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## Assessing the Financial Performance of Forestry-related Investment Vehicles: Capital Asset Pricing Model vs. Arbitrage Pricing Theory

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## Abstract

Capital asset pricing model (CAPM) and arbitrage pricing theory (APT) are used to assess the financial performance of eight forestry-related investment vehicles. While 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 to a lesser extent, publicly traded timberland limited partnerships, have had a low risk level and excess returns; (b) forestry industry companies have not earned risk-adjusted returns, and the performance of medium forestry industry firms is worse than that of the large forest industry companies; (c) stumpage price does not resemble the return generation process of timberland investments; and (d) lumber futures have little excess return.

## I. Introduction

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 paper is to assess the financial performance of all major forestry-related investment vehicles and to better the understanding of 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. Many have purchased the stocks and bonds of forest industry companies and timberland limited partnerships. Many others own forestlands. More sophisticated investors may also hold lumber futures or participate in other mechanisms (Zinkhan et al. 1992). In addition, the restructuring in the forest industry since the middle of the 1980s has provided a supply of investment-grade timberland. 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 1996).

Based on Markowitz's (1952) 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 1978). Thomson (1987) used CAPM to assess the financial risk of growing commercial timber crops of sawlogs in the U.S. Midwest and South. Washburn and Binkley (1993) examined the historical relationship between forestry returns and inflation. Binkley, Raper and Washburn (1996) analyzed the institutional ownership of timberland. Redmond and Cabbage (1988) 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 (Thomson 1992; Washburn

and Binkley 1990, 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 et al. 1988; 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 (1978) and subsequently extended by Roll and Ross (1980), 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 (1980) conducted the first empirical investigation of APT using individual equity data. Arthur et al. (1988) used APT to analyze the relationship between risk and returns for agricultural assets from 1976 to 1984. The APT results were generally more robust than CAPM. However, no APT study could be found in forest-related investment, and studies on timberland investment have not been put in contrast with other forest investment vehicles. This study fills in the gap and presents empirical results on the financial characteristics of all major forest-related investment vehicles. The next section presents methodology, section III describes data, section IV provides data analysis and results, and the final Section concludes.

## II. Methodology

### 1. Capital Asset Pricing Model

Developed by Sharpe (1964) and Lintner (1965) in the mid-1960s, the Capital Asset Pricing Model (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

$R_i$  = the required rate of return on investment  $i$ ;

$R_f$  = the risk-free rate of return (measured by the yield on US T-bills);

$\beta_i$  = investment  $i$ 's risk premium, commonly known as beta; and

$R_m$  = the market's expected rate of return (with a market indicator series such as the S&P 500 as the proxy for the market).

Jensen (1969) proved that CAPM was 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  $\alpha_i$  for CAPM regression signifies the valuation of an asset due to 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.

$\beta_i$  is an indicator of the asset's market risk. If the beta value is greater (less) than one, 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.

## 2. Arbitrage Pricing Theory

Arbitrage Pricing Theory (APT) was developed by Ross (1976) and enhanced by others. APT is based on the law of one 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:

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

where

$R_i$  = the actual (random) rate of return on asset  $i$  in any given period;

$E(R_i)$  = the expected return on asset  $i$ ;

$\delta_n$  = a common factor with a zero mean that influences the returns on all assets;

$\beta_{in}$  = sensitivity of asset i to factor n; and

$e_i$  = random error term, unique to asset i.

The sensitivity measure  $\beta_{in}$  in APT has similar interpretations to  $\beta_i$  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:

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

where the  $\lambda_n$  are interpreted as risk premium (If there is a risk-free rate  $\lambda_f$ , 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.

Census has not been reached on two issues in the empirical application of APT. First, various numbers of factors have been recommended. Roll and Ross (1980) concluded that no more than four or five factors were relevant. Although some studies have identified or pre-specified as many as ten factors (Robin and Shukla 1991), most empirical studies suggested that only three to five factors influenced asset returns and were priced in the market (Chen 1983; Chen et al. 1986; Bubnys 1990). Second, sample size and formation does matter, and different formation may yield different results (Livingston 1977; Dhrymes et al. 1984). 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 1980; Collins 1988) and then used them 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 et al. (1988) used 14 farm assets and 9 non-farm assets together to extract factor scores and then evaluated the performance of the 14 farm assets. This approach showed promising results. Although Bower et al. (1984) 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.

### III. 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 48 observations except the returns for NCREIF timberland index, which have only 44 observations (1987-1997).

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 1994). The basic data for TPI appear in *Real Estate Profiles*, published quarterly by Evaluation Associates, Inc (University of Georgia 1998). 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 1994).

TLP includes four publicly traded timberland limited partnership companies, which were spin-offs from several forest products firms in the 1980s.<sup>1</sup> 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 that are in SIC 24 (wood products) or SIC 26 (paper and allied industries) and were traded continuously between 1986 and 1997.<sup>2</sup> Quarterly returns for these three portfolios are obtained from the Center for Research in Stock Price database by the University of Chicago (CRSP database 1998). Market value weighting is used to form each portfolio.<sup>3</sup>

SSPA is the average of southern pine pulpwood and sawtimber stumpage (Timber Mart-South 1998). PNSPA is the average value of timber harvested on the National Forests of the Pacific Northwest (Haynes 1998).<sup>4</sup> These two are included in this study because stumpage price is one of the major sources

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<sup>1</sup> They are International Paper TLP, Rayonier TLP, Plum Creek TLP, and Pope Resources LP.

<sup>2</sup> A list of these firms in L-FICP and M-FICP can be obtained from the authors.

<sup>3</sup> Equal weighting has been tried, and the results are similar to these reported in this paper.

<sup>4</sup> Several stumpage prices are reported in the Pacific Northwest (Haynes and Warren 1989). 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,

of returns for timberland investment that are relevant for millions of non-industrial private forest landowners, and some researchers (e.g., Redmond and Cabbage 1988) assessed timberland performance based on historical stumpage price alone.

The last forest-related alternative is lumber futures (Spruce-Pine-Fir 2x4), which are traded on Chicago Mercantile Exchange (Bridge CRB 1998). The return series are formed from the contracts whose expirations are closest to the quarters. 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. 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 1998).

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 1998). 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.

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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.

The last three assets are three metals: Gold (GOLD), Steel (STEEL), and Aluminum (ALUM) (Bridge CRB 1998). 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 bills return used in the application of CAPM are from Ibbotson Associates (1998).

#### IV. Data Analysis and Results

##### 1. CAPM

Equation 2 is applied to the eight forestry-related assets, and the results are 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 beta for the large forest industry company portfolio (1.04) is bigger than one and significant at the 10% level. The beta for the medium forest industry company portfolio (0.94) is very close to one. The beta for the timberland limited partnership portfolio is 0.52 and also significant 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 1994).

##### 2. 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 44 quarterly returns (1987-1997) 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 Institutes 1996) 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, 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. The large and medium forest industry companies, for example, show the greatest sensitivity to Factor 1. Because of the orthogonal rotation, most assets load significantly on only one or two factors, reducing the factorial complexity. While factors are generally understood to describe common economic movements, the various asset groupings seem to represent those movements in this study.<sup>5</sup>

*Step 2. Calculate factor scores for every quarter*

Barlett's (1937) procedure is used to estimate 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

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<sup>5</sup> It 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. In reality, naming the factors with certainty is very difficult with this kind of explanatory factor analysis.

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.<sup>6</sup>

*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 (see Table 3):

$$(6) \quad R_{it} = \alpha_{it} + \beta_{i1}F_{1t} + \dots + \beta_{i5}F_{5t} + \phi_{it}$$

where

$R_{it}$  = the realized return on asset i in quarter t,  $i = 1, \dots, 18$ ,  $t = 1, \dots, 44$ ;

$\alpha_{it}$  = the intercept for asset i;

$\beta_{ij}$  = the factor beta or sensitivity coefficients for asset i on factor j,  $j = 1, \dots, 5$ ;

$F_{jt}$  = the value of factor score j in quarter t,  $j = 1, \dots, 5$ ; and

$\phi_{it}$  = the residual error for asset i in quarter t.

*Step 4. Calculate risk premia 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:

$$(7) \quad R_{it} = \lambda_{0t} + \lambda_{1t}\beta_{i1} + \dots + \lambda_{5t}\beta_{i5} + e_{it}$$

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<sup>6</sup> 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.

where

$R_{it}$  = the realized return on asset  $i$  in quarter  $t$ ,  $i = 1 \dots 18$ ,  $t = 1, \dots, 44$ ;

$\lambda_{0t}$  = the intercept in quarter  $t$ ;

$\lambda_{jt}$  = the estimated risk premium for factor  $j$  in quarter  $t$ ,  $j = 1, \dots, 5$ ;

$\beta_{ij}$  = the factor beta or sensitivity coefficients for asset  $i$  on factor  $j$ ,  $j = 1, \dots, 5$ ;

$e_{it}$  = 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:

$$\lambda_0 = 0.0236, \lambda_1 = 0.0186, \lambda_2 = -0.0144, \lambda_3 = -0.0191, \lambda_4 = -0.0210, \lambda_5 = 0.0138.$$

#### *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).

$$(8) \quad E(R_i) = 0.0236 + 0.0186\beta_{i1} - 0.0144\beta_{i2} - 0.0191\beta_{i3} - 0.0210\beta_{i4} + 0.0138\beta_{i5}$$

### 3. 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 (TPI, NCREIF-T, and TLP) have low required rates of returns. The historical returns of timberland in the eleven years (1987-1997) 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 1990; Binkley, et. al. 1996). Second, both large and medium forestry industry companies (L-FICP and M-FICP; labeled as “B” in Table 4) did not earn enough risk-adjusted returns. Furthermore, the performance of medium forestry industry firms is worse than that for the large forestry industry companies. Third, 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).

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 (see 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.

Second, following Chen (1983), a test described in Davidson and Mackinnon (1981) for discriminating between competing models was conducted. In each of 44 quarters, the actual returns on the 18 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;  $\theta_t$  is the regression coefficient; and  $u_{it}$  is the error

term.  $\theta_i$  is expected to be close to one if the APT is a better model. Actually, the mean of  $\theta_i$  is 0.88, and 40 of the 44 coefficients are significant at the 5% level.

Third, following Bower et al. (1984), the quality of the forecast was assessed by using an approach suggested by Theil (1966). 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:

$$(11) \quad U_i^2 = \frac{\sum_{t=1}^{44} (R_{i,t} - R_{i,t}^{\text{models}})^2}{\sum_{t=1}^{44} (R_{i,t} - \bar{R}_i)^2} \quad (i = 1, 2, \dots, 18)$$

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.

## VI. Conclusions and Discussion

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 partnership in the past eleven years (1987-1997) 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.

Forestry industry companies do not earn risk-adjusted returns, and the performance of medium forestry industry firms is 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 the selling off 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 assemble the return generation process of timberland investments as they do not include biological growth. Finally, lumber futures have just earned the required return.

These results imply that timberland investment will continue to be a growing business in the future (Donegan 1998). 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 can enhance the return of investors.

Nevertheless, the results of this study need to be interpreted with caution, as only about eleven years' data are used in this study 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. 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 Institutes 1996). 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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Table 1. Estimated Results with CAPM

Asset	$\alpha$		$\beta$		$R^2$	$\bar{R}^2$
	Coefficient	t-ratio	Coefficient	t-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.

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

Asset	Factor1	Factor2	Factor3	Factor4	Factor5	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

\* The values for factor loading are multiplied by 100.

Table 3. Assets' Sensitivity to Each Factor

Asset	Beta1	Beta2	Beta3	Beta4	Beta5	R <sup>2</sup>	$\bar{R}^2$
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.

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.

## Abstract

Capital asset pricing model (CAPM) and arbitrage pricing theory (APT) are used to assess the financial performance of eight forestry-related investment vehicles. While 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 to a lesser extent, publicly traded timberland limited partnerships, have had a low risk level and excess returns; (b) forestry industry companies have not earned risk-adjusted returns, and the performance of medium forestry industry firms is worse than that of the large forest industry companies; (c) stumpage price does not resemble the return generation process of timberland investments; and (d) lumber futures have little excess return.

## I. Introduction

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 paper is to assess the financial performance of all major forestry-related investment vehicles and to better the understanding of 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. Many have purchased the stocks and bonds of forest industry companies and timberland limited partnerships. Many others own forestlands. More sophisticated investors may also hold lumber futures or participate in other mechanisms (Zinkhan et al. 1992). In addition, the restructuring in the forest industry since the middle of the 1980s has provided a supply of investment-grade timberland. 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 1996).

Based on Markowitz's (1952) 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 1978). Thomson (1987) used CAPM to assess the financial risk of growing commercial timber crops of sawlogs in the U.S. Midwest and South. Washburn and Binkley (1993) examined the historical relationship between forestry returns and inflation. Binkley, Raper and Washburn (1996) analyzed the institutional ownership of timberland. Redmond and Cabbage (1988) 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 (Thomson 1992; Washburn

and Binkley 1990, 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 et al. 1988; 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 (1978) and subsequently extended by Roll and Ross (1980), 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 (1980) conducted the first empirical investigation of APT using individual equity data. Arthur et al. (1988) used APT to analyze the relationship between risk and returns for agricultural assets from 1976 to 1984. The APT results were generally more robust than CAPM. However, no APT study could be found in forest-related investment, and studies on timberland investment have not been put in contrast with other forest investment vehicles. This study fills in the gap and presents empirical results on the financial characteristics of all major forest-related investment vehicles. The next section presents methodology, section III describes data, section IV provides data analysis and results, and the final Section concludes.

## II. Methodology

### 1. Capital Asset Pricing Model

Developed by Sharpe (1964) and Lintner (1965) in the mid-1960s, the Capital Asset Pricing Model (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

$R_i$  = the required rate of return on investment  $i$ ;

$R_f$  = the risk-free rate of return (measured by the yield on US T-bills);

$\beta_i$  = investment  $i$ 's risk premium, commonly known as beta; and

$R_m$  = the market's expected rate of return (with a market indicator series such as the S&P 500 as the proxy for the market).

Jensen (1969) proved that CAPM was 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  $\alpha_i$  for CAPM regression signifies the valuation of an asset due to 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.

$\beta_i$  is an indicator of the asset's market risk. If the beta value is greater (less) than one, 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.

## 2. Arbitrage Pricing Theory

Arbitrage Pricing Theory (APT) was developed by Ross (1976) and enhanced by others. APT is based on the law of one 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:

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

where

$R_i$  = the actual (random) rate of return on asset  $i$  in any given period;

$E(R_i)$  = the expected return on asset  $i$ ;

$\delta_n$  = a common factor with a zero mean that influences the returns on all assets;

$\beta_{in}$  = sensitivity of asset i to factor n; and

$e_i$  = random error term, unique to asset i.

The sensitivity measure  $\beta_{in}$  in APT has similar interpretations to  $\beta_i$  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:

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

where the  $\lambda_n$  are interpreted as risk premium (If there is a risk-free rate  $\lambda_f$ , 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.

Census has not been reached on two issues in the empirical application of APT. First, various numbers of factors have been recommended. Roll and Ross (1980) concluded that no more than four or five factors were relevant. Although some studies have identified or pre-specified as many as ten factors (Robin and Shukla 1991), most empirical studies suggested that only three to five factors influenced asset returns and were priced in the market (Chen 1983; Chen et al. 1986; Bubnys 1990). Second, sample size and formation does matter, and different formation may yield different results (Livingston 1977; Dhrymes et al. 1984). 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 1980; Collins 1988) and then used them 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 et al. (1988) used 14 farm assets and 9 non-farm assets together to extract factor scores and then evaluated the performance of the 14 farm assets. This approach showed promising results. Although Bower et al. (1984) 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.

### III. 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 48 observations except the returns for NCREIF timberland index, which have only 44 observations (1987-1997).

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 1994). The basic data for TPI appear in *Real Estate Profiles*, published quarterly by Evaluation Associates, Inc (University of Georgia 1998). 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 1994).

TLP includes four publicly traded timberland limited partnership companies, which were spin-offs from several forest products firms in the 1980s.<sup>1</sup> 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 that are in SIC 24 (wood products) or SIC 26 (paper and allied industries) and were traded continuously between 1986 and 1997.<sup>2</sup> Quarterly returns for these three portfolios are obtained from the Center for Research in Stock Price database by the University of Chicago (CRSP database 1998). Market value weighting is used to form each portfolio.<sup>3</sup>

SSPA is the average of southern pine pulpwood and sawtimber stumpage (Timber Mart-South 1998). PNSPA is the average value of timber harvested on the National Forests of the Pacific Northwest (Haynes 1998).<sup>4</sup> These two are included in this study because stumpage price is one of the major sources

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<sup>1</sup> They are International Paper TLP, Rayonier TLP, Plum Creek TLP, and Pope Resources LP.

<sup>2</sup> A list of these firms in L-FICP and M-FICP can be obtained from the authors.

<sup>3</sup> Equal weighting has been tried, and the results are similar to these reported in this paper.

<sup>4</sup> Several stumpage prices are reported in the Pacific Northwest (Haynes and Warren 1989). 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,

of returns for timberland investment that are relevant for millions of non-industrial private forest landowners, and some researchers (e.g., Redmond and Cabbage 1988) assessed timberland performance based on historical stumpage price alone.

The last forest-related alternative is lumber futures (Spruce-Pine-Fir 2x4), which are traded on Chicago Mercantile Exchange (Bridge CRB 1998). The return series are formed from the contracts whose expirations are closest to the quarters. 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. 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 1998).

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 1998). 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.

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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.

The last three assets are three metals: Gold (GOLD), Steel (STEEL), and Aluminum (ALUM) (Bridge CRB 1998). 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 bills return used in the application of CAPM are from Ibbotson Associates (1998).

#### IV. Data Analysis and Results

##### 1. CAPM

Equation 2 is applied to the eight forestry-related assets, and the results are 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 beta for the large forest industry company portfolio (1.04) is bigger than one and significant at the 10% level. The beta for the medium forest industry company portfolio (0.94) is very close to one. The beta for the timberland limited partnership portfolio is 0.52 and also significant 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 1994).

##### 2. 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 44 quarterly returns (1987-1997) 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 Institutes 1996) 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, 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. The large and medium forest industry companies, for example, show the greatest sensitivity to Factor 1. Because of the orthogonal rotation, most assets load significantly on only one or two factors, reducing the factorial complexity. While factors are generally understood to describe common economic movements, the various asset groupings seem to represent those movements in this study.<sup>5</sup>

*Step 2. Calculate factor scores for every quarter*

Barlett's (1937) procedure is used to estimate 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

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<sup>5</sup> It 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. In reality, naming the factors with certainty is very difficult with this kind of explanatory factor analysis.

individual estimated returns. This estimates the time series factor scores for each quarter. If  $B$  is taken to be the  $18 \times 5$  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  $18 \times 18$  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  $18 \times 1$  vector of returns on the 18 assets in quarter  $t$ .<sup>6</sup>

*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 (see Table 3):

$$(6) \quad R_{it} = \alpha_{it} + \beta_{i1}F_{1t} + \dots + \beta_{i5}F_{5t} + \phi_{it}$$

where

$R_{it}$  = the realized return on asset  $i$  in quarter  $t$ ,  $i = 1, \dots, 18$ ,  $t = 1, \dots, 44$ ;

$\alpha_{it}$  = the intercept for asset  $i$ ;

$\beta_{ij}$  = the factor beta or sensitivity coefficients for asset  $i$  on factor  $j$ ,  $j = 1, \dots, 5$ ;

$F_{jt}$  = the value of factor score  $j$  in quarter  $t$ ,  $j = 1, \dots, 5$ ; and

$\phi_{it}$  = the residual error for asset  $i$  in quarter  $t$ .

*Step 4. Calculate risk premia 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:

$$(7) \quad R_{it} = \lambda_{0t} + \lambda_{1t}\beta_{i1} + \dots + \lambda_{5t}\beta_{i5} + e_{it}$$

---

<sup>6</sup> 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  $D$ .

where

$R_{it}$  = the realized return on asset  $i$  in quarter  $t$ ,  $i = 1 \dots 18$ ,  $t = 1, \dots, 44$ ;

$\lambda_{0t}$  = the intercept in quarter  $t$ ;

$\lambda_{jt}$  = the estimated risk premium for factor  $j$  in quarter  $t$ ,  $j = 1, \dots, 5$ ;

$\beta_{ij}$  = the factor beta or sensitivity coefficients for asset  $i$  on factor  $j$ ,  $j = 1, \dots, 5$ ;

$e_{it}$  = 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:

$$\lambda_0 = 0.0236, \lambda_1 = 0.0186, \lambda_2 = -0.0144, \lambda_3 = -0.0191, \lambda_4 = -0.0210, \lambda_5 = 0.0138.$$

#### *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).

$$(8) \quad E(R_i) = 0.0236 + 0.0186\beta_{i1} - 0.0144\beta_{i2} - 0.0191\beta_{i3} - 0.0210\beta_{i4} + 0.0138\beta_{i5}$$

### 3. 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 (TPI, NCREIF-T, and TLP) have low required rates of returns. The historical returns of timberland in the eleven years (1987-1997) 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 1990; Binkley, et. al. 1996). Second, both large and medium forestry industry companies (L-FICP and M-FICP; labeled as “B” in Table 4) did not earn enough risk-adjusted returns. Furthermore, the performance of medium forestry industry firms is worse than that for the large forestry industry companies. Third, 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).

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 (see 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.

Second, following Chen (1983), a test described in Davidson and Mackinnon (1981) for discriminating between competing models was conducted. In each of 44 quarters, the actual returns on the 18 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;  $\theta_t$  is the regression coefficient; and  $u_{it}$  is the error

term.  $\theta_i$  is expected to be close to one if the APT is a better model. Actually, the mean of  $\theta_i$  is 0.88, and 40 of the 44 coefficients are significant at the 5% level.

Third, following Bower et al. (1984), the quality of the forecast was assessed by using an approach suggested by Theil (1966). 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:

$$(11) \quad U_i^2 = \frac{\sum_{t=1}^{44} (R_{i,t} - R_{i,t}^{\text{models}})^2}{\sum_{t=1}^{44} (R_{i,t} - \bar{R}_i)^2} \quad (i = 1, 2, \dots, 18)$$

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.

## VI. Conclusions and Discussion

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 partnership in the past eleven years (1987-1997) 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.

Forestry industry companies do not earn risk-adjusted returns, and the performance of medium forestry industry firms is 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 the selling off 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 assemble the return generation process of timberland investments as they do not include biological growth. Finally, lumber futures have just earned the required return.

These results imply that timberland investment will continue to be a growing business in the future (Donegan 1998). 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 can enhance the return of investors.

Nevertheless, the results of this study need to be interpreted with caution, as only about eleven years' data are used in this study 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. 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 Institutes 1996). 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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Table 1. Estimated Results with CAPM

Asset	$\alpha$		$\beta$		$R^2$	$\bar{R}^2$
	Coefficient	t-ratio	Coefficient	t-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.

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

Asset	Factor1	Factor2	Factor3	Factor4	Factor5	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

\* The values for factor loading are multiplied by 100.

Table 3. Assets' Sensitivity to Each Factor

Asset	Beta1	Beta2	Beta3	Beta4	Beta5	R <sup>2</sup>	$\bar{R}^2$
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.

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.