

ASSESSING THE FINANCIAL PERFORMANCE OF FORESTRY-RELATED INVESTMENT VEHICLES: CAPITAL ASSET PRICING MODEL VS. ARBITRAGE PRICING THEORY

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Capital asset pricing model (CAPM) and arbitrage pricing theory (APT) are used to assess the financial performance of eight forestry-related investment vehicles. Although results from APT support previous findings from CAPM about timberland investments, three bodies of evidence show that APT findings are more robust. The major conclusions are (a) institutional timberland investments and timberland limited partnerships have a low risk level and excess returns; (b) forestry industry companies have not earned risk-adjusted returns, and the performance of medium forest industry firms is worse than that of large firms; (c) stumpage price does not resemble the return generation process of timberland investments; and (d) lumber futures have little excess return.

Key words: arbitrage pricing theory, capital asset pricing model, forestry, timberland.

Increased interest in forestry-related investments in recent years, especially from institutional investors, has created a need for improved analysis on their financial performance. The purpose of this article is to assess the financial performance of all major forestry-related investment vehicles and to better explain their financial characteristics by using two financial economics models: capital asset pricing model (CAPM) and arbitrage pricing theory (APT).

Individuals seeking investment opportunities in forestry have several alternatives. Some may purchase the stocks and bonds of forest industry companies and timberland limited partnerships. Some may own forestlands. More sophisticated investors may also hold lumber futures or participate in other mechanisms (Zinkhan et al.). In addition, the restructuring in the forest industry since the middle of the 1980s has provided a supply of investment-grade timber-

land. Since these timberlands are generally too large for individuals to buy, individuals may invest in them through pension funds, insurance companies, and foundations which are often referred to as institutional timberland investors (Binkley, Raper, and Washburn).

Based on Markowitz's portfolio theory, two major models—capital asset pricing model (CAPM) and arbitrage pricing theory (APT)—have been developed for asset valuation. The earliest application of CAPM in forestry-related assets involved evaluating the performance of five forest industry firms (Hotveldt and Tedder). Thomson used CAPM to evaluate the financial uncertainty of tree improvement in the U.S. Pacific Northwest. Washburn and Binkley (1993) examined the historical relationship between forestry returns and inflation. Binkley, Raper, and Washburn analyzed the institutional ownership of timberland. Redmond and Cubbage investigated the possibility of an *ex post* CAPM application to timber assets based on historical regional stumpage prices. These CAPM studies concluded that return for timberland was weakly correlated with returns for many traditional investments and that timberland carries a relatively low level of financial risk. Thus, timberland presents an opportunity for portfolio diversification (Redmond and Cubbage; Washburn and

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Binkley 1993). However, problems with the composition of the true market portfolio, the low explanatory power of the model, and the low accuracy of prediction have been reported in forestry literature as well as in the analysis of other financial assets (Arthur, Carter, and Abrzadeh; Washburn and Binkley 1989).

APT is a theory concerned with deriving the required rates of returns on risky assets based on the asset's systematic relationship to several risk factors. In contrast to the single-factor in CAPM, APT allows multiple factors to influence asset returns. Thus, APT can be viewed as an extension of the single-factor market model (CAPM). Although more intuitive, APT makes no statements about the size or the sign of the risk premium for each factor. Therefore, how to use analytic models to select the factors and interpret them is critical in applying APT. The statistical factor model, originally proposed by Gehr and subsequently extended by Roll and Ross, has been most widely used in APT studies.

Since 1980, numerous empirical studies have been conducted to test whether APT does a better job in explaining asset returns than does CAPM. Roll and Ross conducted the first empirical investigation of APT using individual equity data. Arthur, Carter, and Abrzadeh used APT to analyze the relationship between risk and returns for agricultural assets from 1976 to 1984. The APT results are generally more robust than CAPM. However, no APT study could be found in forestry-related investment, and studies on timberland investment have not been put in contrast with other forestry investment vehicles. This study fills in the gaps by empirically investigating the financial characteristics of all major forest-related investment vehicles and by comparing the results from both CAPM and APT. Although this article is a direct extension of other studies comparing CAPM and APT (e.g., Arthur, Carter, and Abrzadeh), it expands the literature on forestry investments by analyzing all major forestry investment alternatives except much diverse and fragmented non-industrial private forestland ownership (due to data constraint). The main findings of this paper generally confirm previous CAPM results and should be interesting to those who are dealing with timberland investment as well as to a wider audience of financial managers who are interested in alternative asset classes. The next section presents methodology, the third

section describes data, the fourth section provides data analysis and results, and the final section draws some conclusions.

Methodology

Capital Asset Pricing Model

Developed by Sharpe and Lintner in the mid-1960s, CAPM states that the required or expected return on an investment should be equal to the rate earned on a riskless investment plus a premium for the assumption of market risk

$$(1) \quad R_i = R_f + \beta_i(R_m - R_f)$$

where R_i is the required rate of return on investment i , R_f is the risk-free rate of return (measured by the yield on US T-bills), β_i is investment i 's risk premium, commonly known as beta, and R_m is the market's expected rate of return (with a market indicator series such as the S&P 500 as the proxy for the market).

Jenson proved that CAPM is consistent with the regression equation or excess return form

$$(2) \quad R_i - R_f = \alpha_i + \beta_i(R_m - R_f) + \mu_i$$

The intercept α_i for CAPM regression signifies the valuation of an asset due to the factors other than the overall market. A positive alpha indicates that the asset has an expected return that is greater than the market required in the risk class (as measured by beta) and thus indicates a superior risk-adjusted return. β_i is an indicator of the asset's market risk. If the beta value is greater (less) than 1, the asset moves more (less) than a corresponding move in the market. Thus, such asset is said to be more (less) risky than the market.¹

Arbitrage Pricing Theory

APT was developed by Ross and enhanced by others. APT is based on the law of one

¹ We also conducted a CAPM model with inflation, which is termed as capital asset pricing model under uncertain inflation (Brueggeman, Chen and Thibodeau). The results were not much different from these reported for CAPM. The model and results are available from the authors.

price, which states that two otherwise identical assets cannot sell at different prices. It assumes that asset returns are linearly related to a set of indexes, each representing a factor that influences the return of an asset. Asset returns are randomly generated according to an n -factor model

$$(3) \quad R_i = E(R_i) + \beta_{i1}\delta_1 + \beta_{i2}\delta_2 + \cdots + \beta_{in}\delta_n + e_i$$

where R_i is the actual (random) rate of return on asset i in any given period, $E(R_i)$ is the expected return on asset i , δ_n is a common factor with a zero mean that influences the returns on all assets, β_{in} is sensitivity of asset i to factor n , and e_i is random error term, unique to asset i .

The sensitivity measure β_{in} in APT has similar interpretations to β_i in CAPM. They are measures of the relative sensitivity of an asset's return to a particular risk factor. Considering the risk premiums in both cases, the CAPM relationship would be the same as would be provided by APT if there were only one pervasive factor influencing returns.

In conjunction with the assumption of zero arbitrage profits, the above multiple factor model leads to the APT pricing equation:

$$(4) \quad E(R_i) = \lambda_0 + \beta_{i1}\lambda_1 + \beta_{i2}\lambda_2 + \cdots + \beta_{in}\lambda_n + \eta_i$$

where the λ_n are interpreted as risk premium (If there is a risk-free rate λ_f , then $\lambda_0 = \lambda_f$).

Among various techniques in empirical application of APT, the maximum likelihood factor analysis (MLFA) is the most frequently used. MLFA has desirable asymptotic properties and can be used to test hypotheses about the number of common factors. We use MLFA to extract the factor scores, calculate the risk premium for each common factor, and evaluate the financial performance of the forestry-related assets.

Consensus has not been reached on two issues in the empirical application of APT. First, various numbers of factors have been recommended. Roll and Ross concluded that no more than four or five factors are relevant. Although some studies have identified or pre-specified as many as ten factors (Robin and Shukla), most empirical studies suggested that only three to five factors have influenced asset returns and are priced in the market (Chen; Chen, Roll, and Ross; Bubnys). Second, sample size and formation does matter,

and a different formation may yield different results (Livingston; Dhrymes, Friend, and Gultekin). Nevertheless, sample size and formation vary widely in previous studies. Two approaches have emerged. One is to use the returns of a sample of firms to extract factor scores (Roll and Ross; Collins) and then used these factors to estimate the required returns for other firms. Since companies to be evaluated are not included in the statistical factor estimation process, the validity of using the factors generated to evaluate them may be questionable. The second approach uses small, relevant samples, including the assets to be evaluated, to extract factor scores. For example, Arthur, Carter, and Abrzadeh used fourteen farm assets and nine non-farm assets together to extract factor scores and then evaluated the performance of the fourteen farm assets. This approach showed promising results. Although Bower, Bower and Logue tried both ways and found similar results, no consensus has been reached on how to select and form the sample to extract factor scores in APT application. The second approach is used in this study.

There are two other types of factor analysis. Macroeconomic factor models use observable economic time series, such as inflation, interest rates and GDP, as measures of the pervasive shocks to security returns. Fundamental factor models use the returns to portfolios associated with observed security attributes such as dividend yield, book-to-market ratio, and industry identifiers (Connor). In contrast, the statistical factor model used in this study derives the pervasive factors from factor analysis of the panel data set of security returns alone. All three models are used to find the factors influencing the arbitrage opportunities among assets. The factors in the first two models are observable, while those in the third model are not. Although it is interesting to compare the results of these three models, conducting other types of factor analysis requires completely different data sets and methodologies and is beyond the scope of this paper.

Data

Eighteen investment portfolios or price indexes were selected for this study, eight of which are forest-related, and the rest serve as approximate control and comparison groups for return generation process of all assets.

All data have quarterly returns from 1986 to 1997 with forty-eight observations except the returns for NCREIF timberland index, which have only forty-four observations (1987–97).

The eight forestry-related assets are Timberland Performance Index (TPI), NCREIF Timberland Index (NCREIF-T), Timberland Limited Partnership Portfolio (TLP), Large Forest Industry Company Portfolio (L-FICP), Medium Forest Industry Company Portfolio (M-FICP), Southern Stumpage Price Average (SSPA), Pacific Northwest Stumpage Price Average (PNSPA), and Lumber Futures (LUMBER).

The TPI and NCREIF-T are chosen to represent institutional timberland investments. TPI is an indicator based on quarterly total returns from different timberland funds managed by several timberland investment management organizations (Caulfield). The basic data for TPI appear in *Real Estate Profiles*, published quarterly by Evaluation Associates, Inc. (Caulfield). NCREIF-T is published quarterly by the National Council of Real Estate Investment Fiduciaries (NCREIF 1998a). It currently covers more than 75% of all institutionally managed timberlands (Binkley).

TLP includes four publicly traded timberland limited partnership companies, which were spin-offs from several forest products firms in the 1980s.² They own and manage timberland only, and all have timber supply agreements with their general partners, usually the forest products firms that created them. TLP represents an asset for investors who want to own some timberland, but do not want to own forest products processing facilities. The financial characteristics of this investment option serve as a good contrast to those of forest industry firms, which own both timberland and processing facilities. L-FICP consists of fifteen forest industry firms that are listed in Fortune 500 in 1997. M-FICP is made up of fifteen medium-size primary timber processing companies which are in SIC 24 (wood products) or SIC 26 (paper and allied industries) and that were traded continuously between 1986 and 1997.³ Quarterly returns for these three portfolios are obtained from the Center for Research in Stock Price (CRSP) database

by the University of Chicago. Market value weighting is used to form each portfolio.⁴

SSPA is the average of southern pine pulpwood and sawtimber stumpage (Timber Mart-South). PNSPA is the average value of timber harvested on the National Forests of the Pacific Northwest (Haynes and Warren).⁵ The primary reason for including them in this study is to use them (like stock prices) to generate the statistical factors influencing all major forestry-related investment vehicles. In addition, some researchers (e.g., Redmond and Cabbage; Conroy and Miles) assessed timberland performance based on historical stumpage price alone. Since stumpage prices are merely one of several major sources of returns of timberland investment, they may not be used alone as an indicator of returns for forestlands of many non-industrial private forest landowners. The results of this study support this statement.

The last forest-related alternative is lumber futures (Spruce-Pine-Fir 2 × 4), which are traded on Chicago Mercantile Exchange (Bridge CRB). The return series is formed from the contracts whose expirations are closest to the quarters and hence is almost equivalent to the spot price of lumber. The price of lumber futures reflects the situation in the solid wood products market.

The ninth to eighteenth portfolios are only used in APT to generate multiple factors.⁶

⁴ Equal weighting has been tried, and the results are similar to those reported in this article.

⁵ Several stumpage prices are reported in the Pacific Northwest (Haynes and Warren). The most widely used stumpage prices are the bid prices for USDA Forest Service timber sales. They are generally cited as "sold" or "bid" prices. An alternative measure of current stumpage prices is the average prices of stumpage harvested, or the so-called "cut" prices. The major distinction between cut and sold prices is that the cut prices represent the current price of timber harvested or the worth of the timber in the marketplace and the sold prices represent the value (current expectation of future prices) of timber meant for future harvest. Considering the strong forward-looking bias with sold prices in the Pacific Northwest, which is not an issue in the stumpage price data in the South, the cut prices are used for the Pacific Northwest in this study.

⁶ Wood products (not paper) are primarily used in the housing industry. It is widely recognized that the housing cycle runs a little different from the main business cycle. A good measure of housing cycle is housing starts. However, one cannot easily convert housing starts into a return series and directly compare it with other series used in this study because housing starts is a volume variable (not an asset) and cannot have the interpretation of arbitrage. Alternatively, we tried to run a simple OLS regression and to see if the variance in housing starts can be explained by the 18 series that we used in this article to generate multiple factors. The results showed that, to some extent, the space spanned by the linear combination of the existing assets might include housing starts or a transformation of it ($R^2 = 0.49$, adjusted $R^2 = 0.20$). Therefore, future research on macroeconomic factor analysis of forestry-related investments ought to explore the influence of changes in housing starts, in addition to

² The firms are International Paper TLP, Rayonier TLP, Plum Creek TLP, and Pope Resources LP.

³ A list of these firms in L-FICP and M-FICP can be obtained from the authors.

The ninth “portfolio” is the NCREIF Farmland Index (NCREIF-F) (NCREIF 1998b). Since timberland and farmland are interchangeable in many regions of the U.S., their return generation process may be influenced by similar factors. The tenth and eleventh “portfolios” are the representatives of stock market indices, reflecting returns of major financial assets. The Russell 2000 (RUSSELL) stands for the small stocks, and S&P500 (SP500) is a composite indicator of the broad market. Dividends are reinvested in calculating both market returns. The twelfth “portfolio” is the long-term government bond (GBOND), a parameter of the bond market (Ibbotson Associates).

The thirteenth to fifteenth “portfolios” are quarterly returns of three currency exchange rates: Canadian Dollar (CANADA), Deutsche Mark (MARK), and Japanese Yen (YEN) versus US Dollar, respectively (Federal Reserve Bank of Chicago). They are included not only because the foreign exchange market is a large and efficient financial market, but also because forest products trade among U.S. and Japan, Germany, and Canada is significant. Japan and Germany are the two largest U.S. forest products export markets, and Canada is the largest exporter of forest products to the U.S. and the largest competitor of U.S. forest products in Japan and Germany.

The last three assets are three metals: gold (GOLD), steel (STEEL), and aluminum (ALUM) (Bridge CRB). Gold is chosen to represent precious metals, which may have an impact on the timber market. Steel and aluminum are selected because they are substitutes for wood products. Finally, the U.S. Treasury bill rates used in the application of CAPM are from Ibbotson Associates.

Data Analysis and Results

CAPM

Equation (2) was applied to the eight forestry-related assets, and the results were presented in table 1. The alpha coefficients for two timberland indexes, TPI and

NCREIF-T, are significantly different from zero at the 10% level. There are no significant excess returns for other six forestry-related assets. The betas for the large forest industry company portfolio (1.04) and the medium forest industry company portfolio (0.94) are close to one and significant from zero at the 10% level. The beta for the timberland limited partnership portfolio is 0.52 and also significant from zero at the 10% level. These results indicate that timberland alone has a lower risk level than the combining of timberland and timber processing facilities (i.e., forest products firms). The betas for other five assets are not significant.

The R^2 of the regressions on large and medium forest industry company portfolios and timberland limited partnerships are 0.52, 0.51, 0.15, respectively. This is consistent with the correlation coefficients between those three assets and the market portfolio proxy S&P 500, which are 0.73, 0.70, and 0.41, respectively. However, the R^2 s are just around zero for the other five assets, which means that CAPM does not explain the return variation of those assets well. The low R^2 for the NCREIF-T may partly be caused by the quarterly appraisal methods used in generating the index (Binkley).

APT

The application of APT to forestry-related investments is more complicated than that of CAPM. The analysis proceeds in five steps.

Step 1. Calculate factor loading for each asset. For the eighteen selected assets, a maximum likelihood factor analysis is performed on their time series returns. Due to the data constraint from NCREIF-T, only forty-four quarterly returns (1987–97) are used in all following APT analysis. This procedure estimates the number of factors and the matrix of factor loading for each asset. Using the different factor selection criteria (SAS Institute) results in three to seven factors. In light of previous studies, five factors are used in this study. In computing the factor-loading matrix, many previous researches used some kind of rotation method like orthogonal (i.e., varimax) rotation. In theory, no factor-loading matrix is better than others in explaining the correlation of the raw data with orthogonal rotation. Although the impact of any given factor will change, the total explanatory power is unaffected by rotation. In this study,

other macroeconomic variables, such as the unexpected inflation rate, the change in expected inflation, the unexpected change in term structure, the unexpected change in risk premium, and the unanticipated change in growth rate of industrial production (Chen, Roll and Ross). The authors thank an anonymous referee for suggesting this analysis.

Table 1. Estimated Results with CAPM

Asset	α		β		R^2	\bar{R}^2
	Coefficient	<i>t</i> -ratio	Coefficient	<i>t</i> -ratio		
TPI	0.018*	3.09	0.07	0.85	0.02	-0.01
NCREIF-T	0.042*	5.30	-0.05	-0.50	0.01	-0.02
TLP	0.020	1.45	0.52*	2.80	0.15	0.13
L-FICP	-0.003	-0.26	1.04*	7.09	0.52	0.51
M-FICP	-0.007	-0.64	0.94*	6.95	0.51	0.50
SSPA	0.009	0.88	-0.06	-0.45	0.00	-0.02
PNSPA	0.008	0.36	0.21	0.71	0.01	-0.01
LUMBER	0.004	0.15	0.14	0.46	0.00	-0.02

*Significant at the 10% level.

the rotated factor-loading matrix is adopted (table 2).

An advantage of rotating the factor loading is that it reveals how similar assets load on similar factors. Because of the orthogonal rotation, most assets load significantly to only one or two factors, reducing the factorial complexity. The large and medium forest industry companies (L-FICP and M-FICP) and stock market indexes (RUSSELL and SP500), for example, show the greatest sensitivity to Factor 1. This means that they are “similar” assets. Except that Factor 4 explains most variation for TFP and Factor 5 for TPI, the other 16 indexes are loaded on one or two of the first three factors by similar

asset grouping. Therefore, while factors are generally understood to describe common economic movements behind various investment vehicles, the various asset groupings used in this study seem to represent those movements well.⁷

Step 2. Calculate factor scores for every quarter. Bartlett’s procedure is used to esti-

⁷It is tempting to name the five factors in a way such that they reflect the underlying economic movements for different asset groups. Theoretically, in the absence of estimation error and with no limits on data availability, the maximum likelihood analysis should reach the same final result as the macroeconomic factor model or fundamental factor model (Connor). In reality, naming the factors with certainty is very difficult with this kind of explanatory factor analysis.

Table 2. Rotated Factor Loading and Residual Value through Maximum Likelihood Factor Analysis

Asset	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Residual
TPI	6	7	2	-5	55	0.6909
NCREIF-T	-16	21	6	-1	1	0.9249
TLP	46	10	11	62	-13	0.3648
L-FICP	90	-11	22	10	4	0.1235
M-FICP	90	-9	34	11	5	0.0602
SSPA	-8	-29	15	-2	-2	0.8868
PNSPA	17	-25	28	2	-1	0.8315
LUMBER	13	-3	31	2	1	0.8878
NCREIF-F	-12	52	-12	1	3	0.7011
RUSSELL	85	35	1	11	7	0.1448
SP500	88	27	-20	10	6	0.0974
GBOND	12	-4	-40	0	0	0.8244
CANADA	-43	32	-19	-4	0	0.6766
MARK	20	73	63	7	6	0.0113
YEN	12	59	18	4	5	0.6030
GOLD	-13	-56	18	-3	-4	0.6291
STEEL	8	2	25	2	1	0.9316
ALUM	0	-11	23	0	0	0.9373

Note: The values for factor loading are multiplied by 100.

Table 3. Assets' Sensitivity to Each Factor

Asset	Beta 1	Beta 2	Beta 3	Beta 4	Beta 5	R ²	R̄ ²
TPI	0.0522	-0.0427	0.0506	-0.0675*	0.5303*	0.78	0.75
NCREIF-T	-0.0616	0.1185	0.0642	-0.1438*	0.2389*	0.30	0.21
TLP	0.4534*	-0.0137	0.1414*	0.5964*	-0.1426*	0.96	0.95
L-FICP	0.9870*	-0.2517*	0.2475*	0.0233	0.0030	0.91	0.90
M-FICP	0.9027*	-0.2297*	0.4129*	0.1123*	0.0962*	0.96	0.95
SSPA	-0.1501	-0.3466*	0.0528	0.0641	0.2027	0.31	0.22
PNSPA	-0.0226	-0.6913*	0.3324	0.0233	-0.2555	0.25	0.15
LUMBER	0.0359	-0.2839	0.6040*	-0.0505	0.3898	0.15	0.03
NCREIF-F	-0.0086	0.1677*	0.0010	0.0229	0.0841	0.31	0.22
RUSSELL	0.9991*	0.3250*	0.0252	0.1898*	-0.0052	0.84	0.82
SP500	0.7250*	0.1394*	-0.2035*	0.0194	0.0264	0.89	0.88
GBOND	0.0885	-0.0876	-0.2774*	-0.0297	0.1729	0.27	0.18
CANADA	-0.0873*	0.0861*	-0.0268	0.0244	0.0526	0.38	0.29
MARK	0.1930*	0.6177*	0.6661*	0.0472*	0.0504	0.92	0.91
YEN	0.1594*	0.5215*	0.3085*	0.0769	0.1576	0.47	0.40
GOLD	-0.1787*	-0.3935*	0.0200	-0.1240*	-0.1820*	0.51	0.44
STEEL	-0.1037	-0.0680	0.1969	-0.0161	-0.3248	0.09	-0.03
ALUM	-0.1797	-0.1091	0.2470	0.0215	-0.6383*	0.16	0.05

*Significant at the 10% level.

mate the factor scores for each quarter. The estimates of individual asset factor loading from the previous step are used to explain the cross-sectional variation of individual estimated returns. This estimates the time series factor scores for each quarter. If B is taken to be the 18×5 factor loading matrix from the previous step augmented with a column vector of ones, then the factor scores in quarter t , F_t , are calculated as follows

$$(5) \quad F_t = (B'D^{-1}B)^{-1}B'D^{-1}R_t$$

where D is the 18×18 diagonal matrix of residual variances produced by the factor analysis in step 1 (see the last column in table 2), and R_t is the 18×1 vector of returns on the 18 assets in quarter t .⁸

Step 3. Calculate sensitivity coefficients for each asset. To obtain the sensitivity coefficients to systematic factors for each asset, the time series returns are regressed on these quarterly factor scores from the previous step as follows (table 3)

$$(6) \quad R_{it} = \alpha_{it} + \beta_{ij}F_{jt} + \dots + \beta_{i5}F_{5t} + \phi_{it}$$

where R_{it} is the realized return on asset i in quarter t , $i = 1, \dots, 18$, $t = 1, \dots, 44$, α_{it} is the intercept for asset i , β_{ij} is the factor beta

or sensitivity coefficients for asset i on factor j , $j = 1, \dots, 5$, F_{jt} is the value of factor score j in quarter t , $j = 1, \dots, 5$ and ϕ_{it} is the residual error for asset i in quarter t .

Step 4. Calculate risk premium associated with each factor. The risk premium associated with each factor is calculated as the average value from cross-sectional regressions of quarterly asset returns on asset sensitivity coefficients. Forty-four cross-sectional regressions of the asset returns on the factor betas estimated in the previous step are estimated as follows

$$(7) \quad R_{it} = \lambda_{0t} + \lambda_{jt}\beta_{ij} + \dots + \lambda_{5t}\beta_{i5}e_{it}$$

where R_{it} is the realized return on asset i in quarter t , $i = 1, \dots, 18$, $t = 1, \dots, 44$, λ_{0t} is the intercept in quarter t , λ_{jt} is the estimated risk premium for factor j in quarter t , $j = 1, \dots, 5$, β_{ij} is the factor beta or sensitivity coefficients for asset i on factor j , $j = 1, \dots, 5$, e_{it} is the residual error for asset i in quarter t .

The average values of lambda parameters over the above regressions are used as risk premiums for each factor in the APT model. The mean values are the following

$$(8) \quad \begin{aligned} \lambda_0 &= 0.0236, & \lambda_1 &= 0.0186, \\ \lambda_2 &= -0.0144, & \lambda_3 &= -0.0191, \\ \lambda_4 &= -0.0210, & \lambda_5 &= 0.0138. \end{aligned}$$

⁸ The factor scores F_t calculated in this fashion are identical to the results from estimating a cross-sectional generalized least squares regression of the asset returns R_t against the factor loading B weighted by residual variances D .

Table 4. Annual Historical and Required Returns for Forestry-Related Assets: APT vs. CAPM

Asset	Historical Annual Rate of Return	Required Annual Rate of Return with		Excess Return Percentage with		Label**
		CAPM	APT	CAPM	APT	
		I	II	III	(I-II)/II	
TPI	14.28*	6.12	12.06	133	18	A
NCREIF-T	21.41	4.73	7.93	352	170	A
TLP	18.50	11.35	16.06	63	15	A
L-FICP	14.77	17.48	16.57	-16	-11	B
M-FICP	12.91	16.34	15.82	-21	-18	B
SSPA	9.03	4.65	11.58	94	-22	C
PNSPA	8.67	7.81	9.50	11	-9	C
LUMBER	7.26	7.02	8.46	3	-14	C

*All values are percentage.

**A—Historical performance is better than the requirement from both models. B—Historical performance is worse than the requirement from both models. C—Two models produce different results.

Step 5. Calculate the required returns. With the sensitivity coefficients for each asset from step 3 and risk premiums for each factor from step 4, the required returns $E(R_i)$ for each forestry-related asset can be calculated using equation (4) (See table 4)

$$(9) \quad E(R_i) = 0.0236 + 0.0186\beta_{i1} - 0.0144\beta_{i2} - 0.0191\beta_{i3} - 0.0210\beta_{i4} + 0.0138\beta_{i5}$$

Comparison of CAPM and APT

For comparison, the required returns for forestry-related assets associated with the estimated risk level under CAPM are computed using equation (1). Several results have emerged by comparing these required returns from both models (table 4). First, timberland investments have low required rates of returns. This is evident in that both TPI and NCREIF-T have a lower required return than those of forest products firms. Moreover, although the required return of TLP is comparable to those of forest products firms under APT, it has a lower required return under CAPM and its historical return is higher than its own required return. In all three timberland indexes, the historical returns are higher than the required returns (labeled as “A” in table 4), especially for NCREIF-T. The good performance of timberland investment is consistent with several previous studies (Washburn and Binkley 1993; Binkley, Raper and Washburn), and the difference between NCREIF-T and TPI can

be attributed to the fact that these indexes do not cover the same timberlands. On the other hand, the difference in the required rates of return between institutional timberland investments (TPI and NCREIF-T) and timberland limited partnerships (TLP) may be attributed to the existence of a timber supply agreement between timberland limited partnerships and the forest products company which created them.

Second, both large and medium forestry industry companies (L-FICP and M-FICP; labeled as “B” in table 4) seem unable to earn enough risk-adjusted returns, although the difference between historical returns and the required returns is not statistically significant at a reasonable level. Furthermore, the performance of medium forestry industry firms is slightly worse than that of the large forestry industry companies. Since both medium and large forest products firms have more pulp and paper companies (Standard Industrial Code or SIC 26) than wood products companies (SIC 24), this difference may reflect more on the economy of scale than on the group company composition and may explain the heavy merging activities observed in recent years in the forest products industry.

Third, as expected, the return on SSPA or PNSPA is not as good as the two timberland indexes. This suggests that stumpage price alone does not resemble the return generation process of timberland investments and that using a stumpage price index to study the financial performance of timberland investments is inadequate.

The two models have generated some different results as well. APT has a higher requirement than CAPM since six out of the eight required returns are higher with APT than with CAPM. The exceptions are L-FICP and M-FICP. Specifically, the positive excess return with TPI, NCREIF-T, and TLP are smaller under APT than under CAPM. For SSPA, PNSPA, and LUMBER, CAPM concludes that there are positive excess returns, but APT shows negative excess returns (labeled as “C” in table 4).

Further tests reported in table 5 show that the differences between the historical returns of timberland (TPI, NCREIF-T, and TLP) and the required returns under CAPM are statistically significant at or around the 10% level, and so is the difference between the historical return of NCREIF-T and its required return under APT. The required returns for two of the timberland indexes (TPI and NCREIF-T) are statistically different under CAPM and APT, while the other one (TLP) is marginally significant (around the 20% level).

In the light of these different results from these models, we have conducted three comparisons to find out which one of the two competing models provides a better explanation of the relationship between risk and returns. They all support the fact that APT findings are more robust than CAPM findings.

First, APT can explain a larger share of return variation among the securities than

CAPM. For CAPM, only three of the eight forestry-related assets have betas significant at the 10% level (table 1). In contrast, with APT, every asset has at least one reaction coefficient significant at the 10% level, and five have at least two reaction coefficients significant. In addition, the adjusted R^2 , which considers the effect brought by additional explanatory variables, has been greatly improved for seven assets and the average value is 0.52 for APT and 0.14 for CAPM. Only for one asset, LUMBER, the adjusted R^2 values from both models are around zero. The high adjusted R^2 for APT could be directly attributed to the fact that it includes more variables than CAPM. This comparison of R^2 would not be valid if the purpose is to choose one of several APT models.

Second, following Chen, a test described in Davidson and Mackinnon for discriminating between competing models was conducted. In each of forty-four quarters, the actual returns on the eighteen assets are regressed cross-sectionally against the predicted returns as follows:

$$(10) \quad R_{it} = \theta_t R_{apt,t} + (1 - \theta_t) R_{capm,t} + u_{it}$$

where R_{it} is the actual returns to the 18 assets in quarter t ; $R_{apt,t}$ and $R_{capm,t}$ are the required returns for each asset in quarter t from each model, respectively; θ_t is the regression coefficient; and u_{it} is the error term. θ_t is expected to be close to one if APT is a better model. We found that the mean

Table 5. Test of Significance Between Historical and Required Rates of Return, Between CAPM and APT as well as Between Large and Medium Forest Products Firms

	Historical-CAPM	Historical-APT	CAPM-APT
<i>P</i> value for <i>t</i> -test between returns (%)*			
TPI	0.06	29.68	4.52
NCREIF-T	0.00	0.01	5.38
TLP	10.75	37.44	20.81
L-FICP	36.67	41.80	45.92
M-FICP	31.83	36.66	47.87
SSPA	12.27	30.15	1.78
PNWSP	45.96	46.78	37.86
LUMBER	48.90	45.68	40.51
<i>P</i> value for <i>t</i> -test between L-FICP and M-FICP (%)			
Historical Returns		41.24	
CAPM Required Returns		42.48	
APT Required Returns		46.59	

*The null hypothesis is that the two series compared are the same statistically (two tails).

of θ_i is 0.88, and forty of the forty-four coefficients are significant at the 5% level.

Third, following Bower, Bower, and Logue, the quality of the forecast was assessed by using an approach suggested by Theil. The Theil measure, U^2 , assesses whether the two models are an improvement over a naïve model and, if both are, determines which of the two represents a greater improvement. Theil's U^2 is the sum of the squared forecasting errors from a particular model divided by the sum of the squared forecasting errors from a naïve forecasting rule

$$(11) \quad U_i^2 = \frac{\sum_{t=1}^{44} (R_{i,t} - R_{i,t}^{\text{models}})^2}{\sum_{t=1}^{44} (R_{i,t} - \bar{R}_i)^2}$$

$(i = 1, 2, \dots, 18)$

where $R_{i,t}$ is the historical return for asset i in quarter t , $R_{i,t}^{\text{models}}$ is the forecast returns for asset i in quarter t by model CAPM or APT, and \bar{R}_i is the quarterly average historical returns for asset i during the 44 quarters. Here, the naïve forecasting rule uses the average return over the 44 quarters as the predicted return in each quarter.

The smaller the ratio, the better the model forecast is relative to the naïve forecast. A ratio with a value greater than one would indicate the inappropriateness of the pricing model being considered. For CAPM, 7 out of the 18 U^2 values for the 18 assets or indexes are less than one, and the average value is 0.93. For APT, 14 of 18 values are less than one, and the average is 0.60. Therefore, APT outperforms CAPM as a forecasting model of required or expected return.

Discussion and Conclusions

This study evaluates the financial performance of eight forestry-related assets and indexes using capital asset pricing model and arbitrage pricing theory. Under the framework of CAPM, timberland investments have excess returns. Timberland alone has a lower level of risk than forest industry companies which combine timberland and timber processing facilities. APT produces some similar results, although six out of the eight required returns are higher with APT than with CAPM, implying that APT has a higher requirement than CAPM in most cases. Three bodies of evidence support that APT findings are more robust than the findings from CAPM.

The historical returns of institutional timberland investments and, to a lesser extent, timberland limited partnerships in the past eleven years (1987–97) are substantially higher than the required returns. This superior performance of these kinds of assets suggests that they could be good investment vehicles for some investors. However, the widely observed success of the institutional timberland investments might be related to timber price hikes induced by the environmental regulations and the lack of liquidity in timberland markets. Future performance of timberland may well change, depending on the interaction of various factors in the market.

Forest industry companies do not earn risk-adjusted returns, and the performance of medium forestry industry firms is slightly worse than that of the large forestry industry companies. The poor performance of the forest products companies and the good performance of timberland investments may have caused many forest industry firms to restructure through merger, acquisition, and sale of their timberlands in recent years.

The performance of two stumpage price indexes is not as good as that of timberland investments. This implies that they do not resemble the return generation process of timberland investments as they do not include biological growth, land appreciation and other non-market factors. Finally, lumber futures have barely earned the required return.

These results imply that timberland investment will continue to be a growing business in the future (Donegan). It has some good characteristics of an investment asset that investors are looking for, such as low risk, high risk-adjusted return, and low level of correlation with other financial assets. It has performed better than most other forestry investment vehicles. Also, separating timberland from timber processing facilities may enhance investment return.

Nevertheless, the results of this study need to be interpreted with caution. First, due to data constraints, only 11 years' data are used in this study (NCREI-T started the third quarter of 1996 and only four timberland limited partnerships were publicly traded during the study period). In addition, the anomaly of the Heywood Case—some unique factor has negative variance—occurs in the maximum likelihood factor analysis. This might suggest that a larger data set would provide more

stable estimates for the factor scores. Experience shows that MLFA is very prone to this problem with such a small sample. Other causes may include bad prior communality estimates and too many or too few common factors (SAS Institute). Further research could be directed into improving the data by including more investment vehicles or by covering longer periods of time. Other factor analysis techniques such as principal component factor analysis, other APT factor models such as the macroeconomic factor model, or other asset pricing theory could be used as well.

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