Evaluating the Financial Performance of Timberland Investments in the United States

Bin Mei and Michael L. Clutter

Abstract: Timberland properties have gained increasing attention in recent decades. The attractiveness of this asset primarily lies in its unique feature—the biological growth, which is independent of traditional financial markets. Using both parametric and nonparametric approaches, in this study we reexamine the financial performance of private- and public-equity timberland investments in the United States. Private-equity timberland returns are proxied by the National Council of Real Estate Investment Fiduciaries Timberland Index, whereas public-equity timberland returns are proxied by the value-weighted returns on a dynamic portfolio of the US publicly traded forestry firms that had or have been managing timberlands. The parametric analyses reveal that private-equity timberland assets outperform the market and have low systematic risk, whereas public-equity timberland assets fare similarly to the market. The nonparametric analyses reveal that both private- and public-equity timberland assets have higher excess returns. For. Sci. 56(5):421–428.

Keywords: capital asset pricing model, Fama–French three-factor model, state space model, stochastic discount factor

Timberland investments have been unprecedentedly active in the past few decades. Several factors have motivated public attention toward timberlands. On the supply side, because of the internal subsidies from timber divisions to processing mills, timberland properties managed by traditional vertically integrated forest products firms have been undervalued by Wall Street. To deal with this mispricing, these firms began divesting their timberlands as a strategic move. For example, International Paper, a global leading forest products firm, has disposed of most of its timberlands and focused on its core business of paper and packaging products in recent decades. It is postulated that no forest products firms in the United States will own timberlands in the next few years (Clutter et al. 2005). On the demand side, institutional investors, i.e., organizations with fiduciary obligations such as pension funds, university endowments, foundations, and trusts have diversified into nonfinancial assets such as timberlands on the passage of Employee Retirement Income Security Act (ERISA) in 1974.

There are several ways to invest in timberlands. High-net-wealth families and individuals can participate in commingled (pooled) funds or they can own timberland properties directly. Others can buy stocks and bonds of publicly traded forestry firms that maintain timberland business. Most institutional investors hold timberland properties via timberland investment management organizations (TIMOs). TIMOs manage their institutional assets in either separately managed accounts (individually managed accounts) or pooled funds. A separately managed account holds timberland properties of one investor in a single portfolio, whereas a pooled fund collects capital from a number of investors and allocates it to a portfolio of timberland properties. Investors tend to have more discretion with separate accounts than with pooled funds (Zinkhan and Cubbage 2003). In 2008, there were about 30 TIMOs in the United States, and the total value of their timberland assets exceeded $35 billion (Zinkhan 2008).

Since the public recognition of timberland as an alternative asset class, a number of studies have been conducted to assess the financial performance of timberland investments. The major findings of previous research can be summarized as follows. (1) Timberland has countercyclical returns or low (even negative in some cases) correlation with the financial assets (Mills and Hoover 1982, Redmond and Cubbage 1988, Zinkhan 1988, 2008, Washburn and Binkley 1990, Binkley et al. 1996, Cascio and Clutter 2008). (2) Timberland can be an effective hedge against higher-than-expected inflation (Portson 1986, Washburn and Binkley 1993). (3) If timberland investors can exploit the biological growth of timber and thus time the market, they can get higher and better returns (Conroy and Miles 1989, Haight and Holmes 1991, Caulfield 1998). (4) Relative inefficiency tends to exist in timberland markets (Caulfield 1998), although this situation has been alleviated through time (Washburn 2008, Zinkhan 2008). (5) Among a variety of forestry-related investment vehicles, institutional timberland investments and timberland limited partnerships have low risk levels but excess returns (Sun and Zhang 2001). (6) In the long run, timber and/or timberland returns are cointegrated with other non timber financial instruments (Heikkinen 2002, Liao et al. 2009).

Almost all of the above studies are based on the single-period capital asset pricing model (CAPM). Sun and Zhang...
(2001) extended the literature by using the arbitrage pricing theory (APT), and Heikkinen (2002) and Liao et al. (2009) expanded the research by using cointegration analysis, but all of these methodologies are parametric in nature. This study has several contributions in the area of timberland investments. First, timberland assets are considered separately in private and public markets, and their returns are compared. Second, supplementary to the ordinary least-squares (OLS) estimation of the CAPM and Fama–French three-factor model, a state space model with a Kalman filter is used to examine the time-varying risk-adjusted excess return (α) and systematic risk (β). Finally, the nonparametric stochastic discount factor (SDF) approach is introduced for pricing timberland returns.

The major results are first that private-equity timberland investments have significant excess returns but low systematic risk, whereas public-equity timberland investments fare similarly as the market and second that intertemporal consumption decisions do affect the intertemporal marginal rate of substitution of timberland investors and thus affect the rational pricing of timberland assets. These results can further our understanding of the financial aspects of commercial timberland assets in the United States. The next two sections describe the methodologies and the data, followed by a section explaining the empirical results and the concluding section.

**Methods**

For the parametric method, an explicit model is needed. Two candidate models prevalent in the finance literature are the CAPM and Fama–French three-factor model. The parametric method is often criticized for the “joint hypothesis tests” problem, i.e., testing the asset pricing model and the abnormal performance (market efficiency) simultaneously. The nonparametric method does not require such an explicit model specification and is therefore not subject to these critiques. The SDF approach is a general, nonparametric asset pricing approach and is a complement to the parametric approaches.

**CAPM**

Built on Markowitz’s (1952) groundwork of mean-variance efficient portfolio, Sharpe (1964) and Lintner (1965) developed its economywide implications—CAPM. CAPM states that the expected return on an asset or a portfolio E[R_i] equals a risk-free rate R_f plus a premium that depends on the asset’s β_i and the expected risk premium on the market portfolio E[R_m] − R_f. i.e.,

$$E[R_i] = R_f + \beta_i (E[R_m] - R_f).$$

(1)

In empirical regression analysis, CAPM can be estimated in the excess return form

$$R_i - R_f = \alpha_i + \beta_i (R_m - R_f) + \epsilon_i,$$

(2)

where ex post realized returns R_i and R_m rather than ex ante expected returns E[R_i] and E[R_m] are used. The intercept α_i is called Jensen’s (1968) alpha. A positive α suggests that the individual asset outperforms the market and earns a higher than risk-adjusted return, whereas a negative α suggests that the individual asset underperforms the market and earns a lower than risk-adjusted return. Therefore, Jensen’s alpha has become a commonly used measure of abnormal performance, and testing whether it is 0 has been widely used in the empirical asset pricing literature.

**Fama–French Three-Factor Model**

Given the empirical evidence that small-size stocks outperform large-size stocks and value (high book/market ratio) stocks outperform growth (low book/market ratio) stocks on average, Fama and French (1993) developed a model that includes these extra two factors to adjust for risk:

$$E[R_i] = R_f + \beta_{RMRF,i} E[R_{RMRF}] + \beta_{SMB,i} E[R_{SMB}] + \beta_{HML,i} E[R_{HML}].$$

(3)

where $R_{RMRF} = R_m - R_f$ is the same market factor as in CAPM, representing the market risk premium; $R_{SMB} = R_{small} - R_{big}$ is the size factor, representing the return difference between a portfolio of small stocks and a portfolio of large stocks (SMB stands for “small minus big”), $R_{HML} = R_{highBM} - R_{lowBM}$ is the book-to-market factor, representing the return difference between a portfolio of high-book-to-market stocks and a portfolio of low-book-to-market stocks (HML stands for “high minus low”); and $\beta$s are called factor loadings, representing each asset’s sensitivity to these factors. When one is estimating the Fama–French three-factor model, ex post realized returns are used, as in the case of CAPM, and an intercept is added to capture the abnormal performance,

$$R_i - R_f = \alpha_i + \beta_{RMRF,i} R_{RMRF} + \beta_{SMB,i} R_{SMB} + \beta_{HML,i} R_{HML} + \xi_i.$$  

(4)

**CAPM and Fama–French Three-Factor Model under the State Space Framework**

The CAPM (Equation 2) and Fama–French three-factor model (Equation 4) are usually estimated by OLS, possibly with some correction for the autocorrelations in the errors. One restrictive nature of the OLS method is that the coefficients in the regression are imposed to be constant. This condition may be unrealistic in real asset pricing modeling. For instance, one would suspect that both α and β values should be time-varying. To solve this problem, we can estimate the CAPM and Fama–French three-factor model in the state space framework with a Kalman filter (Appendix A). Using CAPM as an example, in the state space framework, the system of equations is specified as

$$R_{i,t} - R_{f,t} = \alpha_{i,t} + \beta_{i,t} (R_{m,t} - R_{f,t}) + \mu_{i,t},$$

(5)

where \(\mu_{i,t}\), \(\xi_t\), and \(\tau_t\) are normally and independently distributed mean-zero error terms. In the state space model, the first equation in display 5 is called the observation or measurement equation, and the second and third equations
are called the state equations. In this particular case, each state variable follows a random walk.

One advantage of the state space approach with time-varying parameters is that it can incorporate external shocks, such as policy and regime shifts, economic reforms, and political uncertainties, into the system, especially when the shocks are diffuse in nature (Sun 2007). This approach has been applied to a variety of issues, including demand systems (e.g., Doran and Rambaldi 1997), aggregate consumptions (e.g., Song et al. 1996), policy analysis (e.g., Sun 2007), and price modeling and forecasting (e.g., Malaty et al. 2007).

**Stochastic Discount Factor Approach**

The single-period asset pricing models ignore the consumption decisions. In effect, investors make their consumption and portfolio choices simultaneously in an intertemporal setting. In the framework of an exchange economy in which an investor maximizes the expectation of a time-separable utility function (Lucas 1978), it can be proved that (Appendix B)

\[ E_t[(1 + R_{i,t+1})M_{t+1}] = 1, \]  

(6)

where \( R_{i,t+1} \) is the return on asset \( i \) in the economy and \( M_{t+1} \) is known as the stochastic discount factor, or intertemporal marginal rate of substitution, or pricing kernel (e.g., Campbell et al. 1997).

Hansen and Jagannathan (1991) demonstrated how to identify the SDF from a set of basis assets, i.e., the derivation of the volatility bounds. These bounds are recognized as regions of admissible mean-SD pairs of the SDF. Their major assumptions are the law of one price and the absence of arbitrage opportunities. Accordingly, there are two particular solutions for the SDF: the law of one price SDF and the no-arbitrage SDF. The process of retrieving the reverse-engineered law of one price SDF is equivalent to the constrained optimization problem,

\[
\min_{M_t} \frac{1}{T-1} \sum_{t=1}^{T} (M_t - \nu)^2 \left[ \frac{1}{T} \sum_{i=1}^{N} M_i \right]^{1/2}
\]

s.t. \[
\frac{1}{T} \sum_{i=1}^{N} M_i = \nu
\]

(7)

for a range of selected \( \nu \) (mean of \( M_t \)), and for all assets \( i = 1, 2, \ldots, N \). Under the stronger condition of no arbitrage, another positivity constraint on \( M_t \) is needed. Therefore, the only difference between the law of one price SDF and the no-arbitrage SDF is whether \( M_t \) is allowed to be negative. In this study, no-arbitrage SDF is used. Following Hansen and Jagannathan (1991), nonnegativity instead of positivity restriction \( M_t \geq 0 \) is added to retrieve the no-arbitrage SDF. Last, sample size \( T \) should be sufficiently large such that the time-series version of law of large numbers applies; that is, the sample moments on a finite record converge to their population counterparts as the sample size becomes large (Hansen and Jagannathan 1991).

Provided the existence of a risk free asset, it can be shown that

\[ E_t[(R_{i,t+1} - R_f)M_{t+1}] = 0. \]

(8)

This equation presents the basis for testing the risk-adjusted performance of a portfolio (Chen and Knez 1996). Namely, one can test whether

\[ \alpha_i = E_t(\alpha, i) = E_t[(R_{i,t+1} - R_f)M_{t+1}] = 0. \]

(9)

Ahn et al. (2003) pointed out that this measure generalizes Jensen’s alpha and does not count on a specific asset pricing model. Based on this method, they reassessed the profitability of momentum strategies and found that their nonparametric risk adjustment explains almost half of the anomalies.

**Data**

**Timberland Returns**

Returns for both private- and public-equity timberland investments are analyzed. Although TIMOs have become the major timberland investment management entities for institutional investors as well as high-net-wealth families and individuals, their financial data are rarely publicly available. To provide a performance benchmark, several TIMOs, together with National Council of Real Estate Investment Fiduciaries (NCREIF) and the Frank Russell Company, initiated the NCREIF Timberland Index in early 1992 (Binkley et al. 2003) (Appendix C). NCREIF members can be divided into data contribution members, professional members, and academic members. Data contribution members include investment managers and plan sponsors who own or manage real estate in a fiduciary setting. Professional members include providers of accounting, appraisal, legal, consulting, or other services to the data contribution members. Academic members include full-time professors of real estate. Data contribution members submit their data on a quarterly basis for computation of the NCREIF Property Index. Regarding the NCREIF Timberland Index, some TIMOs are the major data contribution members. The quarterly NCREIF Timberland Index is reported at both regional (the South, the Northeast, and the Pacific Northwest) and national levels and extends back to 1987. In this study, the national-level NCREIF Timberland Index (1987Q1–2008Q4) is used as a return proxy for the US private-equity timberland investments.

Returns on public-equity timberland investments are proxied by the value-weighted returns on a dynamic portfolio of the US publicly traded forestry firms that had or have been managing timberlands. These firms include Deltec Timber, The Timber Co., IP Timberlands Ltd., Plum Creek, Pope Resources, Potlatch, Rayonier, and Weyerhaeuser. Deltec Timber and Pope Resources are natural resources companies focused on the ownership and management of timberland; The Timber Co. and IP Timberlands Ltd. are subsidiaries of Georgia-Pacific and International Paper that...
track the value and performance of their timberland properties: Plum Creek, Potlatch, and Rayonier are publicly traded real estate investment trusts (REITs) that are engaged in timberland management; and Weyerhaeuser is a forest products firm that has a significant portion of its business in timberlands. The market value of each firm is calculated as the product of stock price and total shares outstanding at the end of each quarter. Financial data for these forestry firms are obtained from the Center for Research in Security Prices (CRSP). To be consistent with the NCREIF Timberland Index, the sample spans from 1987Q1 to 2008Q4.

**Basis Assets**

To mimic the complete investment opportunity set that is available to investors, a parsimonious set of basis assets needs to be specified. King (1966) proved that industry groupings maximize intragroup correlation and minimize intergroup correlation and concluded that market and industry factors capture most of the common variation in stock returns. Following Hansen and Jagannathan (1991), we construct the reference set by forming industry portfolios according to SIC code. In this study, two sets of basis assets are chosen—one is the 5-industry portfolios plus long-term treasury bonds and the other is the 10-industry portfolios plus long-term treasury bonds. The industry groups are derived from stocks listed on NYSE, AMEX, and NASDAQ based on their four-digit SIC codes. The 5 industries are classified as consumer goods, manufacturing, hi-tech, health care, and others, whereas the 10 industries are classified as consumer nondurables, consumer durables, manufacturing, energy, hi-tech, telephone and television transmission, shops, health care, utilities, and others. Value-weighted returns on the industry portfolios are obtained from Kenneth R. French’s website (French 2010), and returns on the portfolio of long-term treasury bonds are obtained from CRSP. Presuming that the basis assets are rationally priced, the SDF can be retrieved.

**Other Indices**

Market returns are approximated by the value-weighted returns on all NYSE, AMEX, and NASDAQ stocks from CRSP. Risk-free rate, as approximated by the 1-month Treasury bill rate from Ibbotson Associates, Inc. and Fama–French factors are available on Kenneth R. French’s website (French 2010).

**Empirical Results**

**Estimation of CAPM and Fama–French Three-Factor Model**

Table 1 presents OLS estimation of the CAPM and Fama–French three-factor model using the quarterly NCREIF Timberland Index after adjustment for seasonality. A significant positive \( \alpha \) from CAPM suggests that private-equity timberland investments have a risk-adjusted excess return of about 9.36% (2.34% \( \times \) 4) per year. This excess return is slightly larger after accounting for Fama–French factors. Market \( \beta \) from both models are insignificantly different from 0 but significantly < 1. This means that private-equity timberland investments are not only weakly correlated with the market but also less risky than the market. The small magnitudes with high \( P \) values of the coefficients for SMB and HML signify that these two extra factors add limited explanatory power to CAPM in pricing private-equity timberland returns.

In contrast, the CAPM and Fama–French three-factor

<table>
<thead>
<tr>
<th>Basis Assets</th>
<th>( \alpha )</th>
<th>( P )</th>
<th>( \beta )</th>
<th>( P )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ordinary least square estimation</td>
<td>2.34</td>
<td>0.001</td>
<td>0.04</td>
<td>0.369</td>
</tr>
<tr>
<td>( \beta )</td>
<td>0.14</td>
<td>0.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( R^2 )</td>
<td>230.48</td>
<td>3.83</td>
<td>2.05</td>
<td>5.56</td>
</tr>
<tr>
<td>Durbin–Watson statistic</td>
<td>2.05</td>
<td>5.65</td>
<td>6.50</td>
<td>5.86</td>
</tr>
<tr>
<td>AIC</td>
<td>2.38</td>
<td>0.000</td>
<td>0.66</td>
<td>0.06</td>
</tr>
<tr>
<td>SBC</td>
<td>0.06</td>
<td>0.464</td>
<td>0.336</td>
<td>0.464</td>
</tr>
<tr>
<td>( H_0: \beta = 1 )</td>
<td>0.04</td>
<td>0.558</td>
<td>0.03</td>
<td>0.681</td>
</tr>
<tr>
<td>( R^2 )</td>
<td>230.04</td>
<td>3.41</td>
<td>230.04</td>
<td>3.86</td>
</tr>
<tr>
<td>Log likelihood</td>
<td>5.65</td>
<td>5.74</td>
<td>5.65</td>
<td>5.74</td>
</tr>
<tr>
<td>SE of regression</td>
<td>6.50</td>
<td>3.14</td>
<td>3.14</td>
<td>3.14</td>
</tr>
<tr>
<td>Durbin–Watson statistic</td>
<td>2.06</td>
<td>2.06</td>
<td>2.06</td>
<td>2.06</td>
</tr>
<tr>
<td>AIC</td>
<td>2.06</td>
<td>2.06</td>
<td>2.06</td>
<td>2.06</td>
</tr>
<tr>
<td>SBC</td>
<td>2.06</td>
<td>2.06</td>
<td>2.06</td>
<td>2.06</td>
</tr>
<tr>
<td>( F ) statistic</td>
<td>2.06</td>
<td>2.06</td>
<td>2.06</td>
<td>2.06</td>
</tr>
<tr>
<td>( H_0: \beta = 1 )</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
</tbody>
</table>

OLS estimates after correction for the fourth-order autocorrelation in the residuals. Only \( \alpha \) is specified stochastic under the state space framework, whereas \( \beta \) is specified deterministic because of its lack of variation and Akaike information criterion (AIC). FF3, Fama–French three-factor model.

SBC, Schwartz Bayesian criterion.
model fit the returns on the dynamic portfolio of forestry firms much better, as implied by the higher $R^2$ values (Table 2). This is within our expectation because these forestry firms are publicly traded and are more exposed to the market. However, $\alpha$ values are insignificant, albeit positive, indicating no abnormal performance. Market $\beta$ values are significantly different from 0 but not from 1. In addition, $\beta$ values for SMB and HML in the Fama–French three-factor model are highly significant, meaning that these factors capture some variations in the portfolio returns that are not explained by the market premium. As a result, the abnormal performance ($\alpha$ value) has dropped by 50%. The magnitudes of $\beta$ values indicate that the dynamic portfolio is dominated by mid-large firms with middle book/market ratios.

State Space Estimation of CAPM and Fama–French Three-Factor Model

Table 1 presents the state space estimation of the CAPM and Fama–French three-factor model using the NCREIF Timberland Index. Those OLS coefficient estimates are used as the starting values. Only $\alpha$ is specified as a state variable (stochastic level) in that little time variation is observed in $\beta$, and both the Akaike information criterion (AIC) and the Schwartz Bayesian information criterion (SBC) favor the deterministic-$\beta$ model. Returning to the model specification in system 5, this is equivalent to restricting $\tau_1 = 0$. The magnitudes of the parameter estimates are similar to those for the OLS estimation. The AIC and SBC are marginally larger than those for the OLS estimation because of the relatively small sample size. Figure 1 depicts the evolution of the risk-adjusted excess returns of the NCREIF Timberland Index estimated from CAPM. For most of the last 22 years, the NCREIF Timberland Index has achieved positive abnormal returns with an average of 10.6% per year (calculated from the estimated $\alpha$ series). Nevertheless, in certain years (2001–2003) the $\alpha$ is low and even negative, indicating no abnormal performance. Although not reported here, the time-varying $\alpha$ estimated from the Fama–French three-factor model exhibit similar patterns.

For the dynamic portfolio, however, only $\beta$ is specified to be stochastic because little time variation is observed in $\alpha$, and both AIC and SBC favor the deterministic-$\alpha$ model.

Table 2. Estimation of capital asset pricing model (CAPM) and Fama–French three-factor model (FF3) using returns on a dynamic portfolio of the US publicly traded forestry firms (1987Q1–2008Q4)

<table>
<thead>
<tr>
<th></th>
<th>CAPM Estimate</th>
<th>$P$</th>
<th>FF3 Estimate</th>
<th>$P$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ordinary least square estimation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\alpha$</td>
<td>0.57</td>
<td>0.562</td>
<td>$\alpha$</td>
<td>0.28</td>
</tr>
<tr>
<td>$\beta$</td>
<td>0.95</td>
<td>0.000</td>
<td>$\beta_{RMRF}$</td>
<td>0.92</td>
</tr>
<tr>
<td>$\beta_{SMB}$</td>
<td>0.47</td>
<td>0.012</td>
<td>$\beta_{HML}$</td>
<td>0.45</td>
</tr>
<tr>
<td>$\beta_{HML}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$H_0$: $\beta = 1$</td>
<td></td>
<td>0.328</td>
<td>$H_0$: $\beta_{RMRF} = 1$</td>
<td>0.56</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.45</td>
<td></td>
<td>$R^2$</td>
<td>0.56</td>
</tr>
<tr>
<td>Log likelihood</td>
<td>-318.18</td>
<td></td>
<td>Log likelihood</td>
<td>-308.60</td>
</tr>
<tr>
<td>SE of regression</td>
<td>9.10</td>
<td></td>
<td>SE of regression</td>
<td>8.26</td>
</tr>
<tr>
<td>Durbin-Watson statistic</td>
<td>2.16</td>
<td></td>
<td>Durbin-Watson statistic</td>
<td>2.32</td>
</tr>
<tr>
<td>AIC</td>
<td>7.28</td>
<td></td>
<td>AIC</td>
<td>7.10</td>
</tr>
<tr>
<td>SBS</td>
<td>7.33</td>
<td></td>
<td>SBC</td>
<td>7.22</td>
</tr>
<tr>
<td>$F$ statistic</td>
<td>69.48</td>
<td></td>
<td>$F$ statistic</td>
<td>34.13</td>
</tr>
<tr>
<td><strong>State space estimation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\alpha$</td>
<td>0.57</td>
<td>0.610</td>
<td>$\alpha$</td>
<td>0.23</td>
</tr>
<tr>
<td>$\beta$</td>
<td>0.95</td>
<td>0.000</td>
<td>$\beta_{RMRF}$</td>
<td>0.89</td>
</tr>
<tr>
<td>$\beta_{SMB}$</td>
<td>0.47</td>
<td>0.005</td>
<td>$\beta_{HML}$</td>
<td>0.45</td>
</tr>
<tr>
<td>$\beta_{HML}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$H_0$: $\beta = 1$</td>
<td></td>
<td>0.388</td>
<td>$H_0$: $\beta_{RMRF} = 1$</td>
<td>0.442</td>
</tr>
<tr>
<td>Log likelihood</td>
<td>-329.48</td>
<td></td>
<td>Log likelihood</td>
<td>-319.86</td>
</tr>
<tr>
<td>AIC</td>
<td>7.56</td>
<td></td>
<td>AIC</td>
<td>7.38</td>
</tr>
<tr>
<td>SBS</td>
<td>7.64</td>
<td></td>
<td>SBC</td>
<td>7.52</td>
</tr>
</tbody>
</table>

Only $\beta$ is specified stochastic under the stochastic framework, whereas $\alpha$ is specified deterministic because of its lack of variation and Akaike information criterion (AIC).

SBC, Schwartz Bayesian criterion.
The time-varying $\beta$ of the dynamic portfolio of forestry firms is plotted in Figure 2. Overall, there is a decreasing trend in the market $\beta$. The average $\beta$ over the sample period is 1.06, which is not significantly different from the market risk.

**Abnormal Performance Measured by the SDF Approach**

The mean of the no-arbitrage SDF $M_t$ is specified in the selected range of $[0.9750, 1]$ with an increment step of 0.0025. When the 5-industry portfolios plus the long-term treasury bonds are used as the basis assets, the global minimum variance of $M_t$ is identified at $\nu = 0.9800$; when the 10-industry portfolios plus the long-term treasury bonds are used instead, the global minimum variance of $M_t$ is identified at $\nu = 0.9750$.

The SDF performance measures for both the NCREIF Timberland Index and the returns on the dynamic portfolio of publicly traded timber firms are reported in Table 3. The $\alpha$ values for both return indices have increased, and the latter has become marginally significant. This indeed implies that intertemporal consumption decisions play a key role in pricing timberland assets. In a word, there is clear evidence of statistically as well as economically significant excess returns for the NCREIF Timberland Index but only some evidence of economically significant excess returns for the portfolio of publicly traded timber firms.

**Conclusions**

Using both parametric and nonparametric techniques, in this study we reexamined the financial performance of timberland investments. Private-equity timberland returns are approximated by the NCREIF Timberland Index, whereas public-equity timberland returns are approximated by the value-weighted returns on a dynamic portfolio of the US publicly traded forestry firms (1987Q1–2008Q4). The trend in the market $\beta$. The average $\beta$ over the sample period

![Figure 2. Evolution of $\beta$ over time from the state space estimation of CAPM using returns on a dynamic portfolio of the US publicly traded forestry firms (1987Q1–2008Q4). The time-varying $\beta$ estimated from the Fama–French three-factor model exhibits similar patterns and thus is not shown separately. The graph is available from the authors on request. RMSE, root mean square error.](https://academic.oup.com/forestscience/article/56/5/421/4604170)

**Table 3. Performance measures of timberland returns by the nonparametric stochastic discount factor approach (1987Q1–2008Q4)**

<table>
<thead>
<tr>
<th>Mean of $M_t$ ($\nu$)</th>
<th>SD of $M_t (\sigma_{M_t})$</th>
<th>Performance measure ($\alpha$)</th>
<th>$P$ (one-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-industry portfolios plus long-term T-bonds</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.9775</td>
<td>0.199</td>
<td>2.625</td>
<td>1.585</td>
</tr>
<tr>
<td>0.9800</td>
<td>0.176</td>
<td>2.599</td>
<td>1.355</td>
</tr>
<tr>
<td>0.9825</td>
<td>0.217</td>
<td>2.573</td>
<td>1.125</td>
</tr>
<tr>
<td>10-industry portfolios plus long-term T-bonds</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.9725</td>
<td>0.244</td>
<td>2.762</td>
<td>2.033</td>
</tr>
<tr>
<td>0.9750</td>
<td>0.237</td>
<td>2.749</td>
<td>1.823</td>
</tr>
<tr>
<td>0.9775</td>
<td>0.255</td>
<td>2.769</td>
<td>1.595</td>
</tr>
</tbody>
</table>

Column 1 is for the NCREIF Timberland Index and column 2 is for returns on a dynamic portfolio of the US publicly traded forestry firms that had or have been managing timberlands.

US publicly traded timber firms. The parametric analyses reveal that private-equity timberland assets outperform the market but have low systematic risk, whereas public-equity timberland assets perform similarly to the market. Therefore, inclusion of private-equity timberland properties can improve the efficient frontier, albeit such potential is limited for public-equity timberland properties. Unlike the parametric methods, the nonparametric SDF approach does not rely on any specific asset pricing models and hence is not subject to the “joint hypothesis tests” criticisms. Results from the SDF approach suggest higher excess returns for both private- and public-equity timberland investments, which in turn signify the important role of intertemporal consumption decisions in rational pricing of timberland assets.

The positive $\alpha$ of private-equity timberland returns may be associated with the patience of institutional investors toward embedded strategic options for timberlands (Zinkhan 2008). If a timberland property has potential for higher and better use such as residential or commercial development opportunities or if it is suitable for conservation easements or if it has mineral or gas opportunities, it may have extra income sources, and the land value can be dramatically higher. The positive $\alpha$ may also be related to the liquidity risk that institutional investors bear because a typical TIMO has an investment time horizon of 10–15 years or even longer. In contrast, stocks of publicly traded timber firms can be easily traded on the stock exchanges. Moreover, initiation of a TIMO-type separately managed account usually requires a capi-
to the massive restructurings of these firms. For instance, Plum Creek, Potlatch, and Rayonier have converted themselves into timber REITs in recent years. With improved tax efficiency and increased concentration on timberland management, these timber REITs are expected to be less risky.

Another interesting fact noted in this study is that, despite the current economic downturn triggered by the subprime residential mortgage blowup, private-equity timberland returns remain relatively strong. Whereas the CRSP market index went down 39% in 2008, the NCREIF Timberland Index achieved a 9% return or, on the risk-adjusted basis, an excess return of 10% (calculated using the estimated α series in 2008). In contrast, the portfolio value of publicly traded timber firms fell 39% just like the market. However, it should be noted that most of those forestry firms do have nontimberland business, such as paper and lumber mills, which may be more sensitive to the overall economic conditions. A close examination of the three publicly traded timber REITs reveals that they were less affected by the gloomy market. Looking ahead, the global economic crisis will last for some time, multiple factors will affect timberland returns, and the net effect on timberland properties has yet to be observed (Washburn 2008).

It should be noted that there have been some concerns about the data and method consistency of the NCREIF Timberland Index. As pointed out by Binkley et al. (1996), there is no standardized appraisal and valuation practice in forestry, so heterogeneity may exist in the data. In addition, because of the lack of quarterly appraisals for many properties in the NCREIF Timberland Index, quarterly return series may be less useful than annual ones. Finally, the NCREIF Timberland Index is a composite performance measure of a very large pool of commercial forestland properties acquired in the private market for investment purposes. Hence caution should be used in interpretation of the NCREIF Timberland Index, especially from an individual investor’s perspective.

Literature Cited


\[
\text{Max}_{C_t} \mathbb{E} \left[ \sum_{t=0}^{\infty} \beta^t U(C_{t+1}) \right] \tag{A4}
\]

subject to

\[
\sum_{j=1}^{N} x_j^t p_t^j + C_t = W_t + \sum_{j=1}^{N} x_{j-1}^t (p_t^j + d_t^j),
\]

where \(x_j^t\) is the amount of security \(j\) purchased at time \(t\), \(p_t^j\) is the price of security \(j\) at time \(t\), \(W_t\) is the individual’s endowed wealth at time \(t\), \(C_t\) is the individual’s consumption at time \(t\), \(d_t^j\) is the dividend paid by security \(j\) at time \(t\), and \(\beta\) is time discount. Express \(C_t\) in terms of \(x_j^t\) and differentiate the objective function with respect to \(x_j^t\); then we can get the first-order condition.

\[
\mathbb{E}_t[U'(C_t)p_t^j] = \mathbb{E}_t[\beta U'(C_{t+1}) (p_t^j + d_t^j)]. \tag{A5}
\]

for all \(j\). After rearranging the terms, we can reach Equation 6, where

\[
M_t = \frac{\beta U'(C_{t+1})}{U'(C_t)} R_{t+1} = \frac{p_t^{j+1} + d_t^{j+1}}{p_t^j} - 1. \tag{A6}
\]

Appendix A: State Space Model with Kalman Filter

The multivariate time series model can be represented by the state space form

\[
y_t = Z_t \alpha_t + \varepsilon_t, \quad \varepsilon_t \sim \text{NID}(0, H_t), \tag{A1}
\]

\[
\alpha_{t+1} = T_t \alpha_t + R_t \eta_t, \quad \eta_t \sim \text{NID}(0, Q_t), \tag{A2}
\]

for \(t = 1, …, N\), where \(y_t\) is a \(p \times 1\) vector of observed values at time \(t\), \(Z_t\) is a \(p \times m\) matrix of variables, \(\alpha_t\) is an \(m \times 1\) state vector, \(T_t\) is called the transition matrix of order \(m \times m\), and \(R_t\) is an \(m \times r\) selection matrix with \(m \geq r\). The first equation is called the observation or measurement equation, and the second is called the state equation. The parameters \(\alpha_0, H_0, \) and \(Q_0\) in the system of equations can be estimated jointly by the maximum likelihood method with the recursive algorithm Kalman filter. The intention of filtering is to update the information of the system each time a new observation \(y_t\) is available, and the filtering equations are

\[
v_t = y_t - Z_t \alpha_t, \quad F_t = Z_t P_t Z_t' + H_t, \quad K_t = T_t P_t Z_t' F_t^{-1}, \tag{A3}
\]

\[
L_t = T_t - K_t Z_t, \quad a_{t+1} = T_t a_t + K_t v_t, \quad P_{t+1} = T_t P_t T_t' + R_t Q_t R_t',
\]

for \(t = 1, …, N\). The mean vector \(a_0\) and the variance matrix \(P_0\) are known for the initial state vector \(a_0\) (Harvey 1989, Durbin and Koopman 2001).

Appendix B: Heuristic Proof of Equation 6

In a pure exchange economy with identical consumers, a typical consumer wishes to maximize the expected sum of time-separable utilities, the second is called the state equation. The parameters \(\alpha_0, H_0, \) and \(Q_0\) in the system of equations can be estimated jointly by the maximum likelihood method with the recursive algorithm Kalman filter. The intention of filtering is to update the information of the system each time a new observation \(y_t\) is available, and the filtering equations are

\[
v_t = y_t - Z_t \alpha_t, \quad F_t = Z_t P_t Z_t' + H_t, \quad K_t = T_t P_t Z_t' F_t^{-1}, \tag{A3}
\]

\[
L_t = T_t - K_t Z_t, \quad a_{t+1} = T_t a_t + K_t v_t, \quad P_{t+1} = T_t P_t T_t' + R_t Q_t R_t',
\]

for \(t = 1, …, N\). The mean vector \(a_0\) and the variance matrix \(P_0\) are known for the initial state vector \(a_0\) (Harvey 1989, Durbin and Koopman 2001).

Appendix C: NCREIF Timberland Index

The NCREIF Timberland Index has two components: the income return and the capital return. The income return is also known as EBITDDA return, which represents earnings before interest expenses, income taxes, depreciation, depletion, and amortization. The capital return is derived from land appreciation. The formulas to calculate these returns are

\[
\text{IR}_t = \frac{\text{EBITDDA}_t}{\text{MV}_{t-1} + 0.5(\text{CR}_t - \text{PS}_t - \text{PP}_t - \text{EBITDDA}_t)}, \tag{A7}
\]

\[
\text{CR}_t = \frac{\text{MV}_t - \text{MV}_{t-1} - \text{CI}_t + \text{PP}_t - \text{PS}_t}{\text{MV}_{t+1} + 0.5(\text{CI}_t - \text{PS}_t + \text{PP}_t - \text{EBITDDA}_t)}, \tag{A8}
\]

where \(\text{IR}_t\) and \(\text{CR}_t\) are the income return and capital return, respectively, \(\text{EBITDDA}_t\) equals the net operating revenue obtained from the tree farm (primarily from timber sales), \(\text{CI}_t\) equals the capitalized expenditures on the tree farm (e.g., forest regeneration and road construction), \(\text{PS}_t\) equals the proceeds from sales of land from the tree farm, \(\text{PP}_t\) equals the gross costs of adding land to the tree farm, and \(\text{MV}_t\) equals the market value of the tree farm (Binkley et al. 2003).