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Insights into index construction methods and results**

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Insights into index construction methods and results**

Abstract: This study compares different index construction methods of timberland investment returns and evaluates the resulting indices by various asset pricing models. In addition to various NCRIF indices, I include a desmoothed index which attempts to restore property market values; a transaction-based index which tracks ex post transaction prices; and a pure-play index which is based on unleveraged returns of public timber firms and only has exposures to the timber segment. The findings are appraisal-based timberland index has higher mean and lower volatility as compared with the transaction-based timberland index; separate accounts outperform comingled funds in the private timberland market; the pure-play timberland index exhibits higher return and lower risk than the corresponding portfolio of public timber firms; and abnormal performance of timberland asset becomes less significant after controlling for the appraisal smoothing or by using real transaction data. These results can help timberland investors better benchmark their financial performance.

Keywords: Appraisal · Asset pricing · Deleveraging · Forestry · REIT

JEL Classification Q23 · R33

Introduction

Over years, timberland has been recognized as an alternative asset class that has low risk and offers commensurate long-term investment returns. Unique to this asset class, timberland value appreciates while trees are growing and timber products can be stored on the stump for many years with little cost other than the opportunity cost of the capital employed (Zinkhan et al. 1992).¹ As such, the biological growth that forests produce functions as a “buffer zone” for timberland investors during economic downturns.² For example, even if timber prices plummet by 15% for a given year, the total timberland investment return will fall by less than 15% because the positive biological growth offsets some of the negative price effect on the total timber revenue. In fact, it has been shown that biological growth outweighs timber price change and land value appreciation, and is the primary return driver for timberland investments (Mei et al. 2013).

Timberland investment management organizations (TIMOs) or real estate investment trusts (REITs) have emerged as major owners of industrial timberland due to the recent shift in timberland ownership within the forest products industry (Mei and Clutter 2010). This ownership change has resulted in a win-win situation where timberland assets realized their fair market values being separated into their own market and forest products firms gained value as well by concentrating more on the core business of manufacturing after their timberland divestiture (Mei et al. 2009; Sun and Zhang 2011). Together, TIMOs, representing private equity, control about 20 million acres of timberland, while public firms, representing public equity, control about 23 million acres of timberland (Hood et al. 2015). In addition to the five major public timber REITs, including Weyerhaeuser (WY), Plum Creek (PCL), Rayonier (RYN), Potlatch (PCH), and CatchMark (CTT), there are two publicly-traded timber firms, Deltic Timber (DEL) and Pope Resources (POPE).³

¹ Capital employed includes standing timber and bare land.

² Biological growth refers to both the increase in total timber volume and the in-growth, in which lower-value product (pulpwood) trees shift to higher-value product (sawtimber) trees with the diameter increase.

³ Weyerhaeuser acquired Plum Creek on Feb 19, 2016.

To provide return information of public- and private-equity timberland investments, a number of indices exist. For private-equity timberland investment, the NCREIF Timberland Index (NTI) is widely acknowledged as the primary source for return information.⁴ For public-equity timberland investment, the value-weighted return of public timber firms (PUBLIC) is often used (e.g., Forisk Timber REIT Index). Comparison of these two return series has been targeted by a few studies (e.g., Mei and Clutter 2010; Wan et al. 2013; Yao et al. 2014). However, there are some fundamental differences in how these return indices are constructed and reported. No study has examined these issues and this study aims to uncover some insights that lie behind each index to help further describe the historical value profile of the US timberland market.

First, public timber firms use a considerable amount of debt. As shown in Fig. 1, debt ratio for the six public timber firms varied from 7% to 35% over 2010-2014. Because financial leverage changes the risk-return profile of the underlying equity, the PUBLIC should not be compared with the NTI directly because the NTI is an unlevered index (NCREIF 2016). Second, liquidity of the public- and private-equity timberland markets is quite different. Shares of stocks of public timber firms can be bought and sold easily without any appreciable impact on the trading price, while private timber funds require a minimum commitment, usually in millions of dollars, and more time to execute transactions. In other words, the PUBLIC is a constant-liquidity index but the NTI is a variable-liquidity index. Third, public timber firms often have some non-timber business segments such as wood products manufacturing that provide substantial operating income, whereas TIMOs focus more purely on timberland investments. As such, the two indices essentially reflect returns on two different business models rather than the core timberland assets. Lastly, the PUBLIC is based on real transactions on security exchanges, while the NTI is based on periodic appraisals, sales and purchases, and measures the performance of a large pool of commercial timberland properties acquired in the private market for investment purposes only (NCREIF 2016).

⁴ NCREIF: National Council of Real Estate Investment Fiduciaries.

The objective of this study is to expand existing benchmarks by including two alternative indices, i.e., the transaction-based timberland index (TBTI) and the pure-play timberland index based on securitized timber firms (PURE) because they measure timberland investment returns from different angles. Then, all indices are evaluated by several asset pricing models. The goal is not to simplistically assert that one index is correct or better than the others but rather to provide some insights into index construction methods and results. Given the fact that timberland investment return data are very limited in both quantity and quality, such comparisons may reveal the historical reality evidenced across all the indices as well as some weaknesses of the assumptions and methods in constructing such indices.

Literature Review

Research in timberland investment returns has been prolific in the past 15 years. The vast majority of these analyses use the NTI. Sun and Zhang (2001) used the CAPM and the arbitrage pricing theory in pricing forest-related assets and concluded that the NTI exhibited a low systematic risk and a positive abnormal return. Newell and Eves (2009) used the NTI to show that US timberland was a strongly performing asset class with significant portfolio diversification benefits over 1977-2007. Liao et al. (2009) and Clements et al. (2011) used cointegration analyses on a number of assets and argued that the NTI was cointegrated with other indices in the long run. Mei and Clutter (2010) compared the NTI with the PUBLIC and concluded that the former had significant abnormal returns over the years 1987 to 2009. Gao and Mei (2013) demonstrated that investor attention has significant impacts on the abnormal performance of the NTI. Wan et al. (2013) found that the NTI could hedge against both anticipated and unanticipated inflation. La and Mei (2015) revealed no general trends among timber REIT returns and the S&P 500, and recommended each timber REIT as a separate long-term risk diversifier. Wan et al. (2015) showed that the NTI maintained a significant allocation in the mixed portfolio under the mean-conditional-value-at-risk framework. Yao et al. (2014) applied the arbitrage pricing theory to the NTI and found that it had higher required returns as more risk factors were included. Yao and Mei (2015) claimed

that the excess returns of both the NTI and the PUBLIC were declining based on the intertemporal capital asset pricing model.

Realizing the weakness of existing timberland indices, a few studies further tested them or explored alternative ways to gauge timberland investment returns. Mei (2015a) illustrated that the assumption of independent and identically distributed returns is violated by the NTI but not the PUBLIC. Scholtens and Spierdijk (2010) removed the appraisal smoothing in the NTI and found less evidence of improved mean-variance efficiency by including timberland assets. Mei (2015b) derived the PURE based on asset values of different business segments of public timber firms, and showed that it differed in the first two moments (mean and variance) from the NTI and that it tended to lead the NTI for about one quarter. Mei (2016) used property-level data to build the TBTI and showed that liquidity of private timberland equity varies with business cycles and that volatility of the TBTI is twice as high as that of the NTI.

Index Construction Methods

NCREIF Timberland Index

The NTI is released on a quarterly basis and dates back to 1987Q1. It is based on data reported by data contributing members and tracks returns from a changing collection of privately held timberland properties in the United States. As of 2014Q4, the NTI consisted of over 13 million acres with a market value of about \$24 billion (NCREIF 2016). The NTI includes both income return⁵, which comes from operating activities such as timber sales, and capital appreciation, which is based on appraisals. The formulas used to calculate the index are

$$IR_t = \frac{EBITDDA_t}{MV_{t-1} + 0.5(CI_t - PS_t + PP_t - EBITDDA_t)} \quad (1)$$

⁵ Also known as cash return or EBITDDA, earnings before income tax, depreciation, depletion, and amortization.

133
$$CR_t = \frac{MV_t - MV_{t-1} - CI_t + PS_t - PP_t}{MV_{t-1} + 0.5(CI_t - PS_t + PP_t - EBITDDA_t)} \tag{2}$$

134 where IR_t and CR_t are the income return and capital return, respectively; CI_t equals the capitalized
135 expenditures (e.g., forest regeneration); PS_t equals the net proceeds from land sales; PP_t equals the gross
136 costs of new land acquisitions; and MV_t equals the market value of the property (Binkley et al. 2003).

137 Many analysts argue that the appraisal-based NTI underestimates the volatility of timberland
138 returns and does not necessarily reveal the information of real transactions. Moreover, the NTI measures
139 gross returns before investment advisory fees. To deal with the latter concern, the NCREIF released the
140 timberland Comingled Fund Index (CFI) and Separate Account Index (SAI) dating back to 1988Q1.⁶ The
141 CFI and SAI reflect returns at the fund level and are available net of management and advisory fees
142 (NCREIF 2016).

143 *Unsmoothed NCREIF Timberland Index*

144 A number of statistical techniques have been proposed to solve the problem of appraisal
145 smoothing. An in-depth comparison of these desmoothing methods is beyond the scope of this study,
146 albeit the one outlined in Geltner (1993) is adopted to desmooth the NTI. To recover the market values,
147 the following transfer function is used

148
$$\kappa_t^* = \frac{\kappa_t - (1-a)\kappa_{t-1}}{a} \tag{3}$$

149 where κ^* is the unobservable return, κ is the observed appraisal-based return and a is an adjustment
150 factor that accounts for seasonality and appraiser confidence. Geltner (1993) suggested that $a = 0.40$

⁶ A comingled fund is used for grouped, relatively small investors or investors that are required to invest in fund vehicles, whereas a separate account is used for a single, large investor.

with a reasonable range of 0.33 to 0.50.⁷ The recovered series should be rescaled so that it preserves the mean of the original series.

Transaction-based timberland index

The NTI is an ex ante index that is based on the expected selling price in the open market that applies to any property assuming a constant market liquidity.⁸ In contrast, transaction-based index is a measure of value changes of a given pool of properties only when they are traded. That is, the TBTI is an ex post index that is based only on actual transactions that differ in quality and market liquidity. A typical timberland sale process can be described by a double-sided search market. In Fig. 2, the bell curves show the frequency distributions of market participants' reservation prices, with buyers' on the left, sellers' on the right, and the horizontal axis denoting reservation prices. The total number of sellers (buyers) willing to sell (buy) at any price P is revealed by the area to the right (left) under the seller (buyer) reservation price frequency distribution. The dispersion in the distributions indicates the difference in perceptions of values and search costs of market players, whereas the overlap grants profitable trades of properties. At time t , P_1 is the highest bid price from buyers, P_2 is the lowest ask price from sellers, P_0 is the expected market clearing price, and the size of the overlap area resembles the trading volume or degree of liquidity. A transaction is likely to arise whenever there is a seller-buyer match with $P_2 \leq P_0 \leq P_1$. When market conditions change or investor / manager objectives change, reservation price distributions may shift or change shape and sellers and buyers will adjust their reservation prices accordingly. These changes may not occur in the same manner and the resulting overlap area varies over time, reflecting the variations in the trading volume for a given population of assets.

The expected sale price responds to both underlying market and firm specific movements in reservation price distributions, whereas the trading volume responds to differential movements only. The

⁷ A value of 0.33 means more smoothing and a value of 0.50 means less smoothing. A value of 0.40 implies that an appraiser puts 50% weight on the past appraised value in assessing the current value and that 55% of all properties are reappraised during the fourth calendar quarter.

⁸ Market liquidity means the degree to which an asset can be traded in the market without affecting its price. It measures the trade-off between the speed of the sale and the price an asset can be sold for.

differential movements influence both trading price and volume, which are linked to the ease of selling a property. Using property-level timberland transaction data and the Heckman (1979) procedure, Mei (2016) derived the TBTI.⁹

Pure-play index based on public timber firms

A modified version of Geltner-Kluger model can be employed to construct pure-play return indices, in which contemporaneous, unleveraged monthly returns of public timber firms are regressed on a set of variables that denote percentage business-segment holdings of each firm (Horrigan et al. 2009),

$$r_{i,t} = b_{1,t}x_{1,i,t} + b_{2,t}x_{2,i,t} + \dots + b_{K,t}x_{K,i,t} + e_{i,t} \tag{4}$$

where $r_{i,t}$ is the delevered total return of firm i ,¹⁰ $x_{j,i,t}$ indicates firm i 's proportion of total assets held in segment j ($j \in \{1, 2, \dots, K\}$ with K representing the total number of segments and $\sum_j^K x_{j,i,t} = 1$ for all i and t), $b_{j,t}$ is segment j 's market index return, and $e_{i,t}$ is the error term, all at time t ($t \in \{1, 2, \dots, T\}$ with T representing the length of the observation period).

Suspecting that larger firms have smaller idiosyncratic return variances owing to larger, more diversified property holdings, generalized least squares (GLS) is typically used to estimate Equation (4). Using unleveraged returns of six publicly-traded timber firms, i.e., WY, PCL, RYN, PCH, DEL, and POPE, in the United States over 2010-2014, Mei (2015b) constructed the PURE.

Other return indices and data frequency

Market return (MKT) is proxied by the value-weighted return of all CRSP firms incorporated in the US and listed on NYSE, AMEX, and NASDAQ. Risk-free rate is proxied by the 1-month Treasury bill rate. These combined with the Fama-French factors, the 5-industry portfolio returns, and the returns

⁹ The TBTI is an annual index ranging from 2003 to 2014 because of limited numbers of transactions for early years. Selected statistics of the property-level data are reported in the Appendix.

¹⁰ Deleveraged using the weighted average cost of capital equation.

on 10-year Treasury bonds all come from WRDS (WRDS 2016). The five industries consist of consumer goods, manufacturing, hi-tech, health care and others.

Data frequency varies across timberland indices. Annual data are used considering the following facts. First, although the NTI is reported quarterly, most appraisals occur at the year end. This introduces artificial variations in the fourth quarter of each year and makes the quarterly NTI less interpretable than the annual one (Cascio and Clutter 2008). Second, the TBTI can only be derived at the annual level after 2002 given the limited number of transactions within each quarter. Hence, all other higher-frequency indices are compounded into annual ones, resulting in 1988-2014 series for all NCREIF indices and the PUBLIC, 2010-2014 series for the PURE, and 2003-2014 series for the TBTI.

Index Evaluation Methods

CAPM

CAPM is a widely used asset pricing model because it offers an intuitive measure of risk and explains the risk-return relation (Fama and French 2004). In a mean-variance efficient setting, 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 beta (β_i) and the expected risk premium on the market portfolio $E[R_m] - R_f$, i.e.,

$$E[R_i] = R_f + \beta_i(E[R_m] - R_f). \quad (5)$$

In particular, β_i is also known as the measure of systematic risk, which is inherent to the entire market and cannot be diversified away by the portfolio strategy. Therefore, in equilibrium, an investor will only be compensated by bearing the systematic risk but not the idiosyncratic risk.

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

$$R_i - R_f = \alpha_i + \beta_i(R_m - R_f) + \mu_i \quad (6)$$

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 measure for abnormal performance. Investors seek assets with positive alphas because they bring superior returns after adjusting for the risks.

Fama-French three-factor model

Based on the empirical observation that small and value firms outperform big and growth firms, Fama and French (1993) developed a model with two extra factors to further adjust for risk:

$$E[R_i] - R_f = \beta_{RMRF,i} E[R_{RMRF}] + \beta_{SMB,i} E[R_{SMB}] + \beta_{HML,i} E[R_{HML}] \tag{7}$$

where $R_{RMRF} = R_m - R_f$ is the same market factor as in CAPM; $R_{SMB} = R_{small} - R_{big}$ is the size factor, representing the return difference between a portfolio of small stocks and a portfolio of large stocks (SMB as "Small minus Big"); and $R_{HML} = R_{highBM} - R_{lowBM}$ 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 as "High minus Low"). In the regression form, ex post realized returns are used and an intercept is added to capture the abnormal performance,

$$R_i - R_f = \alpha_i + \beta_{RMRF,i} R_{RMRF} + \beta_{SMB,i} R_{SMB} + \beta_{HML,i} R_{HML} + \varepsilon_i. \tag{8}$$

Intercept α_i has similar meanings as Jensen's alpha.

Stochastic discount factor

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

$$E_t[(1 + R_{i,t+1})M_{t+1}] = 1 \tag{9}$$

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 the intertemporal marginal rate of substitution, or the pricing kernel (Campbell et al. 1997). The stochastic discount factor can be identified from a set of basis assets (Hansen and Jagannathan 1991). Accordingly, the expected return can be calculated as

$$E[R] = \frac{1 - \text{cov}(R, M)}{E[M]} - 1. \quad (10)$$

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

$$E_t[(R_{i,t+1} - R_f)M_{t+1}] = 0. \quad (11)$$

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

$$E_t[\alpha_{i,t}] = E_t[(R_{i,t+1} - R_f)M_{t+1}] = 0 \quad (12)$$

This measure generalizes Jensen's alpha and does not count on a parametric asset pricing model (Ahn et al. 2003).

Results

Descriptive statistics and summary of the indices

Summary statistics of various return indices are reported in Table 1. According to the length of the PURE and the TBTI, two additional subsamples are used, i.e., 2003-2014 and 2010-2014.¹¹ For the sample period of 1988-2014, the NCREIF indices show significant advantages over the PUBLIC and the MKT with respect to the return-to-risk ratio. However, the advantages disappear after the desmoothing because the UNTI has a volatility almost twice as large as that of the NTI and higher than those of the PUBLIC and the MKT. The PUBLIC and the MKT are very similar in mean and variance. These

¹¹ Statistics for the UNTI are not reported for the two subsamples because the desmoothing method is based on the full sample information.

findings are consistent with those from previous research. For the sample period of 2003-2014, both mean and variance are lower for the NCREIF indices, but not for the PUBLIC and the MKT. By the return-to-risk ratio, the NCREIF indices are still superior to the PUBLIC and the MKT. The TBTI, however, has a much lower mean and a much higher standard deviation than the NCREIF indices, leading to the lowest return-to-risk ratio among all indices. For the sample period of 2010-2014, the public-equity indices have significantly higher means, resulting in similar or even higher return-to-risk ratios than the NCREIF indices. The PURE is most rewarding per unit of risk. In addition, the TBTI shows a slightly negative mean and a risk comparable to those of the public-equity indices.

According to the pairwise correlation coefficients, the NTI is highly correlated with other NCREIF indices but weakly correlated with public-equity indices. The TBTI has moderate positive correlations with the NCREIF indices but negative correlations with public-equity indices. The PURE has negative correlations with other indices except for the UNTI and the PUBLIC. The evolution of these indices are plotted in Fig. 3. Some common themes emerge across different return indices. First, all indices capture the movement of business cycles (e.g., the internet bubble around 2000 and the housing market meltdown around 2008). However, the private-equity timberland indices lag public-equity timberland indices by about one year. Second, appraisal smoothing tends to exist in the NTI but the UNTI tends to overstate the volatility as compared to the TBTI. Third, the PUBLIC performs similar to the MKT and the PURE exhibits the lowest volatility among the three public-equity return indices.

Financial performance of various timberland indices

Performance results for various timberland indices are reported in Table 2. According to the CAPM, timberland assets, especially private-equity timberland assets, show significant positive abnormal returns. For example, the NTI has an α of 11.64%. The magnitude of this abnormality is reduced to 9.43% after the appraisal smoothing is removed, and further reduced to 7.03% when real timberland transactions replace appraisals in deriving the return indices. Between the two types of private timber funds, separate accounts outperform the commingled funds by about 3%. In contrast, the PUBLIC has a

lower abnormal return of 6.30%. Based on β estimates, timberland exhibits lower systematic risk than the market. However, the R^2 remains low for all return indices except for the PUBLIC. This is consistent with results from previous studies on private-equity timberland investment (e.g., Cascio and Clutter 2008; Mei and Clutter 2010). Specifically, the low R^2 results from the small sample size because annual data is used in the regression. Results from the Fama-French three-factor model are similar to those from the CAPM relative to both the expected returns and the precision of those estimates. Overall, the magnitude of α estimates (abnormal returns) is reduced and thus less significant, and the R^2 is improved.

The mean of the no-arbitrage stochastic discount factors is specified in the selected range of [0.9450, 1] with an increment step of 0.0025. With the 5-industry portfolios plus the 10-year Treasury bonds used as the basis assets, the global minimum variance (0.7050) of the stochastic discount factors is identified at $v = 0.9500$. Under such a framework, abnormal returns are lower at 1.25-6.17% but the performance ranking of all timberland indices remains unchanged in general. The 2.81% abnormal return of the PUBLIC is no longer significant at all standard levels of significance.

The actual and expected returns from various models are compared at the bottom of Table 2. In general, common asset pricing models are incapable of estimating private-equity timberland investment returns precisely. When the NTI is desmoothed, the prediction accuracy improves but still not as good as for the public timberland equity. In pricing timberland, the Fama-French three factor model outperforms the CAPM and the SDF approach.

Discussion and Conclusion

Timberland has attracted investor attention in recent years. Return information of timberland investments, however, remains limited. This study compares different index construction methods of timberland investment returns and evaluates the resulting indices by various asset pricing models. In addition to various NCRIEF indices, I include a desmoothed index which attempts to restore property

market values; a transaction-based index which tracks ex post transaction prices; and a pure-play index which is based on unleveraged returns of public timber firms and only has exposures to the timber segment. The findings are appraisal-based timberland index has higher mean and lower volatility as compared with the transaction-based timberland index; separate accounts outperform comingled funds in the private timberland market; the pure-play timberland index exhibits higher return and lower risk than the corresponding portfolio of public timber firms; and abnormal performance of timberland asset becomes less significant after controlling for the appraisal smoothing or by using real transaction data.

This paper does not intend to make improvements of existing timberland indices. Rather, it aims to offer some insightful guidance on index construction methods and results, from which timberland investors can better benchmark their returns. For small, private-equity investors, the TBTI should to be used because they are more exposed to idiosyncratic risk than large, more sophisticated institutional investors. Likewise, for wealthy families or sole investors investing in timberland through TIMOs via separate accounts, the SAI is a more proper benchmark albeit it is only reported at the national level. Second, for investors who prefer timberland assets but appreciate liquidity, public timber firms should be considered. Nonetheless, investors should understand the difference between business wrappers (privately placed vs. publicly traded) and underlying timberland assets because securitization has introduced non-diversifiable systematic risk into public timberland equity (Sun 2013). A direct investment in public timber firms is equivalent to an investment in their business models. Should an investor be interested in pure public timberland equity, however, the pure-play strategy can be followed. The PURE represents a more comparable counterpart to other private-equity timberland indices. Of course, a thorough comparison of timberland indices is only one of many steps in an investor's decision making. Other factors such as tax, investment horizon, governance, and transparency, among others, should be incorporated.

Third, commonly used asset pricing models such as the CAPM, the Fama-French three-factor model and the SDF approach fit returns on public timberland equity better than on private timberland

331 equity. This is consistent with the findings in the real estate literature where non-traded real estate assets
332 are more difficult to be priced (e.g., Fisher et al. 2004). Finally, I have to acknowledge that the sample
333 size of this study is limited by the data availability, especially for the PURE. The performance of various
334 timberland indices remain to be further examined and evaluated in the future as more data are ready.

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418 **Table 1** Descriptive statistics of various return indices

	NTI	UNTI	CFI	SAI	PUBLIC	PURE	TBTI	MKT
Individual samples								
Mean	12.58	12.58	9.59	12.61	13.09	21.69	5.04	12.38
Median	10.92	12.57	10.51	10.64	13.79	21.21	7.69	15.40
Max	37.35	63.80	25.87	34.13	39.09	33.82	23.00	36.81
Min	-5.24	-27.50	-6.32	-3.01	-39.15	9.91	-17.88	-36.74
SD	10.79	21.17	7.67	9.46	18.75	9.85	11.87	18.35
Mean/SD	1.17	0.59	1.25	1.33	0.70	2.20	0.42	0.67
No. obs.	27	27	27	27	27	5	12	27
2003-2014								
Mean	8.71		7.67	8.73	13.60		5.04	11.98
Median	9.61		9.65	9.51	13.24		7.69	13.66
Max	19.36		15.86	18.94	39.09		23.00	35.21
Min	-4.75		-6.32	-2.86	-39.15		-17.88	-36.74
SD	7.11		7.51	6.63	20.39		11.87	18.69
Mean/SD	1.22		1.02	1.32	0.67		0.42	0.64
2010-2014								
Mean	5.87		4.48	6.34	16.04	21.69	-0.06	16.25
Median	7.75		7.42	5.89	9.75	21.21	3.04	16.34
Max	10.48		9.96	13.06	37.89	33.82	11.66	35.21
Min	-0.15		-3.44	1.67	9.17	9.91	-17.88	0.48
SD	4.85		6.20	4.83	12.36	9.85	11.27	12.55
Mean/SD	1.21		0.72	1.31	1.30	2.20	-0.01	1.29
Pairwise correlations								
NTI	1.00							
UNTI	0.79	1.00						
CFI	0.89	0.74	1.00					
SAI	0.98	0.76	0.88	1.00				
PUBLIC	0.15	0.34	0.06	0.04	1.00			
PURE	-0.52	0.13	-0.33	-0.71	0.77	1.00		
TBTI	0.58	0.45	0.56	0.59	-0.43	-0.08	1.00	
MKT	0.25	0.32	0.23	0.18	0.72	-0.13	-0.28	1.00

419 NTI, the NCREIF Timberland Index; UNTI, the desmoothed NTI, CFI, the NCREIF Timberland
 420 Comingled Fund Index; SAI, the NCREIF Timberland Separate Account Index; PUBLIC, portfolio return
 421 of public timber firms; PURE, pure-play timberland index based on securitized timber firms; TBTI,
 422 transaction-based timberland index; and MKT, return on all CRSP firms. PURE runs 2010-2014, TBTI
 423 runs 2003-2014, and all other indices run 1988-2014. The Jarque-Bera test could not reject the null
 424 hypothesis of a normal distribution for all indices. Statistics for the UNTI are not reported for the two
 425 subsamples because the desmoothing method is based on the full sample information.

Table 2 Financial performance of various timberland return indices

	NTI	UNTI	CFI	SAI	PUBLIC	TBTI
CAPM						
α	11.64	9.43	8.97	12.13	6.30	7.03
	0.000	0.043	0.000	0.000	0.032	0.106
β	0.11	0.35	0.07	0.05	0.76	-0.19
	0.374	0.124	0.414	0.613	0.000	0.339
R^2	0.03	0.09	0.03	0.01	0.55	0.09
Fama-French three-factor						
α	11.02	7.94	8.51	11.54	5.67	5.81
	0.000	0.113	0.000	0.000	0.048	0.131
β_{RMR}	0.16	0.41	0.12	0.11	0.72	-0.29
	0.209	0.103	0.181	0.314	0.000	0.142
β_{SMB}	-0.22	0.08	-0.23	-0.25	0.53	0.38
	0.262	0.836	0.094	0.140	0.019	0.310
β_{HML}	0.16	0.26	0.13	0.16	0.02	0.70
	0.327	0.399	0.244	0.253	0.920	0.115
R^2	0.11	0.12	0.17	0.13	0.65	0.46
Stochastic discount factor						
Performance measure	6.17	5.69	3.55	6.40	2.81	1.25
	0.003	0.162	0.016	0.000	0.435	0.585
Expected vs. actual return						
CAPM	4.71	7.75	4.26	4.06	12.78	1.09
Fama-French three factor	5.52	9.44	4.88	4.85	13.29	2.70
Stochastic discount factor	4.99	5.51	4.75	4.76	9.19	0.94
Actual mean	12.58	12.58	9.59	12.61	13.09	5.04
No. obs.	27	27	27	27	27	5

NTI, the NCREIF Timberland Index; UNTI, the desmoothed NTI, CFI, the NCREIF Timberland
Comingled Fund Index; SAI, the NCREIF Timberland Separate Account Index; PUBLIC, portfolio return
of public timber firms; TBTI, transaction-based timberland index; and MKT, return on all CRSP firms.
TBTI runs 2003-2014 and all other indices run 1988-2014. Due to the limited sample size for the PURE,
pure-play timberland index based on securitized timber firms, its results are less meaningful and thus not
reported. Under parameter estimates are p -values from the t distribution for the CAPM and Fama-French
three-factor models, and from the χ^2 distribution for the stochastic discount factor approach. The
stochastic discount factors are retrieved from returns of a set of basis assets consisting of five industry
portfolios and 10-year Treasury bonds.

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Fig. 1 Debt ratio and cost of publicly-traded timber firms over 2010-2014 (Data Source: Firms' 10-K reports)

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439 **Fig. 2** Evolution of buyer and seller reservation price distributions and transaction turnover

Fig. 3 Evolution of various return indices (in percentage)

444 Appendix

445
446 **Fig. A1** Average sale price (\$/ac, left axis) and sale count (right axis) from property-level timberland
447 transaction data