \varepsilon_t,\ \ \varepsilon_t \sim NID(0, H_t)$$
$$\beta_{t+1} = T_t\beta_t + R_t\eta_t,\ \ \eta_t \sim NID(0, Q_t) \qquad (2.6)$$

where y_t is an $n \times 1$ vector of observed values at time t, x_t is an $n \times m$ matrix of variables, β_t is an $m \times 1$ unobserved state variables, T_t is an $m \times m$ conformable system matrix, R_t is an $m \times r$ selection matrix with $m > r$, ε and η are normally and independently distributed mean-zero error terms, and the subscript t is from 1 to N. The first equation is called observation equation which generates the observed data based on the state variables. The second equation is called state equation which captures the time-varying state variables through time. The state variables are usually specified as an autoregressive process and random walk process is assumed to capture the structural change in this study.

After specifying the state space model, the next step is to estimate parameters β_t, H_t, T_t, R_t, and Q_t by Kalman filter. The Kalman filter is a recursive algorithm to estimate the state variables given the initial values and update the state variable until time t by the following equations for each time period,

$$v_t = y_t - x_t\beta_t,\quad F_t = x_t P_t x_t^{'} + H_t,\quad K_t = T_t P_t x_t^{'} F_t^{-1},$$
$$L_t = T_t - K_t x_t,\ \ \beta_{t+1} = T_t\beta_t + K_t v_t,\ \ P_{t+1} = T_t P_t L_t^{'} + R_t Q_t R_t^{'} \qquad (2.7)$$

Where v_t is one-step ahead prediction error, F_t is corresponding variance, and P_t is covariance matrix for the state variables. The state β_1 and the variance matrix P_1 are known as the initial state values. In addition, both Akaike information criterion (AIC) and Schwartz Bayesian criterion (SBC) are employed to select state variables.

Data and Variable Definition

Returns on Timberland Assets

As stated earlier, private- and public-equity timberland investment are two different vehicles, so separate analyses are conducted to test their inflation hedging abilities. Returns on private-equity timberland investment are proxied by National Council of Real Estate Investment Fiduciaries (NCREIF)

Timberland Index[3], which is the most commonly applied index for the U.S. timberland investment. The primary users of the NCREIF Timberland Index are existing and prospective institutional investors, timberland investment management organization (TIMOs), and academic researchers. Data contribution members include investment managers and plan sponsors that own or manage commercial real estate in a fiduciary setting. They submit information including net income, capitalized expenses, appraised value, and any sales or purchases for every property. Then the NCREIF produces the quarterly Index return based on the collected data.

The Index is built similarly to other commercial real estate property indices and can be separated into income return and capital return. This approach allows for an apple-to-apple comparison of timber real estate, commercial real estate, stocks, and bonds performances (Binkley et al., 2003). The EBITDDA return is impacted by biological returns and timber prices. The net operating revenue is obtained from tree farm revenue such as periodic timber sales. Then the income return is calculated by dividing EBITDDA by the average investment per quarter by considering any capital improvements and/or any partial sales occurred in that quarter. Moreover, the income from recreation lease can be included in the EBITDDA return (Cascio and Clutter, 2008). The capital return measures the change in market value from one quarter to the next. It comes from land appreciation based on the annual appraisals.

For public-equity timberland investments, we create a dynamic portfolio of the U.S. publicly traded forestry firms that mainly focused on timberland management over 1987 – 2009. First, the dynamic portfolio can reflect the true performance of public-equity timber firms over time. For example, mergers and acquisitions took place over the last two decades which made some firms get in and out of the portfolio. Second, the CAPM and Fama-French three-factor model were used as benchmarks to evaluate the financial performance of the timberlands (Mei and Clutter, 2010). To better compare to their results, the same approach is used to facilitate this purpose. Returns on the dynamic portfolio are

[3] One anonymous referee concerned about the artificial seasonality in the NCREIF Timberland Index for the fact that appraisals usually occur in the fourth quarter. So we examine whether the quarterly data exhibit certain periodic behavior by ACF and PACF graphs. Based on this analysis, there appears to be no seasonal pattern in the quarterly NCREIF Timberland Index.

calculated as the value-weighted returns of the publicly traded firms in the portfolio. We include Deltic Timber, IP Timberlands Ltd., Plum Creek, Pope Resources, Potlatch, Rayonier, The Timber Co., and Weyerhaeuser for the following reasons. First, Plum Creek, Potlatch, Rayonier, Weyerhaeuser are publicly traded timber REITs that focus on timberland and real estate. The timber REITs are the major timberland owners in the United States. By the end of 2009, Plum Creek, Potlatch, Rayonier, and Weyerhaeuser owned 17.7 million acres of timberlands across the country.

Second, Deltic Timber (C-Corp) is a natural resources company that is engaged primarily in the growing and harvesting of timber. Pope Resources (MLP) has a heritage as a land and timber owner in the Pacific Northwest. Third, the IP Timberlands Ltd. and Timber Co. operated as subsidiaries of International Paper and Georgia-Pacific that focused on timberland properties. Based on the analysis of the EBITDDA breakdown of publicly-traded firms, there are more than 80% of total EBITDDA from timber and real estate revenues on average (McHugh, 2011). Overall, the dynamic portfolio represents well public-equity timberland investment. The market value of each firm is calculated as the product of stock price and total outstanding shares at the end of each quarter. Financial data for these forestry firms are collected from the Center for Research in Security Prices (CRSP).

Inflation Rates

The consumer price index (CPI) is commonly used as the measure of inflation. Actual inflation is calculated according to the formula $\pi_t^a = \ln(CPI_t / CPI_{t-1})$. Expected inflation π^e is the individuals' expected inflation rate based on the information in the previous period. Unexpected inflation π^u is calculated as the difference between actual and expected inflation by the formula $\pi_t^u = \pi_t^a - \pi_t^e$. Due to the unobservable nature of expected inflation, proxy variable has been used to measure it in previous studies. It is common to use ARIMA to estimate the risk-free rate and then subtract these ARIMAs from the 3-month Treasury bill rates to proxy for expected inflation. This approach is employed to calculate the expected inflation in this study.

Returns on market portfolio are the value-weighted returns on all NYSE, AMEX, and NASDAQ stocks from CRSP. Risk-free rate proxied by the 1-month Treasury bill rate is collected from Ibbotson Associates, Inc. Quarterly data from 1987Q1 to 2009Q4 are used in this study.

Empirical Results

Descriptive Statistics

The descriptive statistics of nominal private- and public-equity asset returns and inflation rates over 1987 – 2009 are reported in Table 2.1. The results show that private-equity timberland assets have higher average quarterly nominal return (3.4%) than public-equity timberland assets (3.2%) and the market portfolio (2.7%). The standard deviation of private-equity timberland assets (4.2%) is much lower than that of public-equity timberland assets (12.1%). In terms of annualized return, private-equity timberland assets have the nominal return of 14.1 % with the lowest standard deviation of 8.5%. When it comes to the annualized Sharpe ratio, private-equity timberland assets (1.133) outperforms public-equity timberland assets (0.232), suggesting the higher return per unit of total financial risk. Based on the above descriptive statistics, private-equity timberland assets perform better than public-equity timberland assets over 1987 – 2009.

Different ARIMA models are used to estimate risk-free rate in this study. The model is selected based on SACF and SPACF graphs, AIC and SBC criterions, and Ljung-Box Test. The best ARIMA model of risk-free rate is ARIMA(1,1,1). The specific model is $R_{f,t} = 0.713R_{f,t-1} + \varepsilon_t - 0.437\varepsilon_{t-1}$. The standard error of AR(1) and MA(1) are 0.184 and 0.236, respectively, and statistically significant different from zero at the 10% level. Next step is to calculate the expected inflation by the formula $\pi_t^e = Y_t - ARIMA(R_f)$, where Y_t is the 3-month Treasury bill rate. Based on the historical data, the U.S. had relatively stable and low inflation rate over 1987 – 2009. The average annual actual inflation rate was 2.9% and the average expected inflation rate was 4.6%. Overall, actual inflation in the 1990s was relatively higher than that in the 2000s. Nevertheless, the U.S. deflated at the rate of 4% in 2008Q3 due to the financial crisis.

Hedging Actual Inflation

The hedging ability against actual inflation can be examined by Equation 2.1. To better understand the hedging ability against actual inflation, different investment horizons of 5-, 10-, 15-, and 20-year starting from 1987, and full sample time period of 23-year are considered. The corresponding results are listed in Table 2.2. The return for private-equity timberland assets has a positive relationship with actual inflation, indicating its ability of hedging actual inflation. It is notable that the coefficients of actual inflation are greater than one and statistically significant different from zero with more than 15-year investment horizon. The estimate of δ^a for private-equity timberland assets with a 23-year investment horizon is 1.436 so the nominal rate of return increases by 1.436% as the actual inflation goes up by 1%. It provides a superior protection against actual inflation. In contrast, public-equity timberland assets have a negative relationship with actual inflation and have no statistical significance no matter how long investors hold the assets.

In the context of portfolio, the hedging ability against actual inflation is examined by Equation 2.3 and the results are reported in Table 2.3. The hedging ability against actual inflation is consistent with the results above that private-equity timberland assets exhibit stronger ability to hedge actual inflation with longer investment horizons (e.g., 15-year). R^2 increases from 1.7% to 7.1% as the investment horizon increases from 5-year to 20-year, suggesting that more variance of nominal returns for private-equity timberland assets can be explained by actual inflation[4]. The significant positive γ^a indicates that private-equity timberland assets are underpriced by nominal CAPM. Meanwhile, all the βs for private-equity timberland assets are significantly different from one, indicating their weak correlation with the market and diversification potential to a portfolio. In contrast, public-equity timberland assets do not

[4] The low R^2 in this study need more discussion. First, as discussed by Fama and Schwert (1977), inflation may explain a small portion of the variation in the asset's nominal return even if an asset may be a complete hedge against inflation. It is the case in our study that the variance of the real return may be relatively large to the variance of the inflation rate. Second, the frequency of data affects the R^2 in a regression. Quarterly data are used for all the regressions in this study. Preliminary analysis using annual data have much higher R^2. Third, the R^2 increases as the investment horizon increases as explained in the section of Empirical Results.

hedge actual inflation. It is also interesting to note that the coefficients β for public-equity timberland assets are greater than one with shorter investment horizons (e.g., 5-year) and less than one with longer investment (e.g., 15-year). The coefficients γ^a for public-equity timberland assets are not statistically significantly different from zero, indicating that inflation has no impact on the public-equity timberland assets pricing. In summary, private-equity timberland assets have a negative correlation with the market and are good hedge against actual inflation. On the other hand, public-equity timberland assets behave more like common stocks and have a high correlation with the market.

To examine whether timberland assets perform persistently, the rolling regression is applied to evaluate inflation hedging ability in the context of portfolio. One advantage of the rolling regression is its ability to show how the estimate changes over different rolling windows. In this study, there are 92 quarters in the sample period. The rolling window is chosen from 5- to 15-year[5]. Figure 2.1 shows the rolling regression of private- and public-equity timberland assets hedging actual inflation with rolling windows of 5-, 10-, and 15-year, respectively. As shown in Figure 2.1, the coefficients for private-timberland assets inflation hedging do change dramatically in the sample time period. They climb to the peak around 1995 and then drop to the bottom around 2001. Private-equity timberland assets have a persistent hedge against actual inflation since the coefficients are greater than one in most of the times. We also find that all the coefficients are greater than one when the investment horizon is longer than 15 years. It suggests that the longer people invest in the private-equity timberland assets, the stronger and more consistent hedging ability. For public-equity timberland assets, we find that they started to hedge actual inflation in recent decade but not consistently.

One advantage of the state space model is that it can capture the external shocks and explain how the shocks gradually and naturally diffuse in the system. Thus, the state space model is further used to examine the ability of hedging actual inflation. The OLS estimates over 1987 – 2009 are set as the initial values for the state space model. To evaluate the time-varying hedging ability against actual inflation by

[5] Due to the limited space, only the rolling windows of 5-, 10-, and 15-year are listed and all the other results are available upon request from the authors.

Equation 2.3, only parameter γ^a is selected as the state variable since both α and β do not vary much and both AIC and SBC criterions prefer the deterministic α and β model. Figure 2.2 depicts the evolution of the coefficients γ^a in Equation 2.3 for private- and public-equity timberland assets. The coefficients gradually rise from the beginning of sample period and then smoothly decline until 2001. For the majority of the time, private-equity timberland assets serve as superior hedge against actual inflation, especially strong in the early 1990s. Overall, the coefficients γ^a have an average value of 2.309 which is higher than the OLS estimate. For public-equity timberland assets, most of the coefficients are negative, indicating that they have negative relationship with actual inflation and are not effective in hedging it.

Hedging Expected and Unexpected Inflation

The ability of hedging expected and unexpected inflation is examined by Equations 2.2 and 2.4 in the context of portfolio, respectively. Tables 2.4 and 2.5 present the regression results with different investment horizons. Private-equity timberland assets can hedge both expected and unexpected inflation and the ability becomes stronger as the investment time increases. In contrast, public-equity timberland asset is not effective in hedging either. Consistent results are found in the context of portfolio and the beta is decreasing with longer investment horizons.

The rolling regressions of γ^e and γ^u with 10-year rolling window for both private- and public-equity timberland assets are depicted in Figure 2.3. For private-equity timberland asset, the estimated γ^e is less than zero over 2001 – 2003, which indicates that private-equity timberland assets are not effective in hedging expected inflation at that time. It should be noted that this conclusion is based on the results impacted by the states of the economy in 2001. In contrast, the estimated γ^u is much higher than one over the same period. The hedging ability against unexpected inflation might dominate that against expected inflation, which explains why the private-equity timberland assets can hedge actual inflation. Interestingly, we find that public-equity timberland assets demonstrate stronger ability of hedging unexpected inflation in the recent decade.

The state space model is also employed to assess the time-varying hedging ability against expected and unexpected inflation. The OLS estimates over 1987 – 2009 are used as the initial values for the state space model. Parameters γ^e and γ^u are selected as the state variables at the same time. Figure 2.4 describes the evolution of γ^e and γ^u for private- and public-equity timberland assets. It is consistent with the finding by the OLS that private-equity timberland assets had a stronger ability hedging against expected inflation in the 1990s and became weaker in the 2000s. The pattern of hedging unexpected inflation is similar to that of expected inflation. Public-equity timberland assets are not effective in hedging either expected or unexpected inflation, which is consistent with the results by the OLS.

Discussion and Conclusion

Inflation hedging is one of the unique features of timberland assets that attract pension funds, university endowments, and other institutional investors in recent decades. This study employs the Fisher hypothesis and CAPMUI to analyze how effectively private- and public-equity timberland assets hedge actual, expected, and unexpected inflation in the U.S. during 1987 – 2009. Moreover, the rolling regression and state space model are employed in this study. The rolling regression is used to evaluate whether timberland assets can persistently hedge inflation, while the state space model is employed to capture the external shocks on the system. Returns for private-equity timberland assets are proxied by the NCREIF Timberland Index and returns for public-equity timberland assets are calculated by the value-weighted returns on a dynamic portfolio of the U.S. publicly traded timber firms. Several conclusions are reached in this study.

The performances between private- and public-equity timberland assets are compared. Private-equity timberland assets have higher nominal rates of return and lower standard deviations than public-equity timberland assets between 1987 and 2009. In terms of the Sharpe ratio, private-equity timberland assets are able to compensate investors more at the same level of risk. The higher rate of return for private-equity timberland assets may be due to its liquidity risk since major data contribution members such as TIMOs usually have a 10- to 15-year investment horizon. Moreover, private-equity timberland assets have very low system risk while public-equity timberland assets perform similarly to the market, which is in line with the findings of Mei and Clutter (2010). Our study further complements their results by finding that private-equity timberland assets is underpriced by nominal CAPM and public-equity timberland asset is fairly priced. Since the latter offers a huge liquidity advantage over the former one, it should fully and correctly reflect all the available information in the prices.

Regarding inflation hedging, private- and public-equity timberland assets perform differently. Private-equity timberland assets do hedge actual, expected, and unexpected inflation. They also perform relatively consistently and the hedging ability is stronger with longer investment horizon. Although public-equity timberland assets do not hedge inflation for majority of the times, they started demonstrating stronger hedging ability against inflation in the last decade. It is possible that the recent conversion of forest product companies such as Plum Creek and Weyerhaeuser to timber REITs results in a stronger hedging ability of this dynamic portfolio. We believe the reasons for dramatic difference stem from appraisal, liquidity, and transaction costs. Therefore, the different performances between private- and public-equity timberland assets have important implications for investors.

Whether timberland assets can hedge inflation depends on the states of the economy. Both the rolling regression and state space model indicate that private-equity timberland assets had stronger hedging ability against all three types of inflation in the 1990s and became weaker in the 2000s. Historical data tell us that the inflation rate in the 1990s was relatively higher than that in the 2000s. On the other hand, inflation tends to be high during good economic times (expansions) and low during bad economic times (recessions)[6]. The recession sometimes is signaled by deflation. In this study, the technology bubble burst in 2001, which can be viewed as a divide between high inflation and low inflation period. The weaker inflation hedging ability is probably due to the relative weak performance of NCREIF Timberland Index since 2001. It is further evident that the financial crisis in 2008 led to its weak hedging ability. As a

[6] An expansion is a period when economic activity surges until it reaches a peak, whereas a recession is a general slowdown in economic activity. The macroeconomic indicators such as inflation, GDP, unemployment, and housing starts vary in a similar way during expansion or recession. In the United States, the National Bureau of Economic Research (NBER) determines and announces the dates of expansion and recession.

result, the state of the economy does affect the hedging ability of timberland assets. Private-equity timberland assets are effective in hedging inflation during the expansion and less effective during the recession, which is consistent with the finding of Healey et al. (2005). This conclusion implies that both the time and state of the economy are important for the effectiveness of inflation hedging.

Investment horizon plays a significant role in timberland inflation hedging. Private-equity timberland assets have stronger ability to hedge actual inflation with longer investment horizon. A typical private-equity timberland investment such as a TIMO has an at least 10-year investment horizon so that the timberland assets can play the role of inflation hedging in their portfolios. Even in different time periods, private-equity timberland assets have a relatively persistent hedge against inflation. We also find that private-equity timberland assets have an absolutely persistent hedge against actual, expected, and unexpected inflation when investment horizons are long enough (e.g., 13 years based on the rolling regression). This result suggests that longer investment horizons for private-equity timberland assets could help investor better hedge actual, expected, and unexpected inflation, and determine the timing strategies for their portfolios.

This study not only provides the evidence of inflation hedge ability of timberland assets but also supplies information and suggestions for investors to better allocate their funds. In the future, the macroeconomic factor model can be used to test the robustness on hedging ability. Short-run and long-run hedging ability can be tested by cointegration and error correction model to better understand inflation hedging ability of timberland assets. However, investors need to be careful when interpreting the results from this study. First, the weaknesses of quarterly NCREIF Timberland Index such as heterogeneity and appraisal smoothing posts limitations on this study. The annual data may be more accurate but limited in sample size. Second, the publicly-traded firms use much more debt than TIMOs, which impacts their financial attributes. Third, although we have used all the data available, it is still a short period of time to make strong statistical inferences.

Table 2.1. The descriptive statistics of nominal private- and public-equity asset returns and inflation rates (1987 – 2009).

Variable	$R_{private}$	R_{public}	R_{market}	R_f	π^a	π^e	π^u
			Quarterly				
Observation	92	92	92	92	92	92	92
Minimum	-0.065	-0.379	-0.230	0.000	-0.040	0.000	-0.046
Median	0.023	0.038	0.035	0.012	0.007	0.012	-0.004
Maximum	0.223	0.426	0.216	0.022	0.025	0.024	0.015
Mean	0.034	0.032	0.027	0.010	0.007	0.011	-0.004
Std. Dev.	0.042	0.121	0.088	0.005	0.008	0.005	0.009
Skewness	1.708	-0.322	-0.564	-0.135	-1.944	-0.133	-0.738
Kurtosis	4.469	1.361	0.658	-0.618	10.170	-0.611	4.451
			Annually				
Observation	23	23	23	23	23	23	23
Mean	0.141	0.101	0.094	0.042	0.029	0.046	-0.017
Std. Dev.	0.085	0.243	0.176	0.010	0.016	0.011	0.018
Sharpe Ratio	1.133	0.232	0.286	—	—	—	—

Notes: Variable R denotes nominal return on different assets. The subscripts denote the private- and public-equity timberland assets, the market, and the risk-free rate. Variable π denotes inflation and the superscripts denote actual, expected, and unexpected inflation rate. Sharpe ratio is a measure of the excess return per unit of risk and can be calculated by $S = (\bar{R} - \bar{R}_f) / \sigma$, where $\bar{R}$ is the average asset return, $\bar{R}_f$ is the average risk-free interest rate, and σ is the standard deviation of the asset excess return.

Table 2.2. Estimation of hedge against actual inflation by Equation 2.1 (1987 – 2009).

Time horizon	Private-equity timberland			Public-equity timberland		
	r_i	δ_i^a	R^2	r_i	δ_i^a	R^2
5-yr	0.053**	0.385	0.002	0.016	1.242	0.002
	(0.024)	(2.052)		(0.078)	(6.607)	
10-yr	0.030*	2.493	0.051	0.060	-2.660	0.011
	(0.017)	(1.752)		(0.040)	(4.032)	
15-yr	0.023**	2.249*	0.059	0.013	2.865	0.014
	(0.011)	(1.183)		(0.029)	(3.127)	
20-yr	0.022***	1.934***	0.080	0.010	3.364	0.034
	(0.007)	(0.743)		(0.020)	(2.042)	
23-yr	0.024***	1.436***	0.077	0.034**	-0.277	0.000
	(0.006)	(0.526)		(0.017)	(1.564)	

***, **, * denote significantly different from zero at the 1%, 5%, and 10% level, respectively. Standard errors are in parentheses.

Table 2.3. Estimation of hedge against actual inflation in the context of portfolio by Equation 2.3 (1987 – 2009).

Time horizon	Private-equity timberland				Public-equity timberland			
	α_i	β_i	γ_i^a	R^2	α_i	β_i	γ_i^a	R^2
5-yr	0.039	-0.054†	0.291	0.017	-0.014	1.128***	0.180	0.679
	(0.025)	(0.101)	(2.078)		(0.046)	(0.188)	(3.877)	
10-yr	0.021	-0.046†	2.095	0.040	0.024	1.056***	-2.917	0.483
	(0.018)	(0.110)	(1.788)		(0.030)	(0.182)	(2.972)	
15-yr	0.012	-0.015†	2.039*	0.048	0.003	0.899***	-0.068	0.403
	(0.011)	(0.071)	(1.210)		(0.023)	(0.147)	(2.504)	
20-yr	0.012	-0.006†	1.799**	0.071	0.003	0.912***	0.395	0.432
	(0.007)	(0.058)	(0.758)		(0.016)	(0.124)	(1.628)	
23-yr	0.015***	-0.013†	1.324***	0.068	0.018	0.963***	-1.733	0.473
	(0.006)	(0.049)	(0.520)		(0.012)	(0.108)	(1.154)	

† denotes significantly different from one at the 1% . ***, **, * denote significantly different from zero at the 1%, 5%, and 10% level, respectively. Standard errors are in parentheses.

Table 2.4. Estimation of hedge against expected and unexpected inflation by Equation 2.2 (1987 – 2009).

Time horizon	Private-equity timberland				Public-equity timberland			
	r_i	δ_i^e	δ_i^u	R^2	r_i	δ_i^e	δ_i^u	R^2
5-yr	0.007	2.771	-0.025	0.032	0.260	-11.306	3.392	0.082
	(0.069)	(3.893)	(2.155)		(0.215)	(12.211)	(6.760)	
10-yr	0.041	1.958	2.920	0.056	0.099	-4.643	-1.088	0.026
	(0.028)	(2.108)	(1.991)		(0.065)	(4.829)	(4.561)	
15-yr	0.012	2.936*	1.993	0.064	0.104*	-2.609	4.911	0.062
	(0.023)	(1.724)	(1.279)		(0.060)	(4.456)	(3.305)	
20-yr	0.006	3.197***	1.685**	0.110	0.046	0.577	3.911*	0.054
	(0.012)	(1.073)	(0.751)		(0.035)	(2.969)	(2.077)	
23-yr	0.003	3.156***	1.154**	0.139	0.045	-1.180	-0.129	0.002
	(0.010)	(0.850)	(0.523)		(0.030)	(2.614)	(1.608)	

***, **, * denote significantly different from zero at the 1%, 5%, and 10% level, respectively. Standard errors are in parentheses.

Table 2.5. Estimation of hedge against expected and unexpected inflation in the context of portfolio by Equation 2.4 (1987 – 2009).

Time horizon	Private-equity timberland					Public-equity timberland				
	α_i	β_i	γ_i^e	γ_i^u	R^2	α_i	β_i	γ_i^e	γ_i^u	R^2
5-yr	0.019	-0.044†	1.319	0.104	0.022	0.033	1.105***	-2.216	0.615	0.681
	(0.074)	(0.109)	(4.121)	(2.230)		(0.138)	(0.203)	(7.676)	(4.154)	
10-yr	0.043	-0.054†	0.986	2.976	0.064	0.056	1.043***	-4.587	-1.596	0.493
	(0.029)	(0.110)	(2.134)	(2.014)		(0.048)	(0.184)	(3.556)	(3.356)	
15-yr	0.013	-0.016†	1.979	2.065	0.048	0.051	0.864***	-2.856	1.117	0.415
	(0.024)	(0.073)	(1.741)	(1.330)		(0.049)	(0.150)	(3.567)	(2.725)	
20-yr	0.006	-0.002†	2.270**	1.692**	0.075	0.032	0.894***	-1.781	0.887	0.445
	(0.013)	(0.058)	(1.084)	(0.781)		(0.027)	(0.124)	(2.308)	(1.663)	
23-yr	0.004	-0.010†	2.219***	1.171**	0.086	0.031	0.960***	-2.770	-1.557	0.476
	(0.010)	(0.048)	(0.856)	(0.531)		(0.022)	(0.108)	(1.912)	(1.186)	

† denotes significantly different from one at the 1% . ***, **, * denote significantly different from zero at the 1%, 5%, and 10% level, respectively. Standard errors are in parentheses.

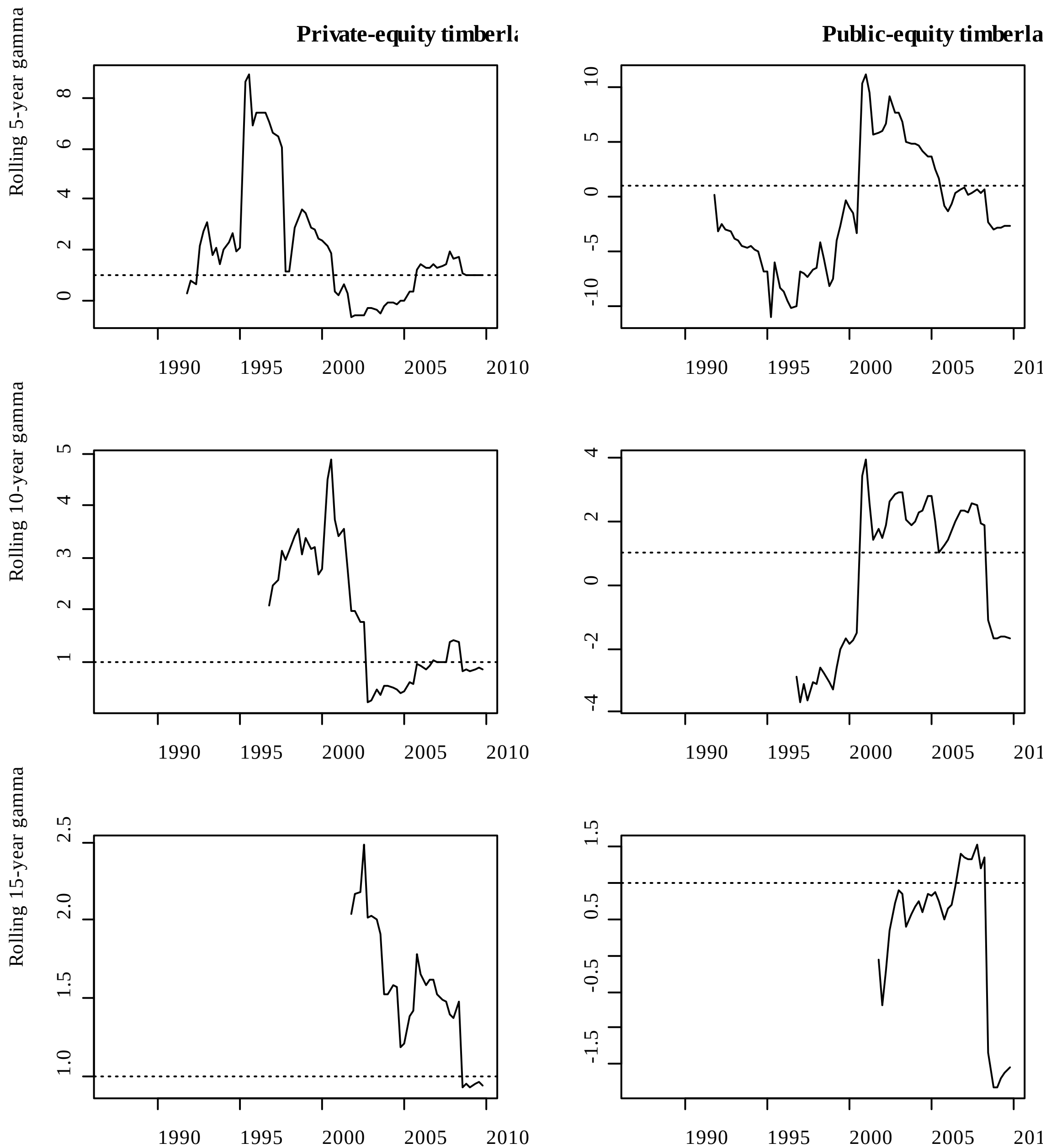

Figure 2.1. Rolling regression estimates for private- and public- equity timberland hedging actual inflation in the context of portfolio.

Notes: The six graphs are the rolling estimates γ^a in Equation 2.3 with rolling window of 5-, 10-, and 15-year, respectively. The three graphs on the left are for private-equity timberland assets and the three graphs on the right are for public-equity timberland asset**s.**

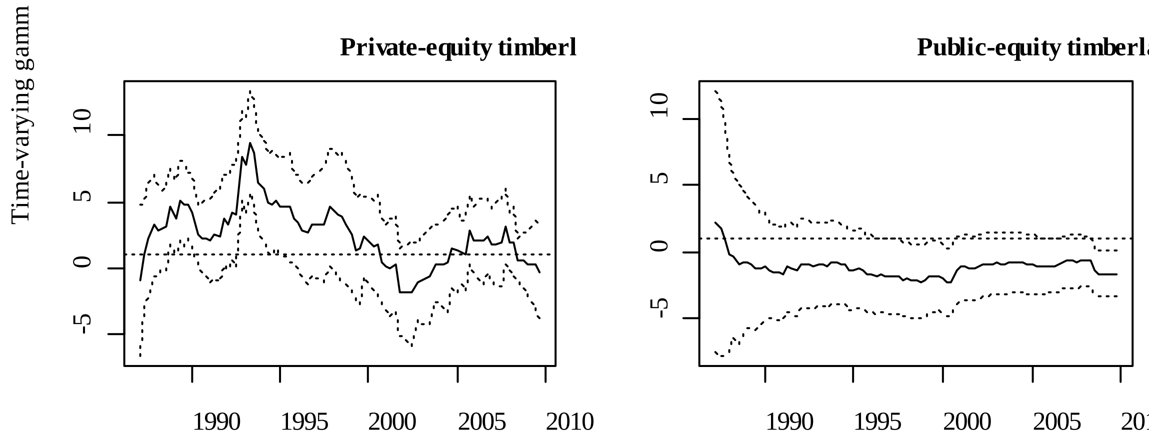

Figure 2.2. State space estimates for private- and public-equity timberland assets hedging actual inflation in the context of portfolio.

Notes: The two graphs are the time-varying γ^a in Equation 2.3 with state space model. The graph on the left is for private-equity timberland assets and the graph on the right is for public-equity timberland assets.

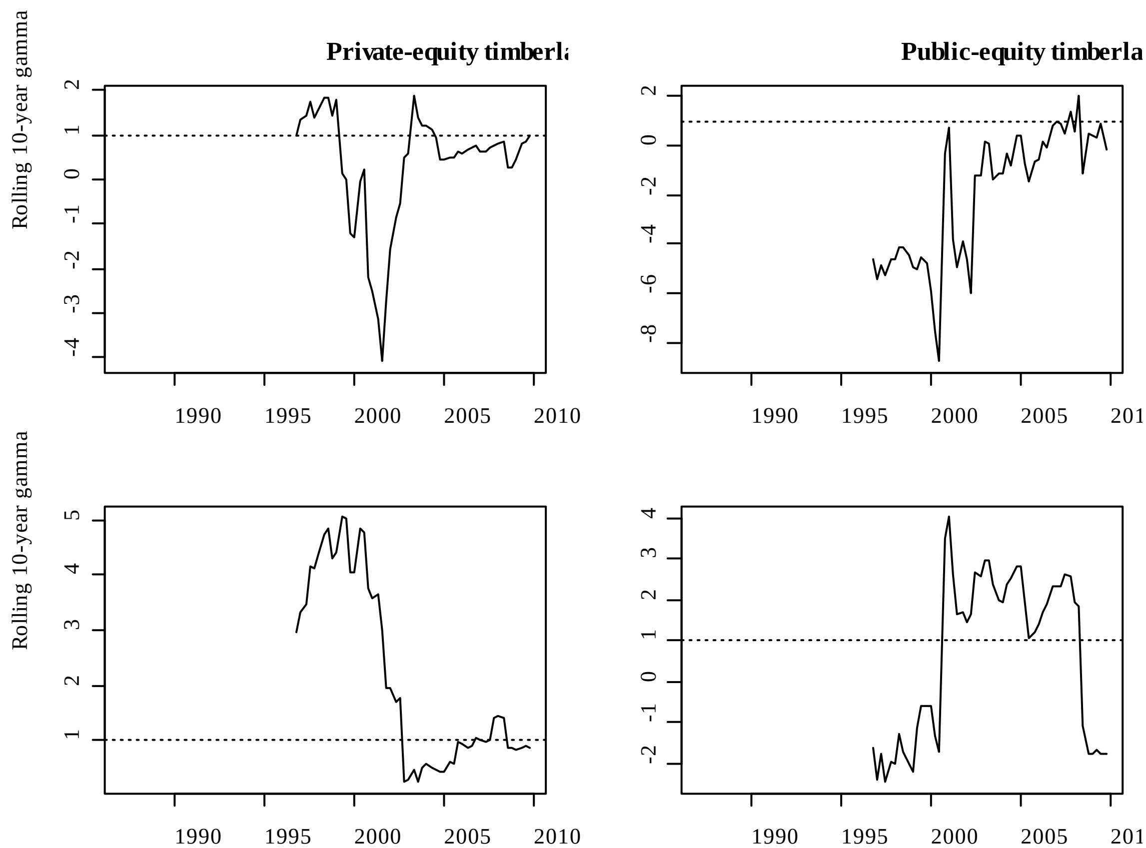

Figure 2.3. Rolling regression estimates for private- and public-equity timberland assets hedging expected and unexpected inflation in the context of portfolio.

Notes: The four graphs are the rolling estimate γ^e and γ^u in Equation 2.4 with rolling window of 10-year. The two graphs on the left are for private-equity timberland assets and the two graphs on the right are for public-equity timberland assets.

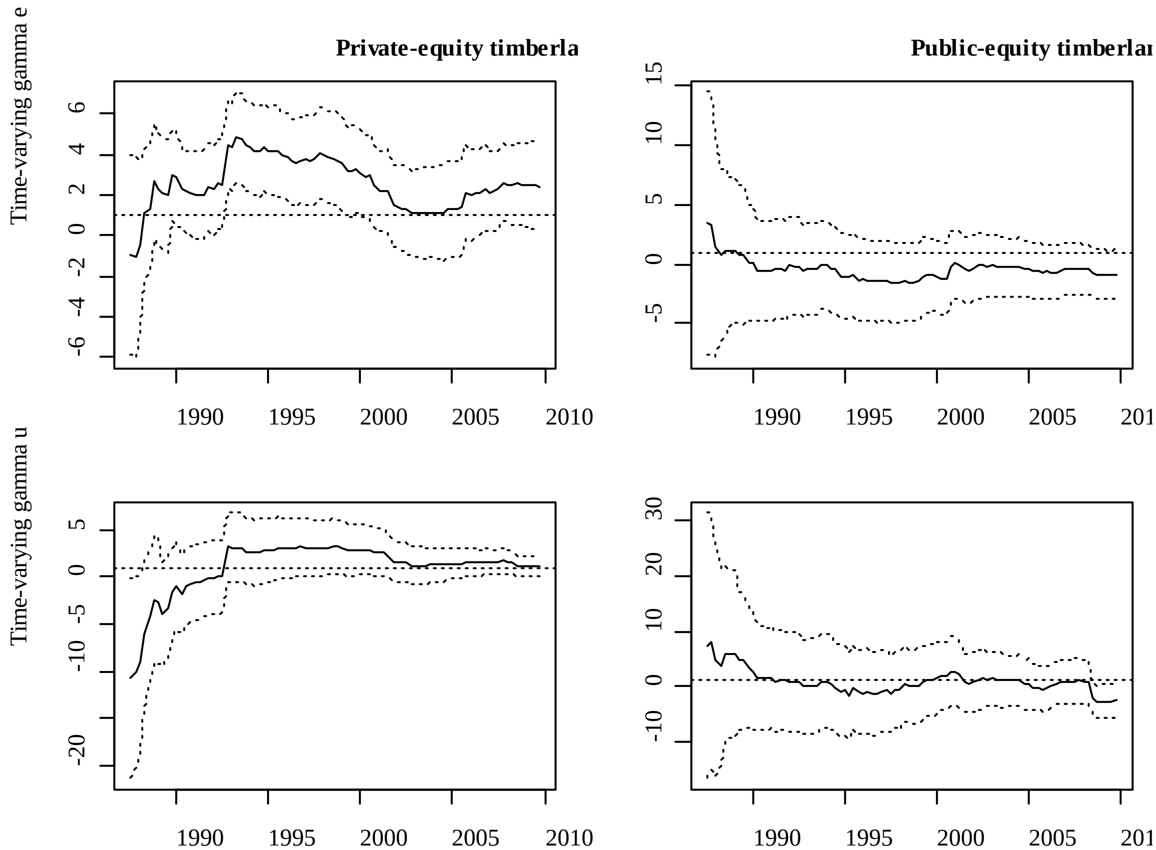

Figure 2.4. State space estimates for private- and public-equity timberland assets hedging expected and unexpected inflation in the context of portfolio.

Notes: The four graphs are the time-varying γ^e and γ^u in Equation 2.4 with state space model. The two graphs on the left are for private-equity timberland assets and the two graphs on the right are for public-equity timberland assets.

CHAPTER 3

ASSESSING THE ROLE OF U.S. TIMBERLAND ASSETS IN A MIXED PORTFOLIO UNDER THE MEAN-CONDITIONAL VALUE AT RISK FRAMEWORK[7]

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Abstract

This study examines the role of U.S. timberland assets in a mixed portfolio from the risk perspective. Under the mean-conditional value at risk (M-CVaR) optimization framework, the efficient frontier of the mixed portfolio is dramatically improved after adding timberland assets in comparison of the mean-variance (M-V) efficient frontier. The asset allocation strategies formulated by the static and dynamic optimizations indicate that timberland assets maintain a significant allocation in the mixed portfolio. Moreover, risk decomposition is used to identify the risk sources under four different scenarios. It is found that large-cap stocks and small-cap stocks are generally risk intensifiers, whereas treasury bonds, treasury bills, and timberland assets are risk diversifiers.

Introduction

Timberland assets[8] have attracted the eyes of individual and institutional investors in recent decades due to distinct features, including high risk-adjusted returns (Cascio and Clutter, 2008), risk diversification potentials (Caulfield, 1998b), and inflation hedging abilities (Washburn and Binkley, 1993). For high net wealth individuals and families, they can invest in timberlands through commingled funds or own timberland properties directly. For institutional investors such as pension funds, university endowments, and foundations, it is typical for them to participate in individual accounts or commingled funds. At the same time, Timberland Investment Management Organizations (TIMOs) emerged to manage private timberlands on behalf of those individual and institutional investors. Currently, the 19 TIMOs manage 20.78 million acres timberland assets in the United States[9].

To better understand timberland assets as an alternative investment, a number of studies employ the modern portfolio theory to evaluate its performance and to analyze its diversification effects. Mills

[8] Timberland assets in this study refer to private timberlands that are mainly owned by high net wealth individuals and institutional investors such as pension funds, university endowments, and foundations in the United States.

[9] The data are collected from the Timberland Monitor section in the Industry Intelligence, Inc. There are 19 TIMOs listed in total. For example, the top three TIMOs including The Forestland Group, Hancock Timber Resource Group, and The Campbell Group manage 3.2, 3.032, and 3.028 million acres timberland assets in the United States, respectively.

and Hoover (1982) introduced the mean-variance (M-V) optimization approach to examine the relationship between returns and risks in forest investments and proved that forest investment could provide diversification benefits. Zinkhan et al. (1992) and Caulfield (1998a) demonstrated that adding timberland assets to a portfolio could improve the portfolio performance and provided asset allocation suggestions for institutional investors. Newell and Eves (2009) analyzed the risk-adjusted performance of U.S. timberland assets in real estate portoflios and concluded that timberland was a strongly performed asset over 1987 – 2007. Scholten and Spierdijk (2010) quantified the diversification effects of timberland investments under the M-V framework and found that U.S. private-equity timberland assets did not significantly improve the efficient frontier after removing the appraisal smoothing bias from the raw data.

The modern portfolio theory also establishes a framework to compare timberlands with other assets such as stocks, bonds, and farmlands. Thomson (1997) employed the multiperiod portfolio optimization approach and showed that timber (e.g., Douglas Fir and Southern Pine) had been valuable either as a single asset or as an addition in a financial portoflio. Waggle and Johnson (2009) adopted the M-V approach to examine the effects of including timberlands, farmlands, and commercial real estates in a mixed asset portfolio with stocks and bonds. They found that timberlands entered all portfolios, whereas farmlands entered only low risk portfolios. Overall, these studies suggest that adding timberland assets to a portfolio can improve the the efficient frontier or enhance the long-term financial performance.

Under the M-V framework, variance or standard deviation (SD) of asset returns is used to measure the portfolio risk under a multivariate normal distributional assumption. When asset returns follow a normal distribution, SD can help us understand how asset returns vary around the mean value. However, investors are more concerned about potential losses or negative returns from the extreme events such as financial crises, and therefore, more attention have been paid to downside risks in practice. Caulfield and Meldahl (1995) used the downside risk semivariance to construct portfolios of southeastern timberland assets and found that this approach resulted in more efficient frontiers than the M-V approach. Hildebrandt and Knoke (2011) also pointed out that downside risk models could provide an important implication for risk management in forestry. Meanwhile, value at risk (VaR) has become a popular tool among portfolio managers to measure the downside risk since it is easy to calculate and interpret. VaR gives the maximum loss that will not be exceeded with a given probability over a period of time. It answers the question “How bad can things get?”. However, it does not answer the question “If things do get bad, how much is the portfolio expected to lose?” (Hull, 2012). Conditional VaR (CVaR) answers this question by incorporating the left-tail distribution to measure the loss greater than VaR.

It is well documented that returns of financial assets such as stocks and bonds are not normally distributed (Sheikh and Qiao, 2010). It is also observed that timberland returns depart from normality to some degree (Petrasek et al., 2011). These asset returns generally exhibit non-normality properties such as skewness and kurtosis in the real world. For instance, negatively skewed asset returns suggest that the left tail is longer than the right tail, implying that the probability of the occurrence of negative returns is higher than that of positive returns. Asset returns with fat tails imply that both of the extreme negative and positive returns occur more likely than those normally distributed. It is obvious that the mean and variance alone fail to describe the true distribution of asset returns. Therefore, the M-V approach may not fully reveal the relationship between returns and risks, and may not correctly construct the efficient frontier for a portfolio.

To address the risk measure and non-normality issues, the mean-conditional value at risk (M-CVaR) optimization method is introduced in this study. The M-CVaR approach minimizes downside risk CVaR with a given target return and does not assume a multivariate normal distribution. This approach has been used to construct hedge fund portfolios with minimum tail risks (Giamouridis and Vrontos, 2007) and to demonstrate the extent to which the M-V approach underestimates the tail risks (Agarwal and Naik, 2004). To better illustrate how downside risk VaR can be appropriately calculated, a set of non-normal asset returns relative to a normal distribution is drawn. In Figure 3.1, the impact of skewness and kurtosis on the downside risk VaR is illustrated. The VaR of negatively skewed or fat-tailed asset returns is underestimated compared with the VaR under a normality assumption. In contrast, it is overestimated if asset returns are positively skewed or thin-tailed. It is intuitive that investors prefer the assets with positively skewed and thin-tailed returns because both cases expose investors to smaller probabilities of extreme negative returns.

The overall purpose of this study is to examine the role of U.S. timberland assets in a mixed portfolio from the risk perspective. First, the efficient frontier is constructed by the M-CVaR optimization approach, which minimizes the downside risk CVaR and accounts for the non-normality of asset returns. The empirical results indicate that the M-CVaR approach leads to more efficient frontiers than the M-V approach. Second, the asset allocation strategies formulated by the M-CVaR approach indicate that timberland assets maintain a significant allocation in the mixed portfolio over static and dynamic optimizations. Next, three risk metrics including SD, VaR, and CVaR are used to evaluate and compare portfolio risks. It is found that SD underestimates the portfolio risk compared with VaR and CVaR, which reflect the true downside risk. Finally, the portfolio risk is decomposed to identify how the aggregate risk is contributed by individual assets through both static and dynamic backtesting under four different scenarios. The results indicate that both large-cap stocks and small-cap stocks are risk intensifiers, whereas treasury bills, treasury bonds, and timberland assets are risk diversifiers.

Methodology

Modern Portfolio Theory

Modern portfolio theory proposed by Markowitz (1952) establishes the foundation of portfolio optimization and asset allocation strategies. This theory constructs a set of optimal portfolios through weighted combinations of assets whose returns are viewed as random variables. The returns of these portfolios are measured by the sample means of the combined assets. Mathematically, a set of assets indexed by i ($i = 1, 2, \cdots, n$) generate individual returns $r = (r_1, r_2, \cdots, r_n)^T$ at the end of the holding period. Their mean values are denoted by $\overline{r} = \varepsilon(r) = (\overline{r}_1, \overline{r}_2, \cdots, \overline{r}_n)^T$. Investors construct their portfolios by adjusting the weight of individual asset $w = (w_1, w_2, \cdots, w_n)^T$ constrained by $\sum_{i=1}^{n} w_i = 1$ and $w_i > 0$ (short-selling is not allowed). Therefore, the portfolio return can be calculated by $R(w, \overline{r}) = w^T \overline{r} = \sum_{i=1}^{n} w_i \overline{r}_i$, where R is a random variable with a cumulative distribution function F_R.

Assume the portfolio risk $\Re$ is a function of asset weights and returns, then the portfolio can be optimized by minimizing the risk subject to a given target return u as follows:

$$\begin{aligned} &Min \;\; \Re(w,r) \\ &s.t. \;\; w^T \bar{r} = u \;\text{ and } \sum_{i=1}^{n} w_i = 1. \end{aligned} \tag{3.1}$$

Risk Measures

Risk measure I: standard deviation (SD). The standard deviation defined in Equation (3.2) is commonly used to measure the portfolio risk, where Σ is the variance-covariance matrix of the n assets. This portfolio optimization is under a multivariate normality assumption and is called the M-V optimization approach. Solving the problem of $Min\,\sigma^2(w,r)$ with a given set of target returns can generate M-V efficient frontiers, where $\sigma^2(w,r) = w^T \Sigma w$ is the variance of the portfolio. The standard deviation of the portfolio is

$$SD(w,r) = \sqrt{w^T \,\Sigma\, w}\,. \tag{3.2}$$

Risk measure II: value at risk (VaR). VaR has become the most widely used industry standard to measure risks. It calculates the downside risk in one number, allowing easy comparisons among individual assets and portfolios (Morgan, 1996). It is defined as the maximum loss that will not be exceeded within a given time period at a specified confidence level[10]. Given a confidence level $\alpha \in (0,1)$, a portfolio's $(1-\alpha)\%$ VaR can be calculated by

$$VaR_\alpha(w,r) = -F_R^{-1}(1-\alpha), \tag{3.3}$$

where F_R^{-1} is the quantile function of the asset or portfolio returns. Although VaR has become a popular risk measure, it lacks of some desirable properties such as subadditivity (Artzner et al., 1999). For

[10] Several specifications are listed here. First, the given period of time in this study refers to a quarter for the calculation of SD, VaR, and CVaR. All the results can be easily converted to one-year values. Second, the confidence level α is specified as 95% throughout this study, so the 95% VaR and 95% CVaR are calculated by the 5% quantile of the return distributions. Third, both the VaR and CVaR should be negative values from mathematical definition by equation (3.3) and denote the losses of assets from the practical point of view. To easily compare and interpret different risk measures, all the results are reported in absolute values: the larger the reported value, the higher the risk.

example, a portfolio's VaR may be greater than the sum of the individual VaRs. Moreover, it is difficult to minimize a portfolio's VaR since it is a non-smooth and non-convex function with respect to asset weights.

Risk measure III: conditional value at risk (CVaR). CVaR overcomes many of the drawbacks of VaR as a downside risk measure. For example, CVaR has the coherent properties[11], including subadditivity, homogeneity, monotonicity, and translation invariance (Krokhmal et al., 2002). CVaR is defined as the conditional expectation of losses exceeding VaR at a confidence level. A portfolio's CVaR can be defined in terms of its own VaR with a confidence level α as

$$CVaR_{\alpha}(w,r) = -E[R(w,r) \mid R(w,r) \le -VaR_{\alpha}(w,r)] = -\frac{1}{1-\alpha}\int_{-\infty}^{-VaR_{\alpha}(w,r)} zf(z)dz, \tag{3.4}$$

where $f(z)$ is the probability density function of portfolio return $R(w,r)$. Solving the problem of $Min\,CVaR_{\alpha}(w,r)$ with a given set of target returns can construct M-CVaR efficient frontiers (Rockafellar and Uryasev, 2000). More importantly, the M-CVaR approach does not assume a multivariate normal distribution of asset returns.

Modified Risk Measures

The above approach is a nonparametric way to calculate VaR and CVaR. The parametric way is commonly used under a normal distribution assumption, but it fails to consider higher moments such as skewness and kurtosis. Cornish and Fisher (1938) proposed a way to correct for asymmetry and fat tails in return distributions. Favre and Galeano (2002) employed this solution to develop a modified VaR and Boudt et al. (2008) further derived a modified CVaR through the Cornish-Fisher expansion. Both of them

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[11] A coherent risk measure satisfies the subadditivity, homogeneity, monotonicity, and translation invariance. First, a risk measure is subadditivity if the risk of a portfolio is never greater than the sum of the risks of individual assets. SD and CVaR are subadditive, whereas VaR is not. Second, homogeneity of a risk measure means that the risk of a portfolio will increase the same times as the size of a position increases in a portfolio. Third, monotonicity means if the losses of a portfolio are larger than another one, then its portfolio risk is also higher than that of another portfolio. Fourth, translation invariance is that adding cash to a portfolio can decrease its risk by the same amount.

collapse to the regular VaR and CVaR if returns are normally distributed. The $\mathrm{VaR}^{\mathrm{M}}$ and $\mathrm{CVaR}^{\mathrm{M}}$ can be calculated by the following formula:

$$VaR_{\alpha}^{M}(w,r) = -\mu - [z_{\alpha} + \frac{1}{6}(z_{\alpha}^{2} - 1)S + \frac{1}{24}(z_{\alpha}^{3} - 3z_{\alpha})K - \frac{1}{36}(2z_{\alpha}^{3} - 5z_{\alpha})S^{2}]\sigma, \tag{3.5}$$

$$CVaR_{\alpha}^{M}(w,r) = -E[R(w,r) \mid R(w,r) \leq -VaR_{\alpha}^{M}(w,r)] = -\frac{1}{1-\alpha}\int_{-\infty}^{-VaR_{\alpha}^{M}(w,r)} zf(z)dz, \tag{3.6}$$

where μ, σ, S, and K are the mean, standard deviation, skewness, and excess kurtosis of the portfolios, and z_{α} is the left-tail α quantile of the standard normal distribution.

Risk Decomposition

Risk decomposition can help portfolio managers to identify the sources of risk in a portfolio, and therefore, provide important implications for risk management. The contribution by each asset in a portfolio is easily calculated by the Euler's theorem since all these three risk measures (SD, VaR, and CVaR) are homogenous of degree one. The risk contribution of the i^{th} asset to the portfolio's SD, VaR, and CVaR can be calculated by the following equations (Martin et al., 2001; Pearson, 2002; Boudt et al., 2008):

$$D_{i}SD(w,r) = w_{i}\frac{\partial SD(w,r)}{\partial w_{i}}, \tag{3.7}$$

$$D_{i}VaR_{\alpha}^{M}(w,r) = w_{i}\frac{\partial VaR_{\alpha}^{M}(w,r)}{\partial w_{i}}, \tag{3.8}$$

$$D_{i}CVaR_{\alpha}^{M}(w,r) = w_{i}\frac{\partial CVaR_{\alpha}^{M}(w,r)}{\partial w_{i}}. \tag{3.9}$$

The individual risk contribution is interpreted as the change of the portfolio risk with respect to the percentage change in weight w_{i}. If the risk contribution is greater than the weight, then the asset is a risk intensifier. If it is less than the weight, then the asset serves as a risk diversifier. If they are equal, then the asset is neutral. Since the function of portfolio's CVaR is homogeneous of degree one, the individual risk contribution satisfies $\sum_{i=1}^{n} D_{i}SD(w,r) = \sum_{i=1}^{n} D_{i}VaR_{\alpha}^{M}(w,r) = \sum_{i=1}^{n} D_{i}CVaR_{\alpha}^{M}(w,r) = 1$.

Backtesting

Backtesting is a common method to evaluate the performance of a portfolio using historical data with given strategies. It can provide crucial implications for asset allocation and portfolio management. Meanwhile, it is likely that the distribution of asset and portfolio returns vary over time, so the role of an asset in a portfolio could be affected by this time-varying characteristic. A rolling backtest taking this property into consideration can examine whether the performance is persistent from a dynamic perspective. In this study, both static and dynamic backtesting are employed to formulate asset allocation strategies and analyze asset risk contributions under the M-CVaR framework. First, asset allocations with a given target return are formulated and compared across different scenarios using the full sample data. The corresponding risk contribution is calculated to evaluate the role of timberland assets in the mixed portfolio. Second, the backtesting with a 10-year rolling window is employed to evaluate the stability of asset allocations and the persistence of risk contributions. The portfolio is annually rebalanced, so the 10-year rolling periods from 1987 to 2011 generates 16 efficient frontiers. For each efficient frontier, the optimal asset allocations and portfolio risk with a given target return are obtained and compared under different scenarios. Last, the portfolio risk is decomposed over the 10-year rolling window to test whether timberland asset is a persistent risk diversifier.

Data and Scenarios

To examine the role of timberland assets in a mixed portfolio, four assets including large-cap stocks, small-cap stocks, treasury bonds, and treasury bills are considered in this study. Among them, returns on large-cap stocks are proxied by the S&P 500 Index collected from the Center for Research in Security Prices (CRSP). Returns on small-cap stocks are approximated by the Russell 2000 Index collected from the Russell Investments[12]. Returns on treasury bonds are proxied by the Barclays Capital U.S. Government/Credit Index collected from the Barclays Capital[13]. Returns on treasury bills are

[12] Thank Oanh Hoang from the Russell Investments for providing the Russell 2000 Index data.
[13] Thank Andrew Chan from the Barclays Capital for providing the Barclays Capital U.S. Government/Credit Index data.

approximated by the 3-month treasury bills collected from CRSP. The NCREIF Timberland Index is used to proxy the returns for U.S. timberland investments. To be consistent with the NCREIF Timberland Index, quarterly data from 1987Q1 to 20011Q4 are used in this study.

Institutional investors primarily invest in traditional assets such as stocks and bonds in their portfolios. In practice, individual assets are constrained by minimum and maximum allowable allocations. Moreover, asset allocations can be constrained by group constraints. These constraints on asset allocations can provide more meaningful asset allocation implications for institutional investors who have different risk tolerance levels. In order to fully understand the role of timberland assets in a mixed portfolio, four scenarios with different constraints are assumed. These scenarios follow previous studies on timberland assets (Caulfield, 1998b; Newell and Eves, 2009; Waggle and Johnson, 2009). Scenario 1 places the minimum asset allocation on large-cap stocks by 20%, small-cap stocks by 15%, treasury bonds by 10%, and treasury bills by 5%. Scenario 2 restricts the minimum and maximum weights on the stock group and the bond group to be 30 – 70% and 20 – 50%, respectively. Moreover, there is no restriction on timberland assets under Scenarios 1 and 2. Scenarios 3 and 4 add the restriction of a maximum 10% weight on timberland assets to Scenarios 1 and 2.

Empirical Results

Descriptive Statistics

The descriptive statistics of the individual assets from 1987 to 2011 are reported in Panel A of Table 3.1. The results show that timberland assets have the highest quarterly return (3.2%) and treasury bills have the lowest standard deviation (0.6%). Returns on large-cap stocks, small-cap stocks, and treasury bills are negatively skewed, whereas returns on treasury bonds are slightly positively skewed and timberland assets are highly positively skewed. Returns on timberland assets have the highest excess kurtosis, indicating a fat-tailed distribution. It is interesting that timberland returns have the combined characteristics of positive skewness and high excess kurtosis. Additionally, results of the Jarque-Bera normality test reveal that the null hypothesis of normal distribution of large-cap stocks, small-cap stocks, and timberland assets are rejected at the 10% confidence level. Meanwhile, the Shapiro-Wilk multivariate normality test is rejected at the 1% confidence level. These are the primary motivation for the use of the M-CVaR optimization approach, which does not assume a multivariate normal distribution.

Three risk measures are applied to individual assets first and the results are reported in Panel B of Table 3.1. The VaR^M and $CVaR^M$ of large-cap stocks and small-cap stocks are much higher than their SDs, indicating SD underestimates individual downside risk. In contrast, the VaR^M and $CVaR^M$ of treasury bonds and treasury bills are close to their SDs. This is because returns on treasury bonds and treasury bills are normally distributed over 1987 – 2011. Regarding timberland assets, the VaR^M are lower than the SD but the $CVaR^M$ is higher than the SD, suggesting that their skewness and kurtosis affect the evaluation of risks. Panel C of Exhibit 2 presents the correlations between each pair of the assets in the mixed portfolio. Large-cap stocks are highly correlated with small-cap stocks but slightly correlated with treasury bills and timberland assets, and negatively correlated with treasury bonds. In addition, small-cap stocks are negatively correlated with treasury bonds, treasury bills, and timberland assets. The low and negative correlations between these assets provide a potential for portfolio diversification.

Efficient Frontiers

Both the M-V and M-CVaR optimization approaches are employed to construct efficient frontiers. The M-V and M-CVaR efficient frontiers are shown in Figure 3.2 to compare the effects of adding timberland assets to the mixed portfolio. The M-CVaR efficient frontier is dramatically improved after adding timberland assets in comparison of the M-V efficient frontier. For example, with a target return of 2% per quarter, the SD and CVaR of the portfolios without timberlands are 2.8% and 3.0%, respectively. After adding timberland assets to the mixed portfolio, the SD of the portfolio with the same target return is 1.6%, whereas the CVaR of that portfolio is 0.8%. These results indicate that the M-CVaR approach can reduce more risk than the M-V approach. The difference between the M-V and M-CVaR approaches is because the M-CVaR approach considers the non-normality of asset returns. Starting from here, we will focus on the M-CVaR approach to formulate asset allocation strategies and calculate portfolio risks.

Static Asset Allocations

Figure 3.3 shows the static asset allocations of optimal portfolios using the M-CVaR approach under four different scenarios. In Scenario 1, the weights on large-cap stocks and small-cap stocks are strictly constrained by 20% and 15%. At low target returns, the allocation on treasury bills is more than that on treasury bonds. However, the weight of timberland assets increases up to 48.5% as investors require high target returns. Scenario 2 presents the weights on individual assets with group constraints on stocks and bonds. The results suggest that significant weights are allocated to timberland assets across different target returns. Scenario 3 shows the situation with a maximum 10% constraint on timberland assets. The asset allocations are similar to Scenario 1 for low target returns. However, for high target returns, timberland assets are substituted by treasury bonds and small-cap stocks. Scenario 4 suggests that the weights on large-cap stocks and treasury bills are higher for low target returns, whereas the allocations on small-cap stocks and treasury bonds are higher for high target returns. Moreover, timberland assets are allocated at its maximum level of 10%. Overall, timberland assets have a significant allocation in the mixed portfolio under the M-CVaR framework.

Static Backtesting by Risk Decomposition

Based on the asset allocation strategies in Figure 3.3, the optimal portfolio with a target return of 2% per quarter is selected and the its corresponding risks measured by SD, VaR^{M}, and CVaR^{M} are reported in Table 3.2. Under Scenarios 1, 3, and 4, the portfolio's SD is less than its VaR^{M} and CVaR^{M}. This indicates that the portfolio's SD underestimates the portfolio downside risk when taking the skewness and kurtosis into consideration. Next, the portfolio's SD, VaR^{M}, and CVaR^{M} are further decomposed by Equations (3.7) – (3.9) to understand the risk contribution of individual assets. Under all scenarios, the risk contributions of large-cap stocks and small-cap stocks are much higher than their own weights, indicating that stocks are risk intensifiers. In contrast, the risk contribution of treasury bonds is much lower than its own weight, suggesting bonds are strong risk diversifiers. As for treasury bills and timberland assets, their decomposition percentages are low and less than their own weights. This implies that they are slight risk diversifiers in the mixed portfolio. Therefore, adding treasury bonds, treasury bills, and timberland assets to a mixed portfolio can significantly reduce the portfolio downside risk.

Table 3.3 provides a comparison of risk decomposition between the low target return of 1.6% and the high target return of 2.4% under Scenario 3. Scenario 3 is concentrated because it is most close to the asset allocation strategies in practice. For low target returns, treasury bills as the lowest risk asset dominate in the mixed portfolio because it has low or negative risk contribution to the portfolio. Moreover, it is noted that the allocation to timberland assets is zero for low target returns. Although the allocations to large-cap stocks and small-cap stocks are at their minimum levels, their risk contributions to the portfolio are more than 50%. For high target returns, treasury bills are replaced by small-cap stocks and timberland assets. The risk contribution of small-cap stocks to the portfolio's SD, VaR^{M}, and $CVaR^{M}$ are 78%, 82.8%, and 82.9%, respectively. In summary, the findings of stocks as risk intensifiers and bonds and timberlands as risk diversifiers are consistent for both low and high target returns.

Dynamic Asset Allocations

The dynamic efficient frontiers are constructed over a 10-year rolling window[14] from 1987 to 2011. As the rolling portfolio is annually rebalanced, there are 16 efficient frontiers constructed in total. The null hypothesis of multivariate normality for the 16 portfolios is highly rejected at the 1% level. Figure 3.4 illustrates the dynamic asset allocations for a target return of 2% with a 10-year rolling window over 1996 – 2011. These asset weights vary across different scenarios. Scenario 1 shows that large-cap stocks and small-cap stocks are allocated by the constraint conditions of 20% and 15%. The weight on timberland assets is more than 30% in most of the times except the time period around 2001. Scenario 2 presents that the weight on large-cap stocks is decreasing to zero, whereas that of timberland assets is increasing. Scenario 3 is similar to the Scenario 2 except that timberland assets are allocated to the maximum level of 10%. Scenario 4 presents that the allocations of small-cap stocks and treasury bonds

[14] The private-equity timberland investment is a long-term investment. The 10-year rolling window is selected because a typical private timberland investment through TIMOs usually requires a minimum 10-year investment horizon for close-end and commingled funds.

dominate those of large-cap stocks and treasury bills. It is also noted that all the asset weights under four scenarios are impacted by the states of economy in 2001.

Dynamic Backtesting by Risk Decomposition

The 10-year rolling portfolio's SD, VaR^{M}, and CVaR^{M} and their corresponding risk decomposition are shown in Figure 3.5. The three rolling risk metrics indicate that the portfolio risk was higher in 1990s and lower in 2000s. However, the portfolio risk started to increase in recent years. The portfolio's SD underestimates the downside risk VaR^{M} and CVaR^{M}, suggesting the importance of considering different risk measures. As for the risk contribution of timberland assets, its 10-year rolling SD contribution spiked around 2001, which may be due to the impact of technology bubble burst on the economy. Its overall risk contribution ranges from zero to 3%, indicating its persistent performance. In terms of the VaR^{M} and CVaR^{M}, timberland assets behave as a risk diversifier in the mixed portfolio. In a word, the portfolio risk is dramatically reduced by adding timberland assets to a portfolio.

Regional Timberland Assets[15]

The NCREIF Timberland Index is reported on a national level, which is aggregated by three geographic indices in the United States including the Pacific Northwest, South, and Northeast. This study also examines the role of these three regional timberland assets in a mixed portfolio under the four scenarios. The weights on three regional timberland assets are constrained within a group. All the results are similar to those from the national data. However, the allocations on regional timberland assets are worth a discussion. The allocation on the Northeast timberland assets is almost zero in both static and dynamic asset allocations. In contrast, the allocations on the Northwest and South timberland assets depend on target returns. For investors with low target returns, the allocation is primary on the South timberland assets. In contrast, the Northwest timberland assets are selected as the key assets and are constrained at its maximum weight in the mixed portfolios with high target returns. The different weights on the regional timberland assets are probably due to their different performances. The performance of

[15] The results for regional timberland assets are available upon request from the authors.

timberland assets in the Northwest is relatively strong compared with that in the South. This is because the Northwest timberlands usually produce high-value wood products such as sawtimber, whereas the South timberlands produce low-value wood products such as pulpwood. In summary, the weights on regional timberland assets vary across regions and target returns.

Conclusions

Timberland assets have become a popular alternative investment for institutional investors in the United States since 1980s. This study employs the M-CVaR optimization approach to formulate asset allocation strategies and to examine the role of timberland assets in a mixed portfolio from the risk perspective. Both static and dynamic backtesting are used to assess the stability of asset allocations and the persistence of asset performance. Several conclusions are reached from the comparison of the M-V and M-CVaR efficient frontiers, the formulation of asset allocations, and the risk decomposition of portfolios.

The choice of risk measures is an important decision for portfolio management. First, the commonly used SD may not fully reflect the nature of risk. As investors are particularly concerned with the downside risk in reality, risk measures such as VaR and CVaR are more appropriate than SD. Second, asset allocations under a minimized downside risk framework provide optimal investment strategies for risk averse investors and the M-CVaR method fully reflects the tradeoff between downside risks and returns. Furthermore, the portfolio downside risk can be decomposed in both static and dynamic ways. The risk decomposition helps us to identify risk sources and manage risks in a mixed portfolio. Overall, risk measures play an important role in portfolio construction and risk management.

Whether the M-V frontiers are efficient or not has been a debatable topic ever since realized asset returns exhibit non-normality such as skewness and kurtosis. This study provides empirical evidence that the M-CVaR approach constructs more efficient frontiers than the M-V approach through adding timberland assets to a mixed portfolio because the M-V approach underestimates the tail loss under a multivariate normality assumption. In contrast, the M-CVaR approach fairly captures the asymmetry and fat tail properties and selects asset returns with positive skewness and low kurtosis to reduce the portfolio risk. Thus, the M-CVaR method is more attractive since it not only incorporates the portfolio downside risk into optimization but also considers the non-normality of asset returns.

The asset allocations and risk decompositions are conducted in both static and dynamic optimizations. If there is no restriction on timberland assets, both treasury bonds and timberland assets dominate in a mixed portfolio because of their positive skewness. Moreover, timberland assets are preferred for high target returns, indicating its ability to generate high returns. The 10-year rolling optimization offers consistent strategies with static asset allocations and reveals that the allocations were affected around 2001 – 2003. It was probably due to the weak performance of the NCREIF Timberland Index over that period of time (Mei and Clutter, 2010). In addition, the different performances of regional timberland assets determine their weights in the mixed portfolios. Using static and dynamic backtesting, this study also provides some empirical evidence that stocks intensify a portfolio risk, whereas treasury bills, treasury bonds, and timberland assets diversify a portfolio risk. This fact implies that portfolio managers can shift weights from high risk contribution assets to the low ones. Overall, timberland assets maintain a significant allocation in the mixed portfolio and behave as a persistent risk diversifier.

This study first introduces the M-CVaR approach to analyze the role of timberland assets in a mixed portfolio from the risk perspective. The methodology and findings provide practical implications for investors with different risk preferences and investment purposes. It should help institutional investors to better manage their portfolios and reduce the portfolio downside risk. Nevertheless, it should be noted that this ex post analysis does not necessarily guarantee future performance, especially in the current changing markets. Moreover, it may be not easy to frequently rebalance the portfolio from a practical perspective since timberland investment is a long term investment. However, investors can adjust their portfolios through the more liquid financial assets such as stocks and bonds.

Table 3.1. Summary statistics of asset returns: quarterly data from 1987 to 2011.

	Large-cap stocks	Small-cap stocks	Treasury bonds	Treasury bills	Timberland assets
Panel A: descriptive statistics					
Observations	100	100	100	100	100
Minimum	-0.232	-0.291	-0.032	0.000	-0.065
Median	0.025	0.040	0.016	0.011	0.020
Mean	0.020	0.027	0.018	0.010	0.032
Maximum	0.209	0.297	0.080	0.024	0.223
Standard Deviation	0.083	0.111	0.024	0.006	0.042
Skewness	-0.609	-0.452	0.081	-0.124	1.797
Excess Kurtosis	0.789	0.565	-0.700	-0.882	4.810
JB Normality Test	0.009	0.074	0.389	0.202	0.000
SW Multivariate Normality Test					0.000
Panel B: risks					
SD	0.083	0.111	0.024	0.006	0.042
VaR^M (95%)	0.129	0.167	0.022	0.000	0.036
$CVaR^M$ (95%)	0.185	0.237	0.029	0.002	0.076
Panel C: correlations					
Large-cap stocks	1.000				
Small-cap stocks	0.882	1.000			
Treasury bonds	-0.145	-0.199	1.000		
Treasury bills	0.066	-0.058	0.198	1.000	
Timberland assets	0.017	-0.042	0.124	0.366	1.000

Note: JB normality test refers to the Jarque-Bera normality test. SW multivariate normality test refers to the Shapiro-Wilk multivariate normality test. p-values for both tests are reported.

Table 3.2. Risk decomposition of the M-CVaR portfolios with a medium target return under four scenarios.

	Scenario 1				Scenario 2			
Portfolio	MU	SD	VaR^M	$CVaR^M$	MU	SD	VaR^M	$CVaR^M$
	2.0	3.3	3.5	4.8	2.0	2.7	2.6	3.6
Assets	Weight	$D_i SD$	$D_i VaR^M$	$D_i CVaR^M$	Weight	$D_i SD$	$D_i VaR^M$	$D_i CVaR^M$
Large-cap	20.0	45.4	65.0	65.4	30.0	81.8	135.3	132.0
Small-cap	15.0	44.1	61.8	63.7	0.0	0.0	0.0	0.0
T-bonds	55.1	9.8	-22.7	-26.0	32.0	5.6	-21.5	-21.1
T-bills	5.0	0.1	-1.3	-1.0	18.0	1.1	-5.5	-3.7
Timberlands	4.9	0.6	-2.8	-2.1	20.0	11.5	-8.3	-7.1
Sum	100	100	100	100	100	100	100	100
	Scenario 3				Scenario 4			
Portfolio	MU	SD	VaR^M	$CVaR^M$	MU	SD	VaR^M	$CVaR^M$
	2.0	3.3	3.5	4.8	2.0	3.4	3.8	5.2
Assets	Weight	$D_i SD$	$D_i VaR^M$	$D_i CVaR^M$	Weight	$D_i SD$	$D_i VaR^M$	$D_i CVaR^M$
Large-cap	20.0	45.4	65.0	65.4	40.0	90.5	125.3	128.2
Small-cap	15.0	44.1	61.8	63.7	0.0	0.0	0.0	0.0
T-bonds	55.1	9.8	-22.7	-26.0	47.8	7.2	-20.6	-23.8
T-bills	5.0	0.1	-1.3	-1.0	2.2	0.1	-0.5	-0.4
Timberlands	4.9	0.6	-2.8	-2.1	10.0	2.2	-4.2	-4.0
Sum	100	100	100	100	100	100	100	100

Note: MU denotes the target return. SD denotes the standard deviation. VaR^M denotes the modified VaR considering the skewness and kurtosis. $CVaR^M$ denotes the modified CVaR considering the skewness and kurtosis. D_i refers to the decomposition of three risk measures. All numbers are in percentage.

Table 3.3. Comparison of risk decomposition between a low target return and a high target return under Scenario 3.

Portfolio	MU 1.6	SD 3.2	VaR^M 4.1	$CVaR^M$ 5.9	MU 2.4	SD 6.9	VaR^M 9.9	$CVaR^M$ 14.0
Assets	Weight	$D_i SD$	$D_i VaR^M$	$D_i CVaR^M$	Weight	$D_i SD$	$D_i VaR^M$	$D_i CVaR^M$
Large-cap	20.0	50.2	61.8	60.7	20.0	22.4	24.8	24.7
Small-cap	15.0	49.2	59.2	58.5	49.2	78.0	82.8	82.9
T-bonds	15.0	-0.5	-10.0	-11.4	15.8	-0.7	-4.8	-5.0
T-bills	50.0	1.2	-11.0	-7.8	5.0	0.0	-0.5	-0.4
Timberlands	0.0	0.0	0.0	0.0	10.0	0.2	-2.3	-2.2
Sum	100	100	100	100	100	100	100	100

Note: MU denotes the target return. SD denotes the standard deviation. VaR^M denotes the modified VaR considering the skewness and kurtosis. $CVaR^M$ denotes the modified CVaR considering the skewness and kurtosis. D_i refers to the decomposition of three risk measures. All numbers are in percentage.

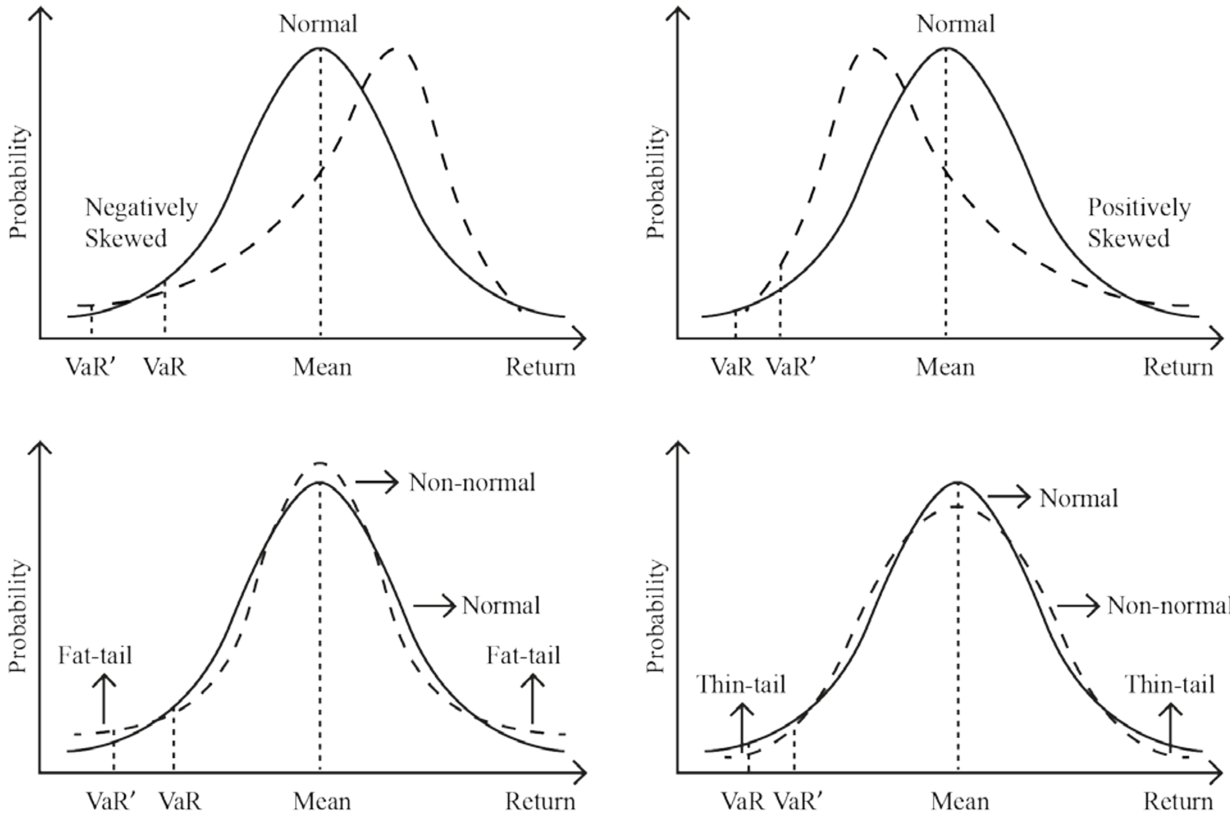

Figure 3.1. The impacts of skewness and kurtosis on the VaR calculation.

Note: The two graphs on the left illustrate the underestimation of VaR when asset returns are negatively skewed or fat-tailed ($\text{VaR} < \text{VaR}'$). The two graphs on the right illustrate the overestimation of VaR when asset returns are positively skewed or thin-tailed ($\text{VaR} > \text{VaR}'$).

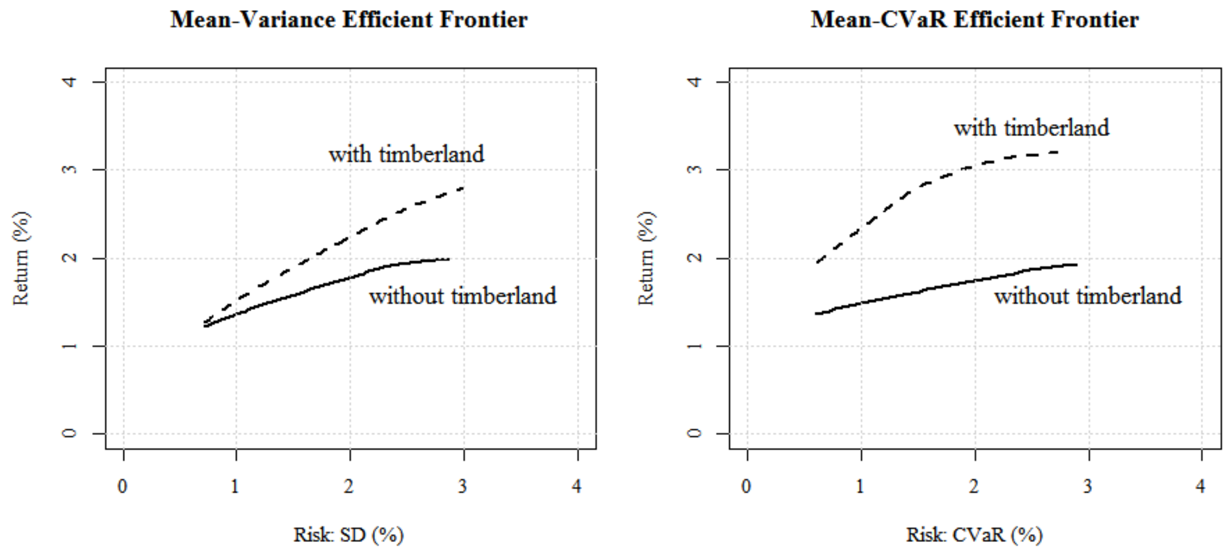

Figure 3.2. Comparison of the M-V and M-CVaR efficient frontiers after adding timberland assets to a mixed portfolio.

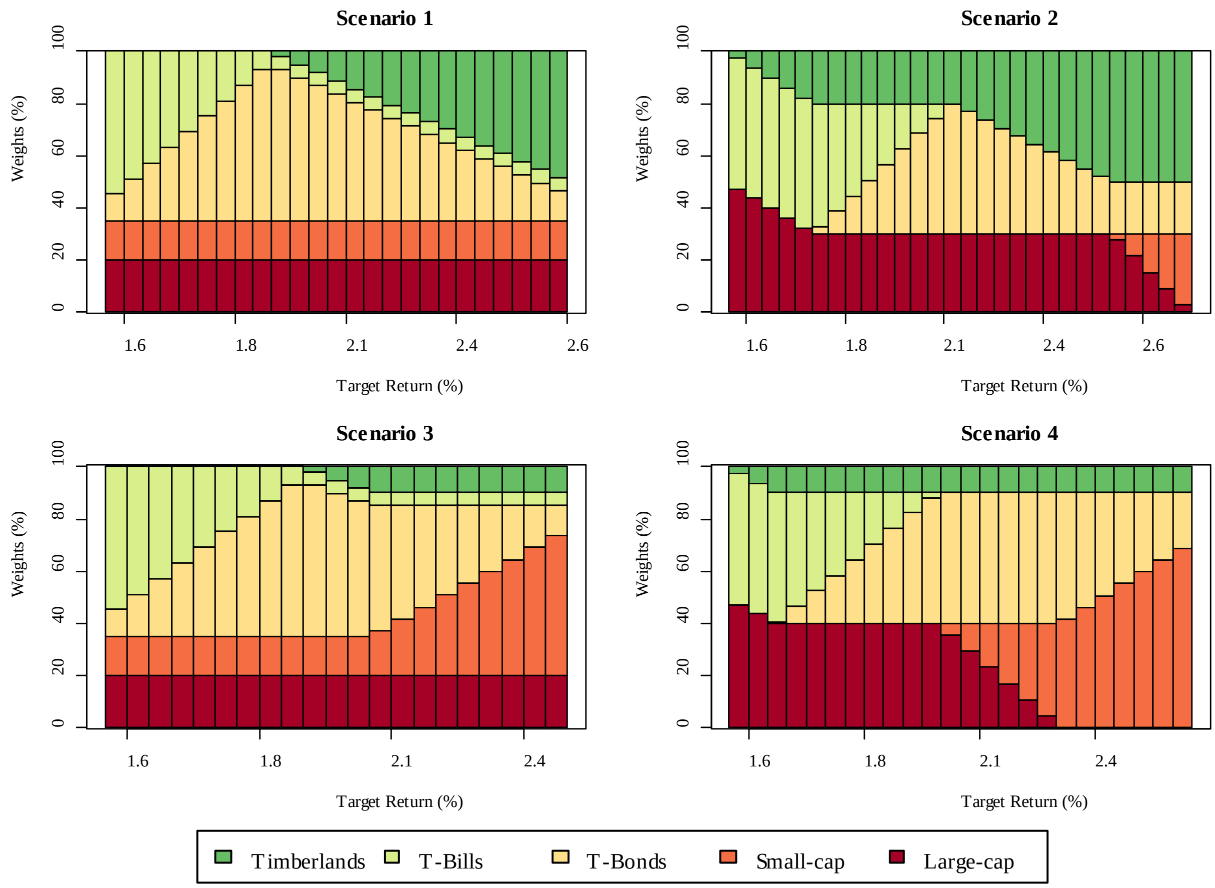

Figure 3.3. Static asset allocations in a mixed portfolio under four scenarios.

Note: Scenario 1 places the minimum asset allocation on the large-cap stocks by 20%, small-cap stocks by 15%, treasury bonds by 10%, and treasury bills by 5%. Scenario 2 restricts the minimum and maximum weights on the stock group and the bond group to be 30 – 70% and 20 – 50%, respectively. Scenario 3 and 4 add the restriction of a maximum 10% weight on timberland assets to Scenarios 1 and 2.

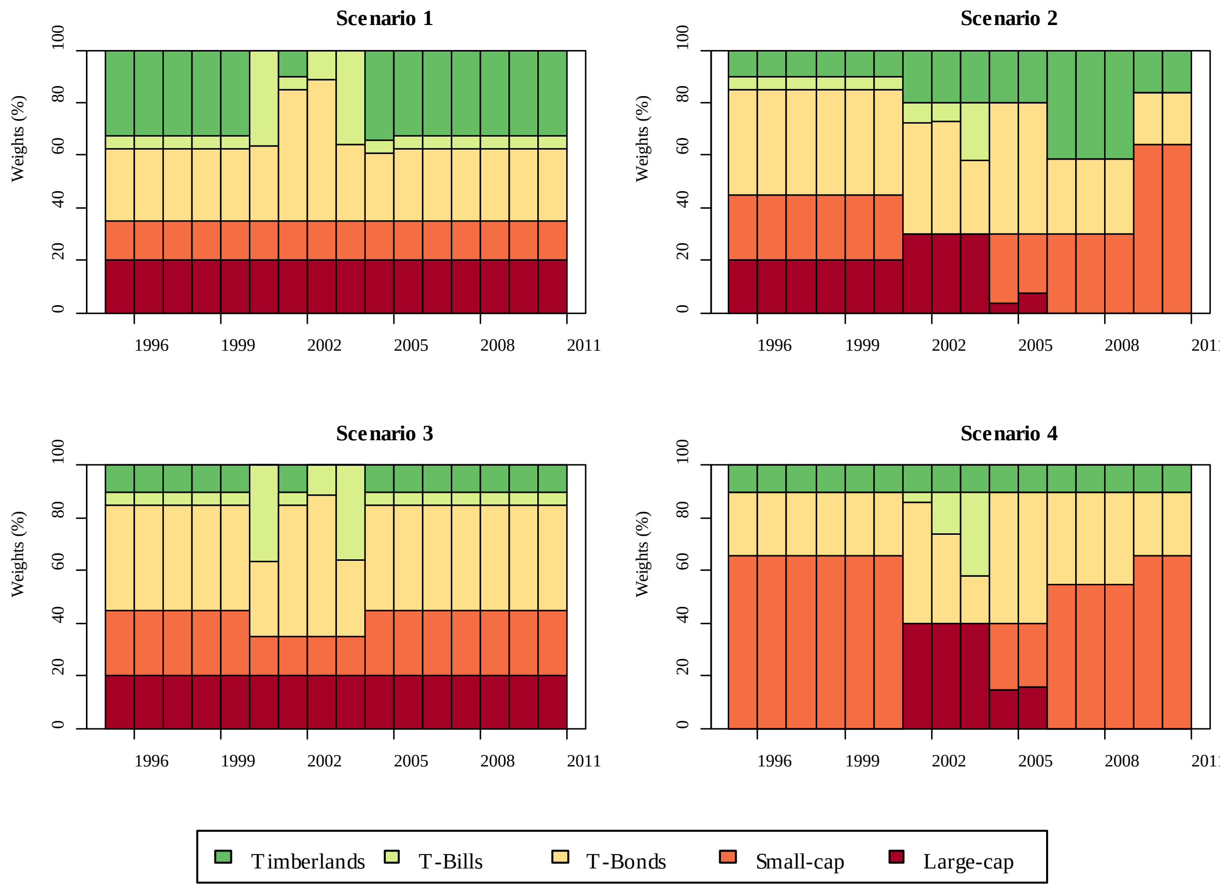

Figure 3.4. Dynamic 10-year rolling asset allocations in a mixed portfolio with a target return of 2% under four scenarios.

Note: Scenario 1 places the minimum asset allocation on large-cap stocks by 20%, small-cap stocks by 15%, treasury bonds by 10%, and treasury bills by 5%. Scenario 2 restricts the minimum and maximum weights on the stock group and the bond group to be 30 – 70% and 20 – 50%, respectively. Scenarios 3 and 4 add the restriction of a maximum 10% weight on timberland assets to Scenarios 1 and 2.

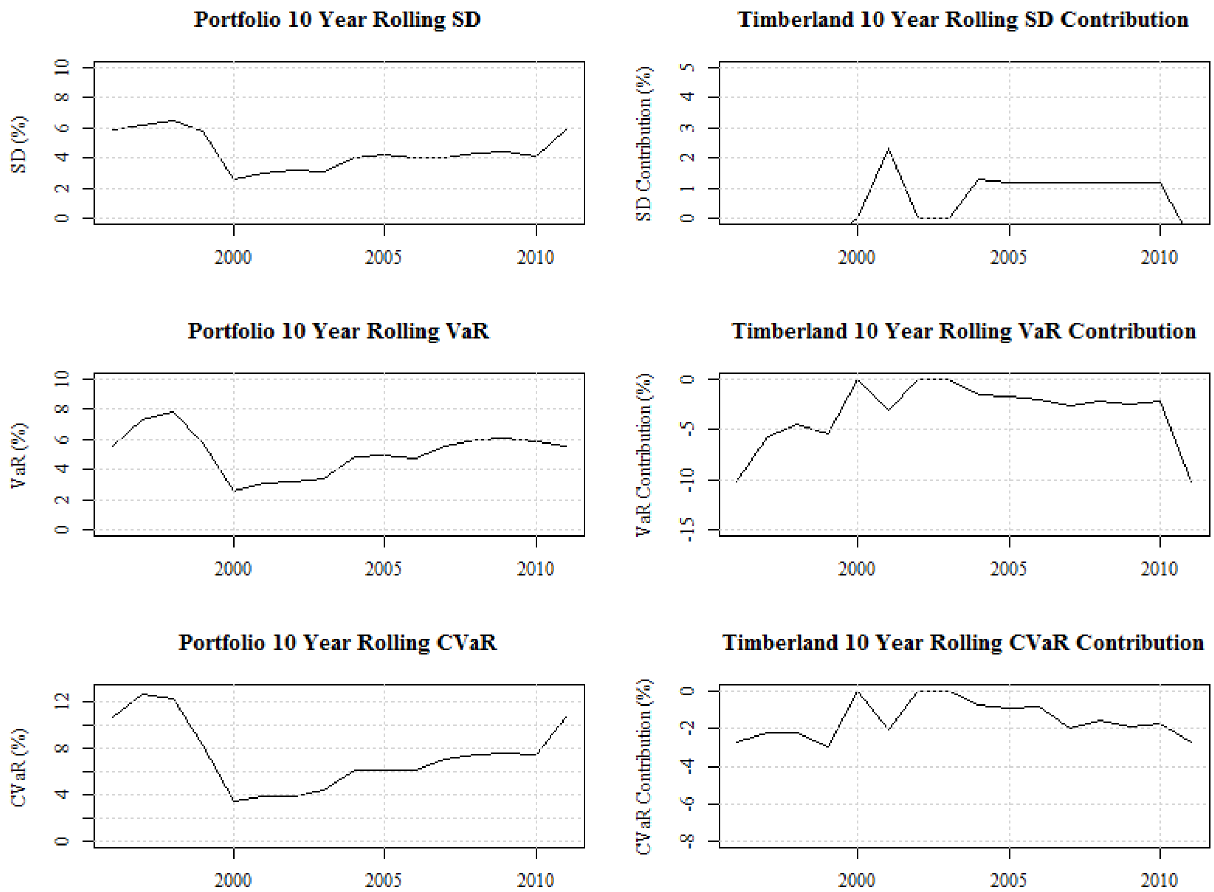

Figure 3.5. 10-year rolling portfolio risks and their corresponding risk decomposition under Scenario 3.

Note: The three graphs on the left show 10-year rolling portfolio risk by three risk measures. The three graphs on the right show the corresponding 10-year rolling risk contribution of timberland assets.

CHAPTER 4

ASSESSING THE IMPACT OF MACROECONOMIC NEWS ON THE U.S. FOREST PRODUCTS INDUSTRY PORTFOLIO ACROSS BUSINESS CYCLES: 1963 – 2010[16]

[16] Wan, Y., M. L. Clutter, J.P. Siry, and B. Mei. Submitted to the *Forest Policy and Economics*, 04/25/2012.

Abstract

Macroeconomic news is viewed as the source of systematic risk in financial markets. This study investigates the impact of macroeconomic news on the returns and volatilities of the lumber and paper industry portfolios in the United States over 1963 – 2010. Using ARMA-EGARCH models, we examine the impact of consumer price index (CPI), industrial production (IP), and unemployment (UNEMP) on daily industry portfolios. Empirical results indicate the existence of volatility clustering and leverage effect in the industry portfolios. In addition, the same macroeconomic news has different impacts on the lumber and paper industry portfolios. The paper industry is more responsive to the CPI news than the lumber industry. The impact of macroeconomic news on industry portfolio returns and volatilities varies across business cycles. Negative shocks have greater impact on portfolio volatilities in recessions than in expansions.

Introduction and Motivations

The forest products industry as one of the top ten manufacturing industries plays an important role in the United States. However, its financial performance has been volatile in recent decades (Mei and Sun, 2008). The financial performance of forest products industry has been investigated through a variety of asset pricing models. From the portfolio perspective, Sun and Zhang (2001) assessed the financial performance of medium and large size portfolio of forest industry firms with capital asset pricing model (CAPM) and arbitrage pricing theory and concluded that both portfolios seemed unable to earn risk-adjusted returns between 1986 and 1997. With respect to individual forest companies, Niquidet (2010) examined forty-five forest industry firms by CAPM and Fama-French three-factor model and found that the forest sector had not earned the cost of equity over 2003 – 2008. Overall, previous studies examine the relationship between the risk-adjusted excess return and systematic risk.

Macroeconomic news, the unanticipated part of economic indicators, is usually viewed as the source of systematic risk. Therefore, the relationship between macroeconomic news and asset returns has been examined to understand how investors are compensated for bearing the systematic risk. Based on the semi-strong form of efficient market hypothesis, stock prices reflect all publicly available information and adjust instantly to reflect new information. The fundamental reason for this price adjustment is that changing economic information usually affects the discount rate, or the expected future cash flow, or both. The key study by Chen et al. (1986) found that macroeconomic indicators such as industrial production and inflation were risks rewarded in stock markets. Other studies indicated that state variables such as gross domestic product (GDP) should be considered in asset pricing models (Merton, 1973). Furthermore, macroeconomic news released periodically is known to create market volatility (Jones et al., 1998). Some macroeconomic news may increase the heterogeneity of beliefs since market participants have different responses to the news. Therefore, it is important for market participants and academic researchers to understand the relationship between macroeconomic news and asset returns.

The forest products industry portfolio is affected by states of the economy to a great extent (Sadorsky and Henriques, 2001). The lumber and wood products industry usually involves the production and development of raw materials for other industries. The lumber sector is sensitive to changes across business cycles because it supplies materials for the housing construction industry which mainly depends on the state of the economy. Moreover, prices of raw materials are largely demand driven. When the economy is on the upswing, the rising demand can lead to higher prices and vice versa. For the paper industry, its allied products are essential components in modern life. This industry is also related to the state of the economy and crucial to the U.S. economy. Overall, the forest products industry portfolio is sensitive to macroeconomic conditions.

Given that few rigorous studies have been conducted regarding the relationship between macroeconomic news and the forest products industry portfolio, the overall objective of this study is to investigate the impact of macroeconomic news on the U.S. lumber and paper industry portfolios across business cycles over 1963 – 2010. First, the response of daily returns of these two industry portfolios to macroeconomic news is investigated. Specifically, the lumber and paper industry portfolios are examined and their reaction to macroeconomic news is compared. The well-known regularly released macroeconomic news is considered in this study because it is widely watched and then passed homogeneously through the market.

Next, the impacts of macroeconomic news on the forest products industry portfolio returns and volatilities are simultaneously assessed. Previous studies assumed a constant volatility and examined the impact of macroeconomic news on stock returns. However, this assumption is not realistic because the volatility may vary over time. A common feature of financial time series is the existence of the volatility clustering. That is, large changes of returns tend to be followed by large changes and small changes tend to be followed by small changes (Mandelbrot, 1963). Hence, the use of the ordinary least squares may not be appropriate if this occurs. On the other hand, volatility is unobservable and, therefore, we need a model to quantify it. The EGARCH-type model facilitates the simultaneous examination of the impacts of news on portfolio returns and volatilities.

Whether the impact of macroeconomic news on the forest products industry portfolio varies across business cycles is further examined. Previous studies found that the responses of stock markets were different depending on the state of the economy, i.e., expansions or recessions (Blanchard, 1981). For instance, McQueen and Roley (1993) found that the stock market responded negatively to news about the industrial production when the economy was in expansion. Additionally, Boyd et al. (2005) found that stock prices could respond positively to a rising unemployment rate during economic expansions, whereas they might react negatively to the same news in recessions. Hence, the impact of macroeconomic news on the lumber and paper industry portfolios across business cycles is compared in this study.

Our study extends previous research in the following ways. First, disaggregate industry portfolios are used to analyze the impact of macroeconomic news across the forest products industries, given the fact that earlier studies concentrated on aggregate indices such as S&P 500 and Russell 2000 and assessed market-wide responses. Industry level data can shed some light on how different industries react to macroeconomic news. Second, high-frequency (daily portfolio) returns of the forest products industry portfolio are employed in this study in contrast to previous studies using low frequency data such as monthly and quarterly returns. Lastly, leverage effect is investigated to understand the asymmetric impact of positive and negative shocks on industry portfolio volatilities. In sum, our study can help market participants make decisions across business cycles as well as assist academic researchers in identifying sources of the systematic risk.

The rest of this paper is organized as follows. Section 2 reviews the literature on how financial markets are affected by macroeconomic news. Section 3 describes the ARMA-EGARCH model. Section 4 presents data, including NBER business cycles, macroeconomic indicators, and forest products industry portfolios. Section 5 reports the empirical results and Section 6 consists of discussion and concluding remarks.

Comprehensive Review on Previous Studies

The U.S. government regularly releases macroeconomic indicators of the performance of the nation's economy. Financial markets usually adjust to the releases of this information because market participants reevaluate their assets based on their current view and future expectations of the economy. The magnitude of market response depends on the type or nature of the announced news. Some economic indicators only affect the stock markets, whereas others may solely influence the bond markets. For example, news related to the interest rate may have a direct impact on the discount factor, whereas news that conveys information about the growth expectation (GDP and unemployment) is expected to affect stock prices. Some unexpected big changes in macroeconomic indicators may be quickly priced into assets, while some small shifts may lead to a permanent impact on asset prices. Moreover, the same type of news may generate different impact on financial markets across business cycles. Due to the close relationship between macroeconomic news and financial markets, a considerable number of studies in this area have been conducted in recent decades.

Some studies mainly focused on the relationship between macroeconomic news and asset returns. In their seminal study, Chen et al. (1986) found that macroeconomic variables such as industrial production and inflation constituted risks rewarded in stock markets. Thereafter, various macroeconomic variables have been used to test these relationships, and these studies have been extended to analyze the impact of macroeconomic news on stock and portfolio volatilities. Jones et al. (1998) examined the impact of released macroeconomic news on daily Treasury bond prices and found that announcement-day volatility did not persist because the information was immediately incorporated into prices. Flannery and Protopapadakis (2002) sought to identify macroeconomic risk factor candidates by simultaneously examining the impact of news announcements on the levels and conditional volatilities of daily stock returns. They found that inflation measures (e.g., CPI) only affected portfolio returns and real factors (e.g., unemployment) only affected portfolio volatilities.

Empirical studies have been conducted across different financial markets including stock markets (Chen et al., 1986; Boyd et al., 2005), bond markets (Jones et al., 1998; Balduzzi et al., 2001), and foreign exchange markets (Almeida et al., 1998). They concentrated on the extent to which macroeconomic news is priced into assets. Other researchers compared the response of stock, bond, and foreign exchange markets to the same macroeconomic news. For instance, Kim et al. (2004) investigated the impact of the releases of six important macroeconomic indicators on the U.S. stock, bond, and foreign exchange markets. Their study highlighted the importance of simultaneous examination of the announced news across financial markets. Anderson et al. (2007) examined the response of the stock, bond, and foreign exchange markets in the U.S., Germany, and the U.K. to real-time U.S. macroeconomic news announcements. They concluded that bond markets reacted most strongly to macroeconomic news, whereas the stock and foreign exchange markets seemed equally responsive.

The studies discussed above implicitly assume that the responses of investors are the same under different states of the economy. However, this assumption may be too restrictive. Blanchard (1981) showed that the same macroeconomic news can be good or bad for financial assets in equilibrium, depending on the economic conditions. His study laid the foundation of the relationship between economic news and the states of the economy. McQueen and Roley (1993) provided the evidence of a different relationship between stock prices and news announcements across business cycles. In particular, higher-than-expected news in expansions could result in lower stock prices, whereas the same news was associated with higher stock prices in recessions. Moreover, Boyd et al. (2005) constructed their own measure of unemployment news based on econometric techniques and found similar results for the unemployment news. They concluded that stock prices rose in expansions and fell in recessions when rising unemployment news was announced.

In summary, studies related to macroeconomic news have been quite diverse in numerous ways. First, both low-frequency and high-frequency data have been employed to investigate the effects of macroeconomic news. As low-frequency data may not capture the true response of markets to the released news, high-frequency data such as daily data and intraday data have become popular in analyzing the impact of economic news (Hanousek et al., 2009; Cenesizoglu, 2011). Second, the leverage effect of negative shocks on market volatility has attracted attention from Campbell and Hentschel (1992), and Engle and Ng (1993). Fang et al. (2008) found the Australian stock markets were more impacted by firm- or industry-specific news due to the leverage effect. Next, as the world economy becomes more integrated, recent studies have concentrated on the international linkages between the financial markets in different countries. Funke and Matsuda (2006) tested how U.S. economic news affected German financial markets. Lastly, various econometric models have been adopted to examine the impact of macroeconomic news, and the GARCH-type models have been developed to capture the volatility clustering property in high-frequency data (Connolly and Stivers, 2005).

Methodology

Macroeconomic News

Macroeconomic news is the unanticipated part of macroeconomic indicators. It is defined as the standardized deviation of actual release values from their expectations (Anderson et al., 2007). The standardization allows us to compare the effects of different macroeconomic indicators with different units of measurement. The equation below represents macroeconomic news k announced at time t (Cenesizoglu, 2011):

$$N_{k,t} = \frac{A_{k,t} - E_{k,t}}{\hat{\sigma}_k} \tag{4.1}$$

where $A_{k,t}$ is actual macroeconomic indicator k at time t, $E_{k,t}$ is the expectation on macroeconomic indicator k at time t, $A_{k,t} - E_{k,t}$ is non-standardized news, $\hat{\sigma}_k$ is the sample standard deviation, and $N_{k,t}$ is the standardized macroeconomic news. The expectation of macroeconomic indicator $A_{k,t}$ is constructed by ARMA models (Connolly and Wang, 2003). They are selected based on ACF and PACF graphs, AIC and SBC criteria, and Ljung-Box test. The news variables are transformed into daily variables by matching the release dates to the portfolio return dates, and then zero values are assigned for the days without news releases.

EGARCH Model

To simultaneously examine the impact of macroeconomic news on the returns and volatilities of forest products industry portfolios, the Exponential Generalized AutoRegressive Conditional Heteroscedasticity (EGARCH) model introduced by Nelson (1991) is used in this study. This model has several advantages. First, the EGARCH model considers the volatility clustering characteristic and guarantees the positive time-varying conditional variance due to the exponential specification (Nelson, 1991). Second, under the assumption of exogenous macroeconomic news, the EGARCH model includes macroeconomic news in the conditional mean equation as well as the conditional variance equation. Meanwhile, it considers the leverage effect of shocks on the conditional variances, in which negative shocks tend to increase volatilities more than positive ones (Zivot and Wang, 2006). Last but not least, the EGARCH model allows for the asymmetric impact between positive and negative shocks. The specification of the EGARCH model is parsimonious, straightforward, and flexible. The EGARCH (p, q) is described in the following equations (Nelson, 1991):

$$r_t = u + \varepsilon_t \tag{4.2a}$$

$$\ln(\sigma_t^2) = \omega + \sum_{i=1}^{p} \gamma_i \frac{\alpha_i \varepsilon_{t-i} + |\varepsilon_{t-i}|}{\sigma_{t-i}} + \sum_{j=1}^{q} \beta_j \ln(\sigma_{t-j}^2) \tag{4.2b}$$

where r_t is daily portfolio return at time t ($t = 1, \cdots, T$) and ε_t is the error term. Parameters u and ω are constants in the conditional mean equation (4.2a) and the conditional variance equation (4.2b), respectively. Parameter α captures the leverage effect of shocks on the conditional variance. The effect of ε_{t-i} is $(\alpha_i + 1)\varepsilon_{t-i}$ when ε_{t-i} is positive (good news) and $(\alpha_i - 1)\varepsilon_{t-i}$ when ε_{t-i} is negative (bad news). If $\alpha < 0$, then a negative shock has greater impact on the volatility than a positive shock. Parameter γ represents the magnitude effect of shocks. Parameter β is the GARCH term that measures the volatility persistence which can be calculated by $\hat{P} = \sum_{j=1}^{q} \beta_j$.

Simultaneous Impact on Portfolio Returns and Volatilities

In order to assess the impact of macroeconomic news on daily portfolio returns, the standard EGARCH model above is modified. First, macroeconomic news is included in both conditional mean and variance equations as exogenous variables. Second, the AutoRegressive Moving Average (ARMA) is included in the mean equation to account for the serial correlation of portfolio returns (Karanasos and Kim, 2003). The ARMA(r, s) – EGARCH (p, q) model can be written as follows:

$$r_t = u + \sum_{i=1}^{r} \phi_i r_{r-i} + \sum_{j=1}^{s} \theta_j \varepsilon_{t-j} + \lambda_k^m N_{k,t} + \varepsilon_t \tag{4.3a}$$

$$\ln(\sigma_t^2) = \omega + \sum_{i=1}^{p} \gamma_i \frac{\alpha_i \varepsilon_{t-i} + |\varepsilon_{t-i}|}{\sigma_{t-i}} + \sum_{j=1}^{q} \beta_j \ln(\sigma_{t-j}^2) + \lambda_k^v N_{k,t} \tag{4.3b}$$

where parameter ϕ_i and θ_j are the i^{th} -order autoregressive (AR) and j^{th} -order moving average (MA) terms. Parameter λ_k measures the impact of news k on portfolio returns and volatilities. Superscripts m and v in the parameters differentiate the mean and variance equations. These equations are used to examine the news impact for the full sample.

Simultaneous Impact on Portfolio Returns and Volatilities across Business Cycles

To compare the impact in both expansions and recessions, a business cycle dummy variable $NBER$ is incorporated into the ARMA-EGARCH model as follows:

$$r_t = u + \sum_{i=1}^{r} \phi_i r_{r-i} + \sum_{j=1}^{s} \theta_j \varepsilon_{t-j} + \lambda_k^m (N_{k,t} * NBER_t) + \varepsilon_t \tag{4.4a}$$

$$\ln(\sigma_t^2) = \omega + \sum_{i=1}^{p} \gamma_i \frac{\alpha_i \varepsilon_{t-i} + |\varepsilon_{t-i}|}{\sigma_{t-i}} + \sum_{j=1}^{q} \beta_j \ln(\sigma_{t-j}^2) + \lambda_k^v (N_{k,t} * NBER_t) \quad (4.4b)$$

The corresponding coefficients measure the impact of macroeconomic news on the industry returns and volatilities during expansions or recessions.

The News Impact Curve

Engle and Ng (1993) introduced the news impact curve to measure how new information affects the volatility in GARCH-type models. The news impact curve is defined as the relationship between the conditional variance at time t and the error term at time $t-1$, holding the earlier information constant and with all lagged conditional variances estimated at the level of unconditional variance (Engle and Ng, 1993; Zivot and Wang, 2006). That is, the news impact curve plots the scenarios of a series of positive and negative shocks against the future volatility of portfolios. Thus, the news impact curve can be used to investigate the leverage effect and compare the news impact in both expansions and recessions. In this study, all the models and figures are generated by the software R (R Development Core Team, 2011).

Data Sources

NBER Business Cycles

Business cycles refer to fluctuations in economic activity over several months or years. An expansion is a period when economic activities surge until they reach a peak, whereas a recession is a general slowdown in economic activities. In the U.S., the National Bureau of Economic Research (NBER) determines and announces the dates of expansions and recessions from the NBER's business cycle Dating Committee. Table 4.1 shows the business cycle reference dates and the duration of expansions and recessions from July 1963 to December 2010. Over this period of time, there were 487 months in expansions and 83 months in recessions. Roughly speaking, expansions and recessions accounted for 85% and 15%, respectively.

Macroeconomic Indicators

Three monthly announced macroeconomic indicators, including consumer price index (CPI), industrial production (IP), and unemployment (UNEMP) are selected for the following reasons. The CPI is one of the most important macroeconomic indicators. It has been widely watched by investors, firms, analysts, and media so that the market usually responses to a CPI release. The IP measures the changes in output for industrial sectors such as manufacturing and utilities. It is also an important tool for forecasting future economic performance and often used as a proxy for GDP. The UNEMP is an influential indicator for labor markets. Investors study it for future trends in employment statistics and disposable income. The UMEMP, as a reference point of Federal Reserve policy, is frequently viewed as newsworthy by the Wall Street and investors.

The macroeconomic indicators above are announced on regular schedules. We use the news release dates since these indicators are announced before the stock markets open, so the markets can absorb the information and respond to them. All the indicators are collected from the Federal Reserve Economic Data (FRED), whereas the corresponding release dates are collected from the Archival Federal Reserve Economic Data (ALFRED). The summary and descriptive statistics for the three macroeconomic indicators are listed in Table 4.2. For example, the CPI is defined as the month to month percentage changes and is seasonally adjusted. The announcement is made by the Bureau of Labor Statistics (BLS) at 8:30 AM Eastern Time before the stock market opens.

Daily Portfolio Returns

The forest products industry portfolios are constructed by the four-digit Standard Industry Classification (SIC) code. Specifically, the lumber industry is based on SIC 24 and the paper industry is by SIC 26. The industry portfolios are used for the following reasons. First, individual firm has idiosyncratic risk that is not compensated for since it can be diversified away. Second, the population of forest products firms is small, so using SIC code can guarantee enough firms in each portfolio. The three industry portfolios include all NYSE, AMEX, and NASDAQ stocks, which are value weighted based on their market capitalizations. These industry portfolio returns are downloaded from Kenneth French's website. The time period is from July 1, 1963 to December 31, 2010. In total, there were 11,959 trading days over this time period. Among them, 10,216 trading days were in expansions and 1,743 trading days were in recessions.

Empirical Results

Descriptive Statistics

The descriptive statistics of standardized macroeconomic news are reported in Table 4.2. In the full sample, the mean values of macroeconomic news indicate that the actual values are higher than the expectations for CPI and UNEMP and lower than the released numbers for IP. The statistics suggest the varying pattern across business cycles. The mean value of CPI news is positive in expansions and negative in recessions, and the opposite is true for other news. For instances, the average of CPI news is 0.8% in expansions and -4.8% in recessions. The expansion period was characterized by a high CPI growth, whereas the recession period was characterized by negative changes in CPI. In contrast, the average unemployment news was -1.2% in expansions and 20.3% in recessions.

The descriptive statistics of daily forest products industry portfolios are reported in Table 4.3. The lumber industry has the higher average daily return (0.044%) with a higher daily volatility (1.533%) in the full sample. In contrast, the paper industry has lower daily return (0.041%) as well as the lower daily volatility (1.161%). Across business cycles, average daily portfolio returns are positive in expansions and negative in recessions. Comparison of the returns and volatilities of these two industry portfolios is shown in Figure 4.1.

EGARCH Model Specification

EGARCH models allow for an asymmetric relationship between returns and volatilities. First, the EGARCH model (2a) and (2b) are used to estimate the returns and volatilities of the lumber and paper industry portfolios. The preliminary analysis indicates that the residuals for each EGARCH model are serially correlated. This misspecification is corrected by adding ARMA components to the EGARCH models. It is found that ARMA (1, 1) is sufficient to account for serial correlations in the EGARCH models.

Impact of Macroeconomic News on Returns and Volatilities of the Industry Portfolios

The impact of macroeconomic news on the lumber and paper industry portfolios are examined by Equations (4.3a) and (4.3b) for the full sample and by Equations (4.4a) and (4.4b) in expansions and recessions. All the estimated results are reported in Tables 4.4 – 4.6. Based on the mean and variance equations, the average returns for the lumber industry portfolio are 4.7%, 5.8%, and -6.7% in the full sample, expansions, and recessions, whereas the average volatilities are 1.6%, 1.6%, and 3.6%, respectively. In contrast, the average returns for the two industry portfolios are -6.7% and -3.6% and the average volatilities are 3.6% and 1.5% in recessions. These results show that the forest products industry portfolios perform with positive returns and low volatilities in expansions, and with negative returns and high volatilities in recessions, implying different performances under different states of the economy.

The ARMA-EGARCH model is appropriate for forest products industry portfolios and the estimated coefficients reveal these properties in several ways. Parameter α is negative and statistically significant in both expansions and recessions, indicating the existence of leverage effect in these industry portfolios. In other words, negative shocks seem to increase volatility more than positive shocks. This is because a lower stock price can reduce the value of equity relative to debt to increase the corporate leverage level, thus increase the risk of stockholders. Moreover, parameter α is more negative in recessions than in expansions, implying that negative shocks affect volatilities in recessions more than in expansions. As expected, parameter γ is positive and statistically significant at the 5% level. Its magnitude increases slightly from expansions to recessions. These results indicate that shocks positively affect the volatility when they are higher than expected. In addition, there exists volatility persistence in the lumber and paper industries since parameter β ranges from 0.977 to 0.990 in expansions and recessions.

As one standard deviation of higher-than-expected CPI news is announced, the return increases by 3.7% and 6.3%, and the volatility decreases by 5.2% and 3.7% for the lumber and paper industry portfolios in the full sample. The same news has stronger impact on the return and volatility in expansions and no significant impact in recessions. There is a similar impact of IP news on the lumber industry but no significant effect on the paper industry. In contrast, the announced UNEMP news reduces the return by

2.9% and the volatility by 3.2% for the lumber industry in the full sample. All the coefficients discussed above are statistically significant different from zero at the 10% level or better.

Asymmetric News Impact Curves

The asymmetric news impact curves shown in Figure 4.2 demonstrate the leverage effect of shocks on industry portfolio volatilities. These news impact curves are centered at zero, but the slope on the left side is deeper than that on the right side for each industry portfolio. The estimated coefficient α is negative and highly significant in both expansions and recessions. For example, with the same magnitude of shocks, the volatility associated with negative shocks is higher than that associated with positive shocks. In addition, negative shocks have greater impact on the industry volatility in recessions than in expansions, which is supported by the estimated coefficients, $|\alpha^{\mathrm{Re}cession}| > |\alpha^{Expansion}|$. For the lumber industry, the volatility with ten-standard-deviations negative shock in expansions is lower than that in recessions. Similar patterns occur in the paper industry, suggesting the importance of the news and the states of the economy when modeling portfolio returns and volatilities.

Discussion and Conclusion

The forest products industry is one of the top manufacturing industries that contribute most to the economic development in the United States. However, it has experienced declining cycles and volatile financial performance over the past several decades. This paper focuses on the role macroeconomic news plays in the U.S. lumber and paper industries across business cycles. Using ARMA-EGARCH models, we examine the impact of three macroeconomic news on the returns and volatilities of the lumber and paper industry portfolios over 1963 – 2010.

The lumber and paper industry portfolios have positive returns during expansionary periods and negative returns during recessionary periods. In terms of volatility, all of them have low volatilities in expansions and high volatilities in recessions. This pattern implies that the state of the economy plays an important role in the financial performance of the forest products industry portfolios. In addition, we provide some evidence for volatility clustering in forest products industry portfolios. This finding not only suggests that incorporating macroeconomic news in the forest products industry may lead to persistent volatility but also provides some evidence for industry-specific rather than market-wide responses.

Asymmetric effects of positive and negative shocks on the forest products industry have been detected in this paper. The estimated coefficients from ARMA-EGARCH models suggest that the volatility of forest products industry portfolios with negative shocks is higher than that with positive shocks. This is probably because negative shocks will increase the debt-to-equity ratio, thus making the corresponding asset more risky. Conditional on the same macroeconomic news, the impact on the paper industry portfolio is more asymmetric than that on the lumber one in expansions, indicating that the paper industry is more sensitive to negative shocks. The finding of the leverage effect is consistent with previous studies about the impact of macroeconomic news (Engle and Ng, 1993). Furthermore, the response to the same macroeconomic news is also asymmetric across business cycles since negative shocks have greater impact in recessions than in expansions. Hence, market participants need to pay attention to these asymmetric effects when considering the forest products industry stocks.

The impact of macroeconomic news on industry portfolio returns and volatilities varies across business cycles. According to our empirical results, CPI news has a positive impact on the portfolio returns in expansions and a negative impact in recessions, whereas it decreases portfolio volatilities in expansions and increase them in recessions. Although UNEMP news affects portfolio returns negatively in both expansions and recessions, the magnitude of the impact is much higher in recessions. In contrast, IP news decreases portfolio volatilities in expansions and increases them in recessions. However, IP news has no significant impact on the paper industry portfolio. Our results confirm that the responses of the lumber and paper industry portfolios to macroeconomic news vary depending on the state of the economy and the type of macroeconomic news.

In summary, this study provides some evidence that macroeconomic news is an important driver for the lumber and paper industry, whose effect depends on the nature of macroeconomic news and the state of the economy. Moreover, the explanatory power of macroeconomic news on portfolio returns and volatilities varies across the forest products industries, indicating distinct structures and operations in different industries. The performance of the forest products industry varies with changing economic conditions, so market participants should adjust to these market shifts by considering different scenarios such as expansions and recessions. Our study can be extended in the following ways. The switching regime GARCH model (Hamilton and Susmel, 1994) can be employed to identify periods of expansions and recessions. The cointegration and error correction model can be used to examine the long- and short-run impacts of macroeconomic news on industry portfolios.

Table 4.1. NBER business cycles turning points (July 1963 – December 2010).

Business cycle reference dates		Duration in months	
Trough	Peak	Expansion[c]	Recession[d]
1963 Jul.[a]	1969 Dec.	77	11
1970 Nov.	1973 Nov.	36	16
1975 Mar.	1980 Jan.	58	6
1980 Jul.	1981 Jul.	12	16
1982 Nov.	1990 Jul.	92	8
1991 Mar.	2001 Mar.	120	8
2001 Nov.	2007 Dec.	73	18
2009 Jun.	2010 Dec.[b]	19	—
		487	83

Notes: [a] The actual trough was February 1961 which is out of the sample period, so July 1963 is the starting trough month in the full sample. [b] The actual peak date is not released yet. December 2010 is the last peak month in the full sample. [c] Expansion starts from the trough to the peak. [d] Recession is from the peak to the trough. All the dates are published on the NBER website.

Table 4.2. Summary and descriptive statistics of the macroeconomic news (July 1963 – December 2010).

Variable[a]	CPI	IP	UNEMP
Definition[b]	M/M% Chg, SA	M/M% Chg, SA	%, SA
Frequency	Monthly	Monthly	Monthly
Source[c]	BLS	FRB	BLS
Release time	8:30 AM EST	9:15 AM EST	8:30 AM EST
ARMA	(2, 1)	(1, 1)	(1, 4)
		In full sample	
Mean	0.001	-0.021	0.016
Std. Dev	1.019	0.983	1.013
Obs.	535	534	531
		In expansions	
Mean	0.008	-0.032	-0.012
Std. Dev	1.047	1.015	0.994
Obs.	464	463	460
		In recessions	
Mean	-0.048	0.050	0.203
Std. Dev	0.815	0.741	1.121
Obs.	71	71	71

Notes: [a] All the macroeconomic indicators are downloaded from the Federal Reserve Economic Data (FRED). [b] M/M% Chg indicates month to month percentage change. SA refer to seasonally adjustment. [c] BLS is the Bureau of Labor Statistics. FRB is the Board of Governor of the Federal Reserve System. [d] All the release dates are downloaded from the Archival Federal Reserve Economic Data (ALFRED). [e] All the release of macroeconomic news started from July 1963.

Table 4.3. Descriptive statistics of daily lumber and paper industry portfolios (1963 – 2010).

Statistics	Lumber[a]			Paper[b]		
	Full	Expansions	Recessions	Full	Expansions	Recessions
Mean	0.044	0.058	-0.042	0.041	0.053	-0.032
Std. Dev.	1.533	1.353	2.321	1.161	1.076	1.568
Min.	-21.760	-21.760	-16.080	-21.480	-21.480	-11.510
Max.	11.590	8.480	11.590	8.360	8.360	7.540
Skewness	-0.181	-0.285	0.046	-0.557	-0.648	-0.251
Kurtosis	8.803	9.017	4.278	14.691	19.491	4.233
Obs.	11959	10216	1743	11959	10216	1743

Notes: The forest products industry portfolio is constructed by the SIC code. [a] Lumber refers to the lumber and wood products industry (SIC 24). [b] Paper refers to the paper and allied products industry (SIC 26).

Table 4.4. Simultaneous impact of CPI on the lumber and paper industry portfolio returns and volatilities.

Parameter	Lumber			Paper		
	Full	Expansion	Recession	Full	Expansion	Recession
μ	0.047***	0.058***	-0.067	0.036***	0.044***	-0.036
	(0.012)	(0.016)	(0.049)	(0.010)	(0.011)	(0.036)
ϕ_1	0.111***	0.124***	0.034	0.239***	0.262***	0.071
	(0.017)	(0.016)	(0.160)	(0.070)	(0.018)	(0.163)
θ_1	0.025*	0.004	0.158	-0.101	-0.131***	0.120
	(0.014)	(0.010)	(0.157)	(0.072)	(0.019)	(0.163)
λ_{CPI}^{m}	0.037*	0.051*	-0.261	0.063*	0.064*	-0.090
	(0.020)	(0.030)	(0.221)	(0.033)	(0.038)	(0.301)
ω	0.016***	0.016***	0.036***	0.005***	0.004***	0.015***
	(0.002)	(0.002)	(0.009)	(0.001)	(0.001)	(0.004)
α	-0.042***	-0.036***	-0.069***	-0.043***	-0.038***	-0.063***
	(0.004)	(0.005)	(0.012)	(0.004)	(0.005)	(0.012)
γ	0.159***	0.160***	0.198***	0.132***	0.133***	0.141***
	(0.010)	(0.012)	(0.027)	(0.008)	(0.009)	(0.018)
β	0.983***	0.977***	0.979***	0.990***	0.989***	0.985***
	(0.002)	(0.003)	(0.006)	(0.001)	(0.002)	(0.004)
λ_{CPI}^{v}	-0.052**	-0.062*	0.025	-0.037*	-0.044*	0.057
	(0.021)	(0.032)	(0.092)	(0.019)	(0.025)	(0.125)

Notes: ***, **, and * denote significantly different from zero at the 1%, 5%, and 10% level, respectively. Standard errors are in parentheses.

Table 4.5. Simultaneous impact of IP on the lumber and paper industry portfolio returns and volatilities.

Parameter	Lumber			Paper		
	Full	Expansion	Recession	Full	Expansion	Recession
μ	0.046***	0.058***	-0.067***	0.036***	0.044***	-0.037
	(0.012)	(0.013)	(0.003)	(0.006)	(0.012)	(0.034)
ϕ_1	0.112***	0.123***	0.038***	0.239***	0.261***	0.052
	(0.007)	(0.012)	(0.001)	(0.001)	(0.062)	(0.118)
θ_1	0.024***	0.004	0.153***	-0.100***	-0.130**	0.141
	(0.007)	(0.007)	(0.004)	(0.006)	(0.063)	(0.119)
λ_{IP}^{m}	0.015***	0.028*	-0.160	0.001	0.008	-0.139
	(0.004)	(0.015)	(0.247)	(0.001)	(0.025)	(0.193)
ω	0.016***	0.016***	0.036***	0.005***	0.004***	0.015***
	(0.002)	(0.002)	(0.009)	(0.001)	(0.001)	(0.004)
α	-0.042***	-0.037***	-0.067***	-0.043***	-0.038***	-0.059***
	(0.004)	(0.005)	(0.012)	(0.004)	(0.005)	(0.012)
γ	0.160***	0.163***	0.198***	0.132***	0.134***	0.143***
	(0.010)	(0.011)	(0.027)	(0.008)	(0.009)	(0.018)
β	0.983***	0.977***	0.979***	0.990***	0.990***	0.984***
	(0.002)	(0.003)	(0.006)	(0.001)	(0.002)	(0.004)
λ_{IP}^{v}	-0.011***	-0.023*	0.071	0.015	0.002	0.210**
	(0.002)	(0.013)	(0.101)	(0.023)	(0.005)	(0.091)

Notes: ***, **, and * denote significantly different from zero at the 1%, 5%, and 10% level, respectively. Standard errors are in parentheses..

Table 4.6. Simultaneous impact of UNEMP on the lumber and paper industry portfolio returns and volatilities.

Parameter	Lumber			Paper		
	Full	Expansion	Recession	Full	Expansion	Recession
μ	0.046***	0.057***	-0.069***	0.036***	0.044***	-0.035***
	(0.012)	(0.002)	(0.001)	(0.008)	(0.010)	(0.001)
ϕ_1	0.109***	0.122***	0.038***	0.240***	0.262***	0.055***
	(0.024)	(0.001)	(0.001)	(0.019)	(0.073)	(0.001)
θ_1	0.027	0.006***	0.154***	-0.101***	-0.131*	0.136***
	(0.025)	(0.000)	(0.001)	(0.020)	(0.075)	(0.002)
λ_{UNEMP}^{m}	-0.029*	-0.024*	-0.188	0.021	0.019	-0.015
	(0.016)	(0.013)	(0.214)	(0.017)	(0.021)	(0.012)
ω	0.016***	0.016***	0.036***	0.005***	0.004***	0.015***
	(0.002)	(0.002)	(0.008)	(0.001)	(0.001)	(0.004)
α	-0.042***	-0.037***	-0.069***	-0.043***	-0.038***	-0.063***
	(0.004)	(0.005)	(0.012)	(0.004)	(0.005)	(0.012)
γ	0.160***	0.162***	0.199***	0.133***	0.134***	0.143***
	(0.010)	(0.011)	(0.027)	(0.008)	(0.009)	(0.018)
β	0.983***	0.977***	0.979***	0.990***	0.989***	0.985***
	(0.002)	(0.003)	(0.005)	(0.001)	(0.002)	(0.004)
λ_{UNEMP}^{v}	-0.032**	-0.033*	-0.048	0.010	0.007	0.019
	(0.016)	(0.018)	(0.073)	(0.016)	(0.009)	(0.060)

Notes: ***, **, and * denote significantly different from zero at the 1%, 5%, and 10% level, respectively. Standard errors are in parentheses.

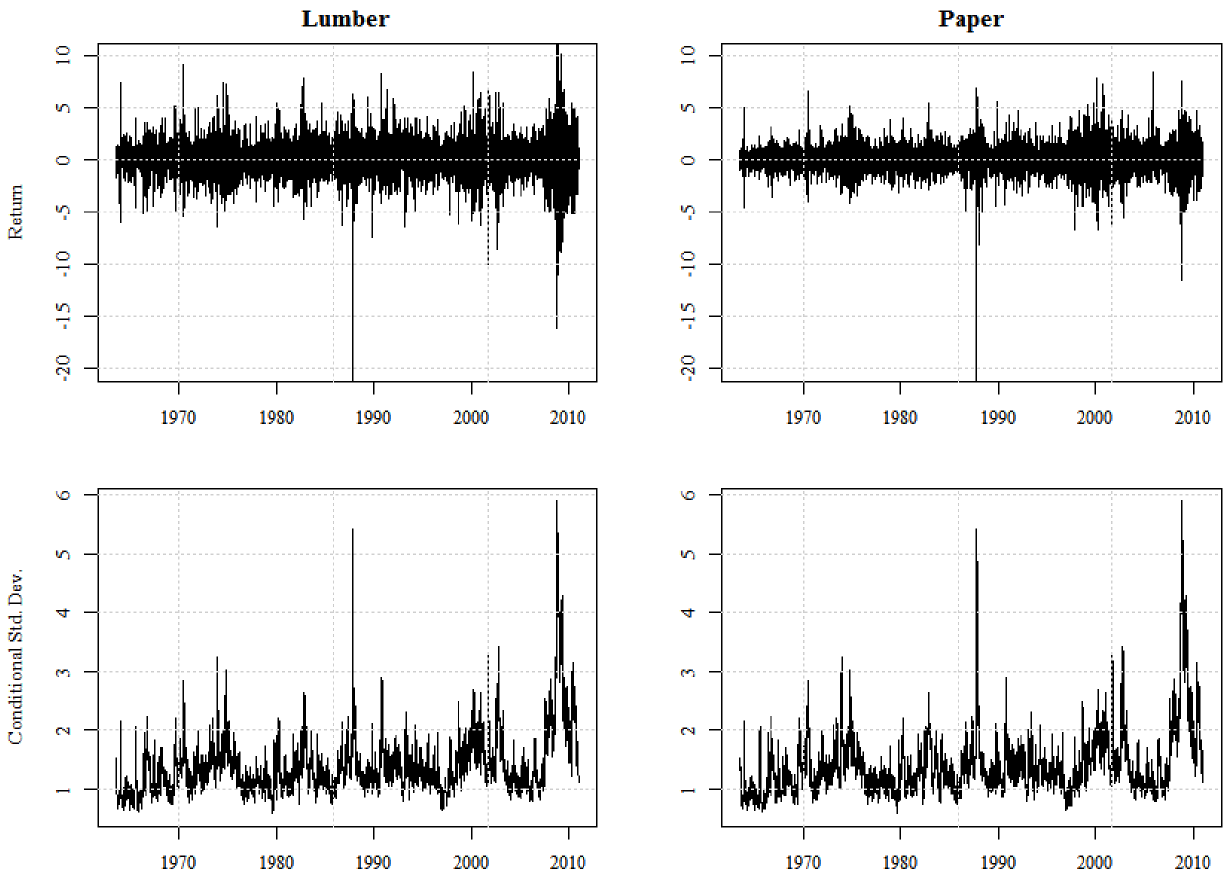

Figure 4.1. Daily lumber and paper industry portfolio returns and conditional standard deviation (July 1, 1963 – December 31, 2010).

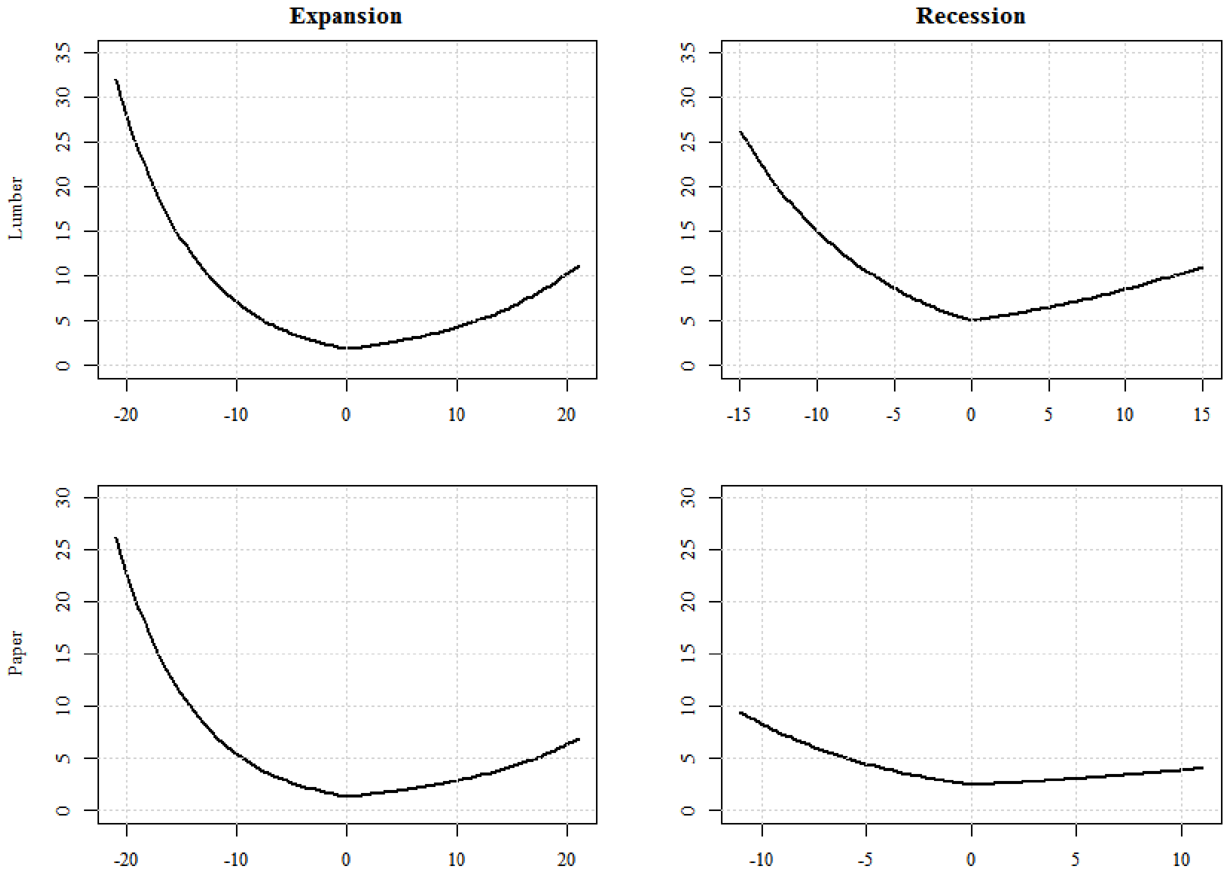

Figure 4.2. News impact curves in both expansions and recessions. Notes: The horizontal line is the shock at time $t-1$, and the vertical line is the volatility at time t.

CHAPTER 5

DISCUSSIONS AND CONCLUSIONS

This dissertation examines the performance of timberland assets and the forest products industry in the United States. Three specific issues are addressed: (1) the static and dynamic inflation hedging abilities of private- and public-equity timberland assets are examined; (2) the role of timberland assets in a mixed portfolio is evaluated under the Mean-CVaR framework; and (3) the impacts of macroeconomic news on the forest products industry portfolios across business cycles are assessed.

Chapter 2 employs the Fisher hypothesis and CAPMUI to analyze how effectively private- and public-equity timberland assets hedge actual, expected, and unexpected inflation in the U.S. during 1987 – 2009. Moreover, the rolling regression and state space model are employed in this study. The rolling regression is used to evaluate whether timberland assets can persistently hedge inflation, while the state space model is employed to examine the time-varying inflation hedging abilities. Returns for private-equity timberland assets are proxied by the NCREIF Timberland Index and returns for public-equity timberland assets are calculated by the value-weighted returns on a dynamic portfolio of the U.S. publicly traded timber firms. Several conclusions are reached in this chapter.

First, the performances between private- and public-equity timberland assets are compared. Private-equity timberland assets have higher nominal rates of return, which may be due to its liquidity risk since major data contribution members such as TIMOs usually have a 10- to 15-year investment horizon. Second, private- and public-equity timberland assets have different inflation hedging abilities. Empirical results suggest that private-equity timberland assets do hedge actual, expected, and unexpected inflation, whereas public-equity timberland assets are not consistent in hedging actual, expected, or unexpected inflation. Third, whether timberland assets can hedge inflation depends on the states of the economy. Private-equity timberland assets are effective in hedging inflation during the expansion and less effective during the recession, which is consistent with the finding of Healey et al. (2005). Last, investment horizon plays a significant role in timberland inflation hedging. Private-equity timberland assets have stronger ability to hedge actual inflation with longer investment horizon. This result suggests that longer investment horizons for private-equity timberland assets could help investor better hedge actual, expected, and unexpected inflation, and determine the timing strategies for their portfolios.

Chapter 3 employs the M-CVaR optimization approach to formulate asset allocation strategies and to examine the role of timberland assets in a mixed portfolio from the risk perspective. Both static and dynamic backtesting are used to assess the stability of asset allocations and the persistence of asset performance. Several conclusions are reached from the comparison of the M-V and M-CVaR efficient frontiers, the formulation of asset allocations, and the risk decomposition of portfolios.

First, the choice of risk measures is an important decision for portfolio management. As investors are particularly concerned with the downside risk in reality, the M-CVaR method fully reflects the tradeoff between downside risks and returns. Second, the efficient frontier of the mixed portfolio is dramatically improved after adding timberland assets in comparison of the mean-variance (M-V) efficient frontier. This is because the M-CVaR approach fairly captures the asymmetry and fat tail properties and selects asset returns with positive skewness and low kurtosis to reduce the portfolio risk. Third, the asset allocations and risk decompositions are conducted in both static and dynamic optimizations. Timberland assets are preferred for high target returns, indicating its ability to generate high returns. Using static and dynamic backtesting, this study also provides some empirical evidence that stocks intensify a portfolio risk, whereas treasury bills, treasury bonds, and timberland assets diversify a portfolio risk. This fact implies that portfolio managers can shift weights from high risk contribution assets to the low ones.

Chapter 4 examines what role macroeconomic news plays in the U.S. forest products industry portfolios across business cycles. Using ARMA-EGARCH models, we examine the impact of consumer price index (CPI), industrial production (IP), and unemployment (UNEMP) on the returns and volatilities of the lumber and paper industry portfolios over 1963 – 2010. Several conclusions are drawn from this chapter.

First, it is found that the lumber and paper industry portfolios have positive returns during expansionary periods and negative returns during recessionary periods. All of them have relatively low volatilities in expansions and relatively high volatilities in recessions. Second, asymmetric effects of positive and negative shocks on the two industry portfolios have been detected. This is probably because negative shocks will increase the debt-to-equity ratio, thus making the corresponding asset more risky. The response to the same macroeconomic news is also asymmetric across business cycles since negative shocks have greater impact in recessions than in expansions. Third, the impact of macroeconomic news on industry portfolio returns and volatilities vary across business cycles. For example, CPI news has a positive impact on the portfolio returns in expansions and a negative impact in recessions, whereas it decreases portfolio volatilities in expansions and increase them in recessions. In summary, this study provides some evidence that macroeconomic news is an important driver for the forest products industry portfolios.

This study also brings up several interesting questions. First, the short-run and long-run inflation hedging abilities can be tested by cointegration and error correction model to better understand inflation hedging ability of timberland assets. Second, the role of timberland assets in other portfolios such as an international one can be examined to test whether it is a consistent risk diversifier. Third, the fundamental reasons for the different impacts of macroeconomic news on the industry portfolios may be addressed by the return decomposition approach in the future.

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