Abstract

Forestry-related assets, especially timberland assets are regarded as good candidates for portfolio diversification because of its low correlation with market. In this paper, the intertemporal capital asset pricing model (ICAPM) is used to assess the risk-return relationship between forestry-related assets and innovations to state variables which proxy for the changes in investment opportunity set. Results in this study show that the ICAPM that includes the market excess returns and innovations to size and value effect, risk-free rate, term spread, default and consumption cannot be rejected and the model succeeds to explain more than 80% of the variation in cross-section returns of forestry-related assets. While the widely used CAPM and Fama-French three factor model are rejected. Moreover, beta loadings on market excess return, innovations to risk-free rate and default spread induce significant positive risk premiums, indicating that in determining the expected returns of forestry-related asset, innovations to these state variables are important risk factors that should be priced.
Introduction

Timberland investment has attracted more and more attention nowadays. Timberland asset has three return drivers: biological growth, timber price change and land value appreciation (Caulfield 1998). Unlike other financial investments or even real estate investments, timberland investment distinguishes itself from other assets by its biological growth, which is independent with the financial market. Many studies on the financial performance of timberland assets have found weakly correlation with financial markets and have low systematic risk. These characteristics make timberland investment play an important role in diversifying risk for portfolio investors (Healey et al. 2005; Lonnstedt and Svensson 2000; Newell and Eves 2009; Waggle and Johnson 2009; Zinkhan and Cubbage 2003). Moreover, timberland has the ability to hedge against anticipated or unanticipated inflation (Martin 2010; Wan et al. 2012; Washburn and Binkley 1993). During the past several decades, the timberland market becomes more and more competitive, which alleviates the inefficiency of the market through time (Caulfield 1998; Zinkhan 2008).

Most of the studies are based on the capital asset pricing model (CAPM) developed by Sharpe (1964) and Lintner (1965). The CAPM is a static single factor model states that the expected return of an asset is proportional to its covariance with market portfolio (Bollerslev et al. 1988). However, the CAPM assumes that investors have homogeneous expectation and ignores the time variation in expected returns, which have been criticized by many studies (Campbell 1996; Merton 1973; Roll 1977). Furthermore, many empirical tests show the failures of the CAPM (Black et al. 1972; Fama and French 2004; Gibbons et al. 1989; Merton 1971).

Due to the imperfect performance of the CAPM, Merton (1973) developed the intertemporal capital asset pricing model (ICAPM). The model is to maximize the expected utility of lifetime consumption and to assume the investors trade continuously. It states that, besides the market risk, risk of unfavorable shifts in the investment opportunity set proxied by the changes of the so-called state-variables may be contained to compensate for expected returns.

Literature Review

The ICAPM is important in the theoretical standpoint; however, it is difficult to identify the state-variables (Breeden 1979). Studies focused on the empirical testing of the ICAPM have identified significant state-variables. The real interest rate is observable and time-varying, which represents the stochastic characteristic of investment opportunity set (Abhyankar and Gonzalez 2009; Brennan et al. 2004; Campbell and Vuolteenaho 2004; Fama and French 1993; Hui 2006; Merton 1973). The aggregate real consumption rate covers a significant fraction of true consumption and adds explanatory power to the expected returns (Bollerslev et al. 1988; Breeden 1979; Hui 2006). The term spread, calculated as the difference between the 10-year Treasury bond and the 3-month Treasury bill, has negative impact in estimating the expected returns (Bali and Engle 2010; Evans 1994; Fama and French 1989). The implied volatility of the market from index options measures the market’s future volatility and significantly negative relation is found between the expected returns and the implied volatility (Bali 2007; Bollerslev et al. 1988; Daly and Vo 2008; Guo and Whitelaw 2006). Other significant state-variables including the market dividend yield (Campbell and Shiller 1988; Fama and French 1988), size and book-to-market ratio (Bali 2007; Bali and Engle 2010; Kothari and Shanken 1997).
The contribution of our study is to investigate the intertemporal relation between the risk and return of the forestry-related assets using different state-variables. And the innovations to state variables are estimated using generalized autoregressive conditional heteroskedasticity model (GARCH). To our best knowledge, no work has been done by applying Merton’s ICAPM framework in forestry-related field.

Methodology

ICAPM Framework

In this study, the discrete-time version of the ICAPM is assumed to account for the cross-section of asset returns. According to the ICAPM, besides the market risk, risks of unfavorable shifts in the investment opportunity set should also be contained to compensate for expected returns. Thus, assets’ expected return is a linear function of the excess return on market portfolio as well as the innovations to state variables. The unconditional expected excess return can be written as:

$$E(R_i) - R_f = \beta_i \lambda_M + \sum \beta_{i,k} \lambda_{k}, \forall i, k = 1,2,\ldots,K,$$

where $E(R_i)$ is the expected return of asset $i$, $R_f$ is the risk-free rate, $\lambda_M$ is the market risk premium, and $\lambda_{k}$ is the price of risk for innovation to state variable $k$. Coefficients $\beta_i$ are obtained from regressions of asset returns on market excess return and innovations to state variables:

$$R_{it} - R_f = \alpha_i + \beta_{i,M} (R_{Mt} - R_f) + \sum \beta_{i,k} \epsilon_i^k + u_{it}, \forall i,$$

where $R_{it}$ and $R_{Mt}$ are returns of asset $i$ and market at time $t$, respectively. $\epsilon_i^k$ is innovation to state variables $k$ at time $t$ and $u_{it}$ is error of the regressions.

Innovation in State Variables

Innovations are the unexpected shocks to state variables, which can be represented as the difference between the actual return and expected return conditional on the given information:

$$\epsilon_i^k = r_i^k - \mu_i^k = r_i^k - E(r_i^k | F_{t-1}),$$

where $r_i^k$ is return of state variable $k$ at time $t$, $\mu_i^k$ is the conditional mean of $r_i^k$ given the information set available at time $t-1$, $F_{t-1}$. To obtain the dynamics of innovations to the state variables, we assume $\epsilon_i^k$ follows a GARCH (1, 1) model, then

$$\epsilon_i^k = z_i \sqrt{h_i^k},$$

$$h_i^k = \alpha_0 + \alpha_i (\epsilon_{i-1}^k)^2 + \beta_i h_{i-1}^k,$$

where $\{z_i\}$ is a sequence of iid random variables with mean 0 and variance 1. $h_i^k$ is the conditional variance for the innovation $\epsilon_i^k$ given the information set $F_{t-1}$, $\alpha_0 > 0$, $\alpha_i \geq 0$, $\beta_i \geq 0$, and $\alpha_i + \beta_i < 1$. The maximum-likelihood method is applied to estimate the parameters in the GARCH (1, 1) model. Since the magnitudes of different state variables vary, in order to make innovations comparable among all state variables, we use the standardized innovations $\tilde{\epsilon}_i^k = \epsilon_i^k / h_i^k$.

Cross-sectional Regression
According to the ICAPM, the innovations derived from the GARCH (1, 1) model are risk factors in addition to the market excess returns. From equation (1), the expected excess return of asset depends on the exposures to the risk factors and the rewards for bearing such risks. To test the implication of the ICAPM as well as estimating the expected returns for assets, the 2-step cross-sectional regression procedure is used. As introduced by Fama and Macbeth (1973), this method is widely used in the analysis of cross-section of asset returns. In the first step, OLS is used to estimate a series of time-series regressions of equation (2) for each asset, which provides assets’ loadings with respect to the market excess returns as well as innovations to state variables. The beta coefficients are obtained as the loadings with respect to the risk factors. In the second step, the excess returns of all the assets studied are related to their loadings on the risk factors. In another word, the prices of the risk factors are estimated using the cross-sectional regressions.

\[
R_{it} - R_f = \lambda_{0j} + \lambda_{M,i} \hat{P}_{i,M} + \sum \lambda_{\epsilon_{it}} \hat{P}_{i,\epsilon} + e_{it}, \forall i,
\]

for \( i = 1, 2, ..., N \) and \( t = 1, 2, ..., T \), where \( \lambda_{0j} \) is the intercept, \( e_{it} \) is the error term, \( N \) is the total number of assets, and \( T \) is the sample length. That is, there is one regression across the \( N \) assets for each time period and there are \( T \) such regressions in total. This way, a time series is constructed for each risk premium. Then, averages are taken over the whole sample time period as \( \bar{\lambda}_j = \frac{1}{T} \sum_{t=1}^{T} \lambda_{jt} \) for \( j = 1, 2, ..., n \). In equation (6), \( \hat{\beta}_{i,M} \) and \( \hat{\beta}_{i,\epsilon} \) are slope coefficients of market excess return and innovation to state variables that are estimated in the first step using equation (2).

As many studies indicated that, the 2-step cross-sectional regression will cause the so-called error-in-variable (EIV) problem. That is to say, betas used in equation (6) as independent variables are generated from time-series regression may contain errors. To account for sampling errors of betas when computing standard errors and overstating precision of price of risk factors, a correction method provided by Shanken (1992) is applied. Based on Shanken’s correction (Shanken 1992), the EIV adjustment is yielded from combining the price of risk estimates with the sample covariance matrix of the factors. To account for EIV, the standard error of the estimates should be multiplied and the t-statistic should be divided by square root of the EIV adjustment.

Data

This study tends to explore the risk return relationship between the forestry-related assets and the innovations to state-variables. Quarterly data used in this study ranges from 1988Q1 to 2011Q4. Forestry-related assets in this study include the private- and public-equity timberland assets, forest products and timbers. Returns for private-equity timberland investments are approximated by NCRIEF (NTI) and John Hancock (JHTI) timberland indices. NTI is a quarterly reported data at the national and regional levels. Due to the data limitation, in this study, the national, the South and the Pacific Northwest levels abbreviated as NTI_US, NTI_S and NTI_PNW are used. In May 2012, NCREIF released the Timberland Fund and Separate Account Index (TFSAI), which reflects actual returns of a portfolio of timber funds and account. This index overcomes the criticized appraisal nature of the NTI and is further disaggregated into the commingled fund index (CFI) and the separate account index (SAI). In this study, the TFSAI, the
CFI, and the SAI, all net of fees, are used to represent real business returns of private-equity timberland investments. John Hancock Timber Indices, i.e., US domestic timberland return index (JHTI-US), non-US timberland return index (JHTI-NUS), and global timberland return index (JHTI-G), compiled by the Hancock Timber Resource Group represent individual TIMO returns at different regional scales (Hancock Timber Resource Group 2010).¹

Public-equity timberland investment returns (PUBLIC) are approximated by value-weighted returns on a dynamic portfolio of publicly-traded timber firms in the United States that had or have been managing timberlands. These firms include Deltic Timber, IP Timberlands Ltd., Plum Creek, Pope Resources, Potlatch, Rayonier, The Timber Co., and Weyerhaeuser. Deltic Timber and Pope Resources are natural resources companies focusing on the ownership and management of timberlands; The Timber Co. and IP Timberlands Ltd. are subsidiaries of Georgia-Pacific and International Paper that were separately listed and tracked the values and financial performances of their timberland assets; Plum Creek, Potlatch, Rayonier, and Weyerhaeuser are publicly-traded REITs that invest in timberlands. Values of these firms are defined by their market capitalizations calculated as the closing stock prices multiplied by the total shares outstanding. These data are obtained from the Center for Research in Security Prices (CRSP).

Returns of the lumber and wood products industry (WOOD), furniture and fixtures industry (FURNI), and paper and allied products (PAPER) come from French (2012) and represent the overall performance of the forest products industry. Stumpage prices for southern pines in the South (SSP), average values of timber sold on national forests in the Pacific Northwest (PNWSP), and Random Lengths Framing Lumber Composite Prices (LUMBER) represent market conditions for various forest products and are extracted from Timber Mart-South (Norris Foundation 1977-2012), Kling (2008), and Random Length (2012), respectively.

For risk factors, market returns (MKT) are approximated by value-weighted returns on all NYSE, AMEX, and NASDAQ stocks come from the CRSP. For state-variables, the macroeconomic variables (short-term Treasury bill and term spread), financial factors (size and book-to-market) and aggregate consumption rate are considered. Short-term Treasury bill (RF) is approximated by the One-month Treasury bill rate that is obtained from the CRSP. Term spread (TERM) is the return difference between the 10-year Treasury bond and 3-month Treasury bill. Default spread (DEF) is the return difference between the AAA bond rate and BAA bond rate. The data is from the H.15 database of the Federal Reserve Board. Size and book-to-market are approximated by SMB and HML factors obtained from the French website. The quarterly real personal consumption expenditures are used to represent the aggregate consumption (CONS). All level indices are converted to returns by taking differences after the logarithm transformations. In summary, there are seven proxies for timberland investment returns and 5 state-variables.

¹ Hancock Timber Resource Group is one of the largest TIMOs in the world. As of 2011, assets under management totaled $9.1 billion. These assets are located in the United States, Canada, Australia, New Zealand, and Brazil.
Empirical results

Innovations to State Variables

The innovations to state variables are used as risk factors which are estimated using a joint estimation of mean equation – GARCH (1, 1) model. The residuals from the mean equation for each state variable are standardized by their dynamic volatility from the GARCH (1, 1) model. Figure 1 show the time-series of standardized shocks to state variables. The figures show that the standardized innovations to financial factors such as size and value effect vary from negative 4 to positive 3, which have the largest variations. On the other hand, macroeconomic variables such as risk-free rate, term spread and default spread have relatively smaller variations in the standardized innovations, which are from negative 0.5 to 2. Specifically, innovations to risk-free rate are flat over time compare to other state variables. The innovations to consumption spread from negative 1 to 1.5. Although the magnitudes of the innovations to the state variables vary a lot, all variables track the shocks during financial crises around 2007.

Figure 1. Innovations to state variables

Fama-Macbeth Cross-sectional Regression

To test the risk-return relationship between forestry-related assets and the innovations to state variables, the Fama-Macbeth cross-sectional regressions are conducted. Initially, we test the quarterly excess returns on the 16 forestry-related assets for the period 1988 to 2011. In the first stage, the quarterly excess returns were regressed on the market excess returns and the estimated innovations to the six state variables to obtain the factor loadings using equation (2). Table 1 reports the factor loadings on market excess returns and state variables innovations from time-series regressions.
Table 1 documents assets’ beta loadings on market excess returns and innovations to state variables from time-series regressions. In particular, excess returns of the appraisal and fund-level NCREIF indices and John Hancock timberland indices, have negative beta loadings on innovations to SMB, HML, term spread and consumption. Positive loadings are obtained on market excess return, risk-free rate and default spread. The results indicate that private equity timberland investments correspond negatively to the positive shocks to the size and value portfolios, term spread and consumption. The opposite is true for the positive betas. On the other hand, the dynamic portfolio of publicly-traded timberland assets and forest products perform almost reversed as compared to the private timberland assets except for the market excess returns. Be more specific, we obtain positive beta loadings on markets excess returns and innovations to SMB, term spread and consumption. Negative beta loading are found on risk-free rate and default spread. One thing to address here is, although positive betas on market excess returns are obtained for both public and private timberland assets, the magnitudes are much smaller for the private- than the public-equity timberland assets. Moreover, beta loadings for timber prices on the risk factors are not consistent with each other.

In the second stage, the risk premiums for each state variable were estimated by running the cross-sectional regressions. To correct the EIV problem, the standard error was corrected by the Shanken’s correction. In addition, the widely used CAPM and Fama-French three factor model are tested as a comparison with the ICAPM using the same approach. Table 2 reports the estimated risk premiums corresponding to market excess returns and the innovation to each state

<table>
<thead>
<tr>
<th>Asset</th>
<th>$\beta_{MKT}$</th>
<th>$\beta_{SMB}$</th>
<th>$\beta_{HML}$</th>
<th>$\beta_{RF}$</th>
<th>$\beta_{TERM}$</th>
<th>$\beta_{DEF}$</th>
<th>$\beta_{CONS}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>NTI_US</td>
<td>0.008</td>
<td>-0.546</td>
<td>-0.283</td>
<td>2.479</td>
<td>-0.704</td>
<td>1.160</td>
<td>-1.356</td>
</tr>
<tr>
<td>NTI_S</td>
<td>0.000</td>
<td>-0.390</td>
<td>-0.780</td>
<td>0.565</td>
<td>-1.352</td>
<td>1.496</td>
<td>-0.874</td>
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<tr>
<td>NTI_PNW</td>
<td>0.005</td>
<td>-0.585</td>
<td>0.248</td>
<td>5.340</td>
<td>-1.281</td>
<td>-0.046</td>
<td>-2.479</td>
</tr>
<tr>
<td>TFSAI</td>
<td>0.016</td>
<td>-0.370</td>
<td>-0.335</td>
<td>1.865</td>
<td>-0.816</td>
<td>2.200</td>
<td>-1.143</td>
</tr>
<tr>
<td>CFI</td>
<td>0.024</td>
<td>-0.598</td>
<td>-0.263</td>
<td>0.925</td>
<td>-1.022</td>
<td>1.591</td>
<td>-0.729</td>
</tr>
<tr>
<td>SAI</td>
<td>0.019</td>
<td>-0.252</td>
<td>-0.328</td>
<td>2.131</td>
<td>-0.740</td>
<td>2.315</td>
<td>-1.305</td>
</tr>
<tr>
<td>JHTI_US</td>
<td>0.027</td>
<td>-0.073</td>
<td>0.009</td>
<td>3.084</td>
<td>-1.251</td>
<td>-0.843</td>
<td>-1.329</td>
</tr>
<tr>
<td>JHTI_NUS</td>
<td>0.015</td>
<td>-0.274</td>
<td>0.158</td>
<td>3.207</td>
<td>1.037</td>
<td>-2.509</td>
<td>-1.034</td>
</tr>
<tr>
<td>JHTI_G</td>
<td>0.024</td>
<td>-0.113</td>
<td>0.039</td>
<td>3.109</td>
<td>-0.794</td>
<td>-1.176</td>
<td>-1.270</td>
</tr>
<tr>
<td>PUBLIC</td>
<td>0.870</td>
<td>-0.216</td>
<td>0.732</td>
<td>-3.261</td>
<td>2.962</td>
<td>-7.344</td>
<td>1.634</td>
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<td>WOOD</td>
<td>1.055</td>
<td>-1.089</td>
<td>0.857</td>
<td>-4.575</td>
<td>7.599</td>
<td>-8.939</td>
<td>5.302</td>
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<td>FURN</td>
<td>1.202</td>
<td>0.409</td>
<td>-0.143</td>
<td>-7.503</td>
<td>5.603</td>
<td>-14.812</td>
<td>1.838</td>
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<tr>
<td>PAPER</td>
<td>0.822</td>
<td>-0.129</td>
<td>-0.512</td>
<td>-3.272</td>
<td>0.964</td>
<td>-4.883</td>
<td>3.317</td>
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<tr>
<td>SSP</td>
<td>0.054</td>
<td>-0.913</td>
<td>0.201</td>
<td>0.418</td>
<td>-0.636</td>
<td>-4.728</td>
<td>0.636</td>
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<tr>
<td>PNWSP</td>
<td>-0.036</td>
<td>-2.798</td>
<td>-0.301</td>
<td>7.598</td>
<td>11.646</td>
<td>-6.183</td>
<td>-8.941</td>
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<tr>
<td>LUMBER</td>
<td>0.046</td>
<td>0.312</td>
<td>-0.149</td>
<td>-0.964</td>
<td>1.672</td>
<td>-8.496</td>
<td>0.189</td>
</tr>
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</table>
variable for three models. Moreover, the t-statistics before and after Shanken’s correction are reported.

Table 2 shows that the multi-factor ICAPM explains about 80% of the cross-sectional returns for the 16 forestry related assets. While only 6% and 7% of the variation in the cross-section returns is explained by the Fama-French three factor model and the CAPM. Moreover, p-value for F-test suggests rejecting the Fama-French three factor model and the CAPM, but fails to reject the ICAPM.

In addition, the ICAPM successfully establishes a significant relationship for the price of market risk while the other two models fail. Even corrected for the sample error in the beta loadings, a significantly positive market risk premium is obtained. The results indicate that the market risk is positively priced in the cross-section of forestry related assets using the ICAPM. The positive market risk premium is consistent with previous studies, since risk-averse investors do require positive premium for the market portfolio (Fama 1996). In addition, represented by significant Shanken’s t-statistics with values of 2.076 and 2.452, innovations to the risk-free rate and default spread induce positive and significant risk premiums. On the other hand, the hypotheses of significant risk premiums for the Fama-French three factor model and the CAPM are rejected since insignificant values are observed. Moreover, since excess returns are used as dependent variables, the intercept in the second stage regressions should be zero under the null hypothesis. From the results, a t-statistic of 1.691 is obtained using Shanken’s correction under the ICAPM, indicates the model fails to reject such a hypothesis, which further suggests the adequate explanatory power of the risk factors.

<table>
<thead>
<tr>
<th></th>
<th>ICAPM</th>
<th></th>
<th>FF 3-Factor</th>
<th></th>
<th>CAPM</th>
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<tr>
<td></td>
<td>Estimat</td>
<td>FM</td>
<td>t-stat</td>
<td>SH</td>
<td>t-stat</td>
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<tr>
<td>$\lambda_0$</td>
<td>0.789</td>
<td>1.927</td>
<td>1.691</td>
<td>0.901</td>
<td>1.644</td>
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<tr>
<td>$\lambda_{\text{MKT}}$</td>
<td>5.561</td>
<td>6.295</td>
<td>5.524</td>
<td>1.438</td>
<td>1.245</td>
</tr>
<tr>
<td>$\lambda_{\text{SMB}}$</td>
<td>0.724</td>
<td>1.797</td>
<td>1.577</td>
<td>-0.651</td>
<td>-1.391</td>
</tr>
<tr>
<td>$\lambda_{\text{HML}}$</td>
<td>0.477</td>
<td>1.014</td>
<td>0.890</td>
<td>-0.284</td>
<td>-0.397</td>
</tr>
<tr>
<td>$\lambda_{\text{RF}}$</td>
<td>0.347</td>
<td>2.365</td>
<td>2.076</td>
<td>-0.032</td>
<td>-0.284</td>
</tr>
<tr>
<td>$\lambda_{\text{TERM}}$</td>
<td>-0.032</td>
<td>-0.284</td>
<td>-0.249</td>
<td>0.196</td>
<td>2.794</td>
</tr>
<tr>
<td>$\lambda_{\text{CONS}}$</td>
<td>-0.294</td>
<td>-2.126</td>
<td>-1.865</td>
<td>F-stat</td>
<td>9.390</td>
</tr>
<tr>
<td>p-value</td>
<td>0.003</td>
<td>0.553</td>
<td>0.863</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adj $R^2$</td>
<td>0.797</td>
<td>0.059</td>
<td>0.069</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Overall, the multi-factor ICAPM which includes market excess returns and innovations to several state variables cannot be rejected under Shanken’s t-statistics, while the Fama-French three factor model and the CAPM are rejected. Furthermore, the market excess returns and innovations to value risk-free rate and default spread provide significant systematic risk which should be priced to the cross-section returns of forestry related assets.

Conclusion

Forestry-related assets, especially timberland assets are regarded as good candidates for portfolio diversification because of its low correlation with market. However, in this study, a complicated but more accurate ICAPM is used to study the risk-return relationship between forestry related assets and innovations to state variables which proxy the change in investment opportunity set. Results show that besides the market portfolio risk, risk in innovations to risk-free rate and default spread should be priced to the cross-section returns of forestry related assets. Positive risk premiums induced by market portfolio risk is within our expectation. In the market, investors are rational and risk-averse. Therefore, they expect the market portfolio to earn a higher return than risk-free rate because of higher risk they bear. Moreover, positive risk premiums are obtained for innovations to risk-free rate and default spread from the cross-sectional regressions. This indicates that positive shocks to risk-free rate and default spread induce positive risk premiums to cross-sectional returns of forestry related assets.

In addition, beta loadings on the risk factors between private- and public-equity timberland investments show that two assets have different performance. For example, returns of both assets are positively correlated with the market portfolio; however, public-equity timberland assets are more correlated with the market than that of the private-equity timberland assets, which are shown by the larger beta loadings. This result is consistent with previous results that private-equity timberland assets are weakly correlated with the market compared with the public-equity timberland asset (Mei and Clutter 2010; Sun and Zhang 2001). Moreover, beta loadings on innovation to risk-free rate are positive for all private-equity timberland assets and negative loadings are found for private-equity timberland assets and forest products. During recession, risk-free rate will be cut to boost economics, combined with positive risk premiums induced by riskless rate factor, negative shock to risk-free rate will decrease the expected return of private-equity timberland assets and increase expected return of public-equity timberland asset and forest products. One explanation to this is that private-equity timberland assets whose returns correlate positively with innovations to risk-free rate would be seen as hedges against the risk, during bad times, such assets would be demanded more by risk-averse investors, which further drives the prices up, implying lower future average returns. Public-equity timberland asset and forest products, on the other hand, do not hedge against shocks to riskless asset. Furthermore, innovations to default spread add positive risk premium to cross-section returns of forestry-related assets. Default spread measures the yield difference between different bonds due to their different credit quality. Higher default spread indicates higher default risk, which can reflect a weakening of the macroeconomic condition. With positive shocks to default spread, expected returns of private-equity timberland assets tend to increase, which suggests a lower price of such assets. In contrast, public-equity timberland assets have negative correlation with innovations to default spread, with positive shocks to default spread, expected returns will decrease, implying higher price during weak macroeconomic condition.
In summary, the ICAPM that includes the market excess returns and innovations to size
and value effect, risk-free rate, term spread, default spread and consumption cannot be rejected
and the model succeeds to explain more than 80% of the variation in cross-section returns of
forestry-related assets. While the widely used CAPM and Fama-French three factor model are
rejected. Moreover, beta loadings on market excess return, innovations to risk-free rate and
default spread induce significant positive risk premiums, indicating that in determining the
expected returns of forestry-related asset, innovations to these state variables are important risk
factors that should be priced.

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