SOME PROBLEMS IN ESTIMATING THE CAPITAL ASSET PRICING MODEL FOR TIMBERLAND INVESTMENTS

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ABSTRACT

Portfolio theory and asset pricing models have become common tools for analyzing the risk and return of timberland investments. Not surprisingly, problems arise in applying tools developed for financial assets such as stocks to timberlands. In this paper, we discuss some of the problems for estimating the Capital Asset Pricing Model for forest assets, and by implication indicate some fruitful areas for further research.

INTRODUCTION

The use of portfolio theory and asset pricing models to examine the risk and return of forest assets has become commonplace since Mills and Hoover (1982) first utilized portfolio optimization to examine the capacity of Indiana hardwood forests to diversify a portfolio of traditional financial assets. Subsequent analysts have examined the diversification potential of timberland investments in other geographic regions (e.g. Thomson 1987; Thomson and Baumgartner 1988; Conroy and Miles 1987; Zinkhan and Mitchell 1988; DeForest et al. 1989). These and other researchers have also applied asset pricing models—generally either Sharpe's (1963) single-index market model (with returns to the overall market portfolio serving as the index) or the Capital Asset Pricing Model (CAPM; Sharpe 1964; Lintner 1965)—to timberland investments to measure their risk and evaluate their performance (e.g. Thomson 1987; Zinkhan 1988; Zinkhan and Mitchell 1988; Cubbage, Harris, and Redmond 1988; Redmond and Cubbage 1988; Binkley and Washburn 1988a, 1988b).

These efforts have been fruitful. Two broad, yet apparently fundamental, results have emerged. First, returns for forest assets are weakly correlated with returns for many traditional investments, and therefore timberlands present an opportunity for portfolio diversification. Second, forest assets carry relatively low levels of financial risk. This suggests that investors should demand relatively low rates of return from timberland investments.

Significant problems remain, however, in the application of portfolio theory and asset pricing models to forest assets. To fully comprehend the implications of extant analyses, and to design new research for increasing our understanding of the risk and return of timberland investments, these problems must be acknowledged, and resolved. This paper discusses some of these issues. Although most of our results have implications for portfolio analysis and asset pricing models in general, we center our discussion around the CAPM.

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1 This research is part of a larger project on the evaluation of investments in southern pine forestry which is sponsored jointly by Yale University, the USDA Forest Service Southeastern Forest Experiment Station, Scott Paper Company, Weyerhaeuser Company, South Carolina National Bank, and First Wachovia Bank and Trust. None of these organizations is responsible for the data, analysis, or conclusions presented here.

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The CAPM specifies an equilibrium relationship between asset i's expected rate of return (\(ER_i\)), the rate of return on a riskless asset (\(R_f\)), and the expected risk premium on the market portfolio of all assets in the economy (\(ER_m - R_f\)):

\[
ER_i = R_f + \beta (ER_m - R_f),
\]

(1)

where \(\beta\) equals \(\text{cov}(R_i, R_m) / \text{var}(R_m)\). As expected returns cannot be observed, the model must be estimated from \textit{ex post} data. Following Jensen (1969), historical risk premia for the asset are typically regressed on contemporaneous risk premia for the market portfolio:

\[
R_{i,t} - R_{f,t} = \alpha + \beta (R_{m,t} - R_{f,t}) + \epsilon_t,
\]

(2)

where the error term \(\epsilon\) is a random disturbance. Risk-free returns are calculated from a proxy for a riskless asset, such as 90-day U.S. Treasury bills, and market returns from a proxy for the overall market portfolio, such as the Standard and Poors Index of 500 common stocks (with dividends reinvested).

The slope coefficient, called the CAPM beta, measures the systematic or nondiversifiable risk of the asset. The larger the value of beta, the greater the asset's financial risk. Investors require assets with a beta of one, for example, to earn the overall market rate of return, those with a beta of zero to earn only the risk-free rate of return, and those with a negative beta to earn even less than the risk-free rate. The intercept term, called the CAPM alpha, measures the difference between the return that an asset has actually generated and the return that is justified by its level of systematic risk. If capital markets are in equilibrium, then the value of alpha is zero.

Estimation of the CAPM equation (2) requires a time series of historical returns for the asset under study. Unfortunately, records of returns for actual forest assets rarely exist. In place of historical data, analysts have created synthetic time series based on assumptions about the structure of the forest asset. In some cases, different assumptions can produce substantially different estimates of risk and return. The next section discusses the consequences of various approaches for measuring stumpage, growing stock, and bare land values.

Given historical data on timberland returns, some additional problems arise in model estimation. Returns for forest assets are calculated from period-average stumpage prices (e.g. the average of prices observed throughout a year). This obscures some of the variability of forestry returns, and has confused estimation of the CAPM by confounding the measurement of contemporaneous market and risk-free returns. Period-averaging of stumpage prices also induces serial dependence into forestry returns, which affects tests of the CAPM assumption that markets for forest assets are informationally efficient. The third section discusses these features of CAPM estimation for forest assets.

Although these problems are important, they do not dampen the prospects for further research in this field. To the contrary, they describe an agenda of interesting research questions. The final section of the paper summarizes those results we consider to be well supported by theory and data, and concludes by describing what we consider to be the most important areas for future research.
CALCULATING RETURNS FOR FOREST ASSETS

Records of historical returns for actual forest assets are not generally available for estimating the CAPM. As a substitute, researchers have constructed time series of returns for hypothetical forests from historical values of the assets' component parts: stumpage, growing stock, and bare land values; timber growth; and various holding costs (e.g. regeneration expenses, property taxes, and protection from fire and pests). Using this method, the continuous rate of return during period t for any forest asset i ($R_{i,t}$) is given by:

$$R_{i,t} = \ln \left( \frac{(H_{i,P_t} - C_t + GSV_t + BLV_t)}{(GSV_{t-1} + BLV_{t-1})} \right),$$

(3)

where $H$ is the volume of stumpage harvested at the conclusion of the period, $P$ is the price of stumpage at the conclusion of the period, $C$ is the cost of holding the asset during the period (payable at its conclusion), and GSV and BLV are the respective values of the growing stock and bare land at the conclusion of the period.

Unfortunately, even this indirect approach to obtaining forestry returns is hindered by a dearth of information. The current level of growing stock and bare land values are difficult to observe; records of their historical values are essentially non-existent. Information on historical holding costs is sketchy. Historical stumpage prices are the most abundant source of data for calculating forestry returns, but even they are often of dubious accuracy or not available at all.

Researchers must therefore rely on a series of assumptions about bare land and growing stock values, holding costs, and even stumpage prices to construct a time series of returns for forest assets. And the proper assumptions to make are arguable. As a consequence, past research has taken a variety of approaches to measure current and historic values of the key variables.

**Stumpage Value**

Stumpage prices are the most influential determinant of the value of hypothetical forests. If one assumes that bare land and growing stock values track stumpage prices, holding costs are negligible, and timber growth is constant, then all of the variation in forestry returns arises from changes in stumpage price. Even when other assumptions are made, changes in stumpage price often account for the bulk of variation in returns. In such cases, CAPM betas can be estimated to a good approximation from rates of change in stumpage price alone. The other components of forest asset value only affect the estimate of alpha.

Cubbage, Harris, and Redmond (1988) and Redmond and Cubbage (1988) have in fact estimated the CAPM from rates of change in stumpage price. (They sometimes add a constant rate of timber growth, which increases the alpha estimate accordingly, but should leave the beta unchanged.) Thomson and Baumgartner (1988) demonstrate that, given their particular assumptions about growing stock and bare land values and holding costs, market-model coefficients estimated from rates of change in stumpage price alone are nearly identical to those obtained with their detailed series of constructed returns.

Stumpage prices are also the most abundant source of data for calculating historical returns to forest assets. But despite their relative availability, there are few price series of sufficient length or perceived accuracy for estimation of the CAPM. This is particularly true outside the South. When data on stumpage values are not available, or when they are of dubious accuracy, forestry returns must be calculated with some proxy measure for price. Here, we examine the consequences for the CAPM of two important proxies: (i) bid prices for national forest stumpage in the West, and (ii) log or lumber prices.
Bid Prices for National Forest Stumpage. Often the only reported prices for stumpage in the West are the successful bids for public timber. This is not surprising, as relatively little private stumpage is sold on the open market. It creates a problem for estimating returns for forest assets, however, because public timber is not sold for immediate harvest. Rather, winning bidders are granted several years to harvest their timber. Aside from a relatively small deposit, they do not actually pay for the timber until it is harvested. Bid prices for public stumpage are therefore based on the price that buyers expect to prevail when they harvest the timber. In other words, bid prices measure expected future timber prices, not current stumpage values (Rucker and Leffler 1988).

The average price of national forest timber that is actually harvested is a much better measure of the current market price of stumpage. Consider the case of a profit-maximizing firm which holds an array of contracts to harvest public timber, each with a different bid price. For simplicity, ignore the problems of contract termination, forest growth, bid deposits, and the like. If current prices are the best estimates of future prices (an assumption supported in the next section), then in any year the firm will cut all of the timber with a bid price less than or equal to the current market value, and will leave unharvested all of the timber with a higher bid price. Hence, the bid price of the marginal unit of timber actually harvested will accurately measure current market value. The Forest Service reports a so-called "cut price" or the average value of timber harvested in a particular year. Accepting the argument given above, this price is clearly a more accurate measure of the actual market value of timber in a particular year.

Table 1 compares the mean, standard deviation, correlation with stock market returns, and CAPM betas calculated from continuous rates of change in annual cut and bid prices for national forest sawtimber stumpage in four western regions. CAPM betas were obtained from estimates of equation (2). Returns for 90-day U.S. Treasury bills and the S&P 500 stock market index (with dividends reinvested), obtained from Ibbotson Associates (1987), were used as proxies for returns to the risk-free asset and market respectively. Ordinary least squares regression was used to estimate the equation if the Durbin-Watson statistic for first-order autocorrelation of the error was within its upper bound for significance at the 0.05 level. If the Durbin-Watson statistic was beyond this bound, then the maximum likelihood option of the SAS ETS AUTOREG procedure (SAS Institute Inc. 1984) was used to estimate the model with a first-order autoregressive error. Unless noted otherwise, this same estimation procedure is used throughout our analysis.

Although their mean rates of change are similar, cut prices are much less volatile than bid prices. In western Oregon and western Washington, rates of change in cut prices are also less correlated with market returns than are rates of change in bid prices. Consequently, the CAPM beta estimated from rates of change in cut price is less than one-third the size of that estimated from bid prices. In the other western regions, cut prices are more highly correlated with the market than are bid prices. This tends to offset their lower volatility, and nearly equate CAPM betas estimated from cut and bid values.

In short, it appears that using bid prices for national forest sawtimber stumpage to measure current market values substantially overestimates price variability. For the commercially important Douglas-fir species (which dominates the Pacific Northwest, Westside), using bid prices to estimate the CAPM overstates systematic risk by more than threefold.

Log and Lumber Prices. In cases when stumpage prices have not been recorded, or when their accuracy is questionable, presumably-accurate series of prices for logs or lumber are sometimes used as a substitute for calculating forestry returns. Two approaches can be taken. Stumpage prices can be derived using a conversion surplus approach which deducts processing costs from log or lumber values. Alternatively, rates of change in log and lumber price can be used directly as a proxy for rates of change in stumpage price. Thus far, few researchers have used log
TABLE 1.--A comparison of the mean, standard deviation, correlation with the stock market, and CAPM beta for rates of change in national forest cut and bid prices

<table>
<thead>
<tr>
<th>Price Series</th>
<th>Rate of Change (%)</th>
<th>Standard Deviation (%)</th>
<th>Correlation with Market Returns</th>
<th>CAPM Beta</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pacific Northwest, Westside (1950-87)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cut</td>
<td>6.42</td>
<td>16.07</td>
<td>0.169</td>
<td>0.406**</td>
</tr>
<tr>
<td>Bid</td>
<td>6.47</td>
<td>37.55</td>
<td>0.367*</td>
<td>1.265*</td>
</tr>
<tr>
<td>Pacific Northwest, Eastside (1950-87)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cut</td>
<td>5.47</td>
<td>22.58</td>
<td>0.340*</td>
<td>0.700*</td>
</tr>
<tr>
<td>Bid</td>
<td>5.54</td>
<td>43.52</td>
<td>0.194</td>
<td>0.824</td>
</tr>
<tr>
<td>Rocky Mountains (1960-87)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cut</td>
<td>5.40</td>
<td>30.18</td>
<td>0.414*</td>
<td>1.199*</td>
</tr>
<tr>
<td>Bid</td>
<td>6.46</td>
<td>45.99</td>
<td>0.330*</td>
<td>1.538*</td>
</tr>
<tr>
<td>California (1950-87)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cut</td>
<td>6.28</td>
<td>27.11</td>
<td>0.419*</td>
<td>0.993*</td>
</tr>
<tr>
<td>Bid</td>
<td>5.58</td>
<td>39.12</td>
<td>0.328*</td>
<td>1.181*</td>
</tr>
</tbody>
</table>

Note: A single asterisk (*) indicates statistical significance at the 0.05 level of confidence, two asterisks (**) at the 0.10 level of confidence. Cut and bid prices were obtained from Adams, Jackson, and Haynes (1988).

or lumber prices to calculate forestry returns, Mills and Hoover (1982) and Mills (1988) being the primary examples.

The use of log or lumber prices has several practical difficulties. Because of the structure of forest products markets, log and lumber prices are typically less volatile than are stumpage prices (Haynes 1977), and may not be perfectly correlated with stumpage prices through time (see, for example, Luppold 1984). Thus, rates of return for forest assets calculated from rates of change in log and lumber price will produce misleading estimates of risk and return. Using the conversion surplus approach to estimate stumpage prices from lumber or log prices introduces the need for accurate time series on logging and processing costs. Data on these variables frequently are less available or accurate than are the stumpage price series themselves.

Table 2 compares the mean, standard deviation, correlation with stock market returns, and
CAPM beta for rates of change in sawtimber stumpage, sawlog, and lumber prices of southern pine and Douglas-fir. As anticipated, price volatility declines from stumpage to logs to lumber. Coincident with this decline in volatility is a decline in the average rate of price change. Rates of change in lumber prices are more highly correlated with returns to the stock market than are rates of change in either stumpage or lumber prices.

<table>
<thead>
<tr>
<th>Price Series</th>
<th>Mean Rate Of Change (%)</th>
<th>Standard Deviation (%)</th>
<th>Correlation with Stock Returns</th>
<th>CAPM Beta</th>
</tr>
</thead>
<tbody>
<tr>
<td>Southern Pine</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Louisiana Private Stumpage</td>
<td>4.42</td>
<td>14.51</td>
<td>-0.022</td>
<td>0.229</td>
</tr>
<tr>
<td>Louisiana Private Sawlogs</td>
<td>4.22</td>
<td>10.79</td>
<td>-0.017</td>
<td>0.181</td>
</tr>
<tr>
<td>Lumber PPI</td>
<td>3.87</td>
<td>8.85</td>
<td>0.137</td>
<td>0.261**</td>
</tr>
<tr>
<td>Douglas-Fir</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>W. Oregon and W. Washington National Forest Cut Price</td>
<td>5.62</td>
<td>16.52</td>
<td>0.058</td>
<td>0.342</td>
</tr>
<tr>
<td>W. Oregon and W. Washington Private Sawlogs</td>
<td>5.08</td>
<td>14.75</td>
<td>-0.128</td>
<td>0.057</td>
</tr>
<tr>
<td>Lumber PPI</td>
<td>4.13</td>
<td>12.68</td>
<td>0.368*</td>
<td>0.649*</td>
</tr>
</tbody>
</table>

Note: A single asterisk (*) indicates statistical significance at the 0.05 level of confidence, two asterisks (**) at the 0.10 level of confidence. National forest cut prices for Douglas-fir stumpage were obtained from Adams, Jackson, and Haynes (1988). All other prices were obtained from Ulrich (1987).

What are the consequences of using rates of change in log or lumber price rather than stumpage price to estimate the CAPM? In the case of southern pine, the net result of the differences in volatility and correlation with market returns is surprisingly similar betas for stumpage, logs, and lumber. For Douglas-fir, however, the stumpage, log, and lumber betas are very different, ranging from 0.057 for sawlogs to 0.649 for lumber. Use of lumber or log prices to estimate the risk of owning Douglas-fir timber would be very misleading.
Growing Stock Value

Forestry is a capital-intensive production enterprise (Binkley 1985), with the capital represented by the growing stock comprising as much as three-quarters of the value of a fully regulated forest asset taken as a whole. Consequently, changes over time in growing stock value are crucial for evaluating the risk and return of timberland investments. It is difficult, however, to measure the current market value of different ages of growing stock, let alone observe how these values have changed over time (Washburn and Romm 1988) provide one analysis for California). As a consequence, researchers must estimate the capital value of growing stock in order to construct estimates of the returns for forest assets.

Two approaches are conventional. Most researchers have assumed, either explicitly (e.g. Conroy and Miles 1987; Binkley and Washburn 1988a, 1988b) or implicitly (e.g. Redmond and Cabbage 1988), that the market value of growing stock is simply equal to its value if sold for immediate harvest in the stumpage market. Growing stock therefore has no value until it grows to a merchantable size. Other analysts (e.g. Thomson 1987; Thomson and Baumgartner 1988) have discounted expected future harvest revenues to obtain an estimate of growing stock value.

Both approaches assume that the value of growing stock tracks the price of stumpage (although allowing the discount rate to vary over time could cause some slight departures when the discounted harvest revenue approach is used). Thus, the choice between these two methods will primarily affect the magnitude of the return for the forest asset rather than its covariance with market returns, and consequently influence the CAPM alpha estimate rather than the beta estimate. The value of the growing stock calculated as the immediate harvest value will generally be lower than when calculated as the discounted value of future harvest income. Consequently, valuing the growing stock at its harvest value will produce a higher rate of return and a higher estimate of alpha.

To compare the two approaches, we used each method to calculate the value of the growing stock in a 30 acre fully regulated forest of southern pine. We assumed an initial planting density of 400 trees per acre, no thinnings, and a harvest age of 30 years. Yields for both pulpwood and sawtimber were taken from Burkhart et al. (1987) for site 50 land. Sawtimber and pulpwood prices were set at $163 per thousand board feet and $19 per cord respectively; bare land value was set at $350 per acre (these values were obtained from a survey of forestland appraisers throughout the South that we are presently conducting). Annual operating costs for the forest as a whole were set at $200, a typical cost of regenerating one acre. We assumed that all prices and costs would increase at an inflation rate of 4.3 percent (the average rate of change in the CPI from 1950 through 1987). For the discounted cash flow calculations, we used a nominal discount rate of 6.8 percent (calculated from the CAPM using a beta of 0.2 and returns for 90-day U.S. Treasury bills and the S&P 500 of 5.2 and 13.2 percent respectively, their average values from 1950 through 1987). As a benchmark for assessing the accuracy of the two approaches, we used current market values reported in our survey of southern forestland appraisers for various ages of young southern pine timber.

Figure 1 compares the three alternative estimates of value by age of growing stock. Table 3 gives the total value of all ages of growing stock, its proportion of the forest asset value as a whole, and the annual rate of return for the forest asset given by each procedure. The discounted value of future harvest revenues is nearly double the immediate harvest value. The lower capital value given by the immediate harvest approach yields a rate of return of 10.5 percent compared to 8.1 percent for the discounted harvest income. According to the appraisers, the immediate harvest value understates the value of growing stock and therefore overstates the return for the forest asset; the discounted harvest revenue overstates growing stock value and understates forest asset return.
FIGURE 1.—The immediate harvest value, the market value attributed by southern forestland appraisers, and the value of discounted future harvest income of different ages of southern pine growing stock in a 30 acre fully regulated forest.
TABLE 3.--The consequences of alternative growing stock valuation methods on the rate of return to a 30 acre fully regulated forest of southern pine

<table>
<thead>
<tr>
<th>Growing Stock Valuation Method</th>
<th>Growing Stock Value ($)</th>
<th>Proportion of Total Value (%)</th>
<th>Rate of Return (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Immediate Harvest Value</td>
<td>20,261</td>
<td>65.9</td>
<td>10.5</td>
</tr>
<tr>
<td>Forest Appraiser Survey</td>
<td>22,785</td>
<td>68.5</td>
<td>10.0</td>
</tr>
<tr>
<td>Discounted Future Harvest Income</td>
<td>39,273</td>
<td>78.9</td>
<td>8.1</td>
</tr>
</tbody>
</table>

**Bare Land Value**

Like the value of growing stock, the current value of bare land is difficult to observe and records of its historical values are nearly non-existent. As a substitute for actual data, researchers have made three assumptions about rates of change in bare land value. Some analysts posit that the value of bare land changes at the same rate as the return for the timber component of the forest asset (e.g. Redmond and Cubbage 1988). Thus, measures of asset risk such as CAPM betas that are calculated from timber returns (or rates of change in stumpage price) are assumed to apply to the land component as well. This approach finds support in the notion that bare land derives its value from the revenue it generates from timber production.

There may, however, be other determinants of bare forestland value. If so, the timber returns assumption is inappropriate. Other researchers have used rates of change in farmland values to measure rates of change in forestland values (e.g. Mills and Hoover 1982; Mills 1988; Binkley and Washburn 1988a, 1988b). Past values of bare forestland are backcasted from the current value with historical rates of change in farmland value. This approach is valid to the extent that common factors similarly affect farmland and forestland value. It is perhaps most applicable in regions such as the South, where the option to convert land between crop and forest should keep prices for either use closely aligned. Still other researchers have assumed that bare forestland values change at the rate of inflation (e.g. Zinkhan 1988 and Zinkhan and Mitchell 1988 through their analyses of the Southern Timberland Index Fund constructed by Forest Investment Associates).

The choice of assumption for bare land value is consequential. Table 4 compares the alternative risk and return characteristics of bare timberland and of a fully regulated southern pine forest asset in Louisiana. Both the mean and standard deviation of returns for bare land are substantially lower for the rate of change in farmland-value assumption than they are for the timber-return assumption. These same measures for the inflation rate assumption are, in turn, substantially lower than they are for the farmland-value assumption. Coincident with this decline in mean return and variability is an increasingly negative correlation with market returns. The timber-returns assumption results in a much higher CAPM beta for bare forestland than
backcasting with either rates of change in farmland value or inflation. When we look at the risk and return of a composite timber and land asset, the same patterns emerge, although the effects of the different bare land assumptions are dampened through the addition of growing stock to the valuation exercise.

TABLE 4.--A comparison of the mean, standard deviation, correlation with stock market returns, and CAPM beta for forestry returns in Louisiana assuming that rates of change in bare land value follow timber returns, rates of change in farmland value, or the inflation rate, 1955-85

<table>
<thead>
<tr>
<th>Bare Land Value Assumption</th>
<th>Mean Return (%)</th>
<th>Standard Deviation (%)</th>
<th>Correlation with Stock Returns</th>
<th>CAPM Beta</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bare Land</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Timber Returns</td>
<td>10.77</td>
<td>13.50</td>
<td>-0.041</td>
<td>0.182</td>
</tr>
<tr>
<td>Farmland</td>
<td>7.02</td>
<td>6.81</td>
<td>-0.143</td>
<td>-0.015</td>
</tr>
<tr>
<td>Inflation</td>
<td>4.62</td>
<td>3.25</td>
<td>-0.242</td>
<td>-0.010</td>
</tr>
<tr>
<td>Timber and Land</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Timber Returns</td>
<td>10.77</td>
<td>13.50</td>
<td>-0.041</td>
<td>0.182</td>
</tr>
<tr>
<td>Farmland</td>
<td>9.38</td>
<td>9.57</td>
<td>-0.074</td>
<td>0.125</td>
</tr>
<tr>
<td>Inflation</td>
<td>8.50</td>
<td>8.75</td>
<td>-0.073</td>
<td>0.118</td>
</tr>
</tbody>
</table>

Note: Timber returns are calculated for a fully regulated southern pine forest managed on a 35 year rotation to produce both pulpwood and sawtimber. They include changes in the immediate harvest value of the growing stock, harvest income, regeneration expenses, and various operating costs. Prices for private stumpage in Louisiana, obtained from Ulrich (1987), were used for the analysis. See Binkley and Washburn (1988a) for a detailed description of the calculations.

Rates of change in farmland value were calculated from the USDA series for Louisiana. The CPI was used to obtain the inflation rate. Returns to the composite timber and land asset were calculated as the weighted average of annual timber and land returns. Constant weights (37% land and 63% timber) were calculated from 1985 stumpage prices and land values, and applied to all years.
ESTIMATING THE CAPM FOR TIMBERLAND INVESTMENTS

Given a time series of timberland returns, another group of issues arise in using these data to estimate CAPM parameters. This section discusses several of these problems. First, because stumpage prices are reported as period averages, the measurement of market and risk-free returns is not straightforward. Mismeasurement has led past research to produce biased parameter estimates. Second, the CAPM assumes that asset markets are informationally efficient. Markets for forest assets appear to be inefficient when viewed over periods as short as month, which suggests that the CAPM may not be an appropriate framework for analyzing short-term forestry returns.

Period-Average Stumpage Prices

Stumpage prices are reported as period averages; that is, an average of prices observed throughout a month, quarter, or year. Averaging creates several problems for analyzing timberland returns. First, rates of change calculated from averaged data are less variable than the corresponding rates of change in instantaneous values. The precise effect depends on the averaging process (Daniels 1966; Rosenberg 1971). Working (1960) demonstrated that the variance of rates of change in a series of arithmetic averages calculated from values at n regular intervals within the period (e.g. an annual average calculated from monthly values) is equal to \((2n^2 + 1)/3n^2\) of the corresponding variance in rates of change in instantaneous values (e.g. the value at the conclusion of the year). The variance-reduction factor quickly approaches \(2/3\) as \(n\) increases. Thus, measures of the variability of returns for forest assets must be suitably increased to make them comparable with variability measures of returns for other assets.

Second, period averaging introduces spurious first-order serial correlation into the rates of change in the averaged series. This renders ordinary least squares regression an inefficient estimator for the parameters of asset pricing models, and also produces difficulties for tests of market efficiency which are based on the correlation structure of asset returns (Washburn and Binkley 1989a). Working (1960) demonstrates that the first-order serial correlation in a series of rates of change in arithmetic averages calculated from random values at n regular intervals within the period is equal to \((n^2 - 1)/(2n^2 + 1)\). This value quickly approaches 0.25 as \(n\) increases. Averaging does not induce any higher-order serial correlation.

Period averaging of stumpage prices has also confused the measurement of market and risk-free returns for estimation of the CAPM. Consider annual values, which are most frequently used to analyze forest assets. Annual forestry returns are calculated from rates of change in annual-average stumpage price. In contrast, annual returns for the market portfolio and risk-free asset are typically measured during single calendar years by the rate of change in their value (including any interim cash payments) from the outset of the year to its conclusion. During the two years spanned by the rate of change in annual-average stumpage price, there are two sets of calendar year market and risk-free rates of return. Some researchers (e.g. Binkley and Washburn 1988a, 1988b) have related annual-average forest returns to market and risk-free returns during the first calendar year. Others (Thomson 1987; Cabbage, Harris, and Redmond 1988; Redmond and Cabbage 1988; Zinkhan 1988; Zinkhan and Mitchell 1988) have related forest returns to market and risk-free returns during the second calendar year.

The choice is of more than theoretical interest because the two procedures produce vastly different empirical results. We used first and second calendar year market and risk-free returns to estimate the CAPM for rates of change in eleven of the series of annual-average sawtimber stumpage prices analyzed by Redmond and Cabbage (1988). For this analysis, periodic rates of change were used rather than continuous rates. First and second calendar year betas (along with
three other beta estimates that we discuss shortly) for national forest bid price series (we analyzed bid prices rather than cut prices despite the problems of the former in order to make our results comparable with previous research) are compared in Figure 2. Figure 3 makes the same comparison of betas estimated from private stumpage prices in Louisiana.

The different calendar years for measuring market and risk-free returns produced contrary estimates of the systematic risk of forest assets. When market and risk-free returns over the first calendar year were used to estimate the CAPM, the betas for all eleven of the price series were positive, and most of them were significant. This leads one to conclude that ownership of forest assets (especially the softwood species) entails substantial systematic risk. On the other hand, market and risk-free returns measured over the second calendar year produced negative betas; three of them were significantly different from zero. These estimates suggest the contrary conclusion that holding forest assets entails "negative" systematic risk, and that they should therefore earn less than the riskless rate.

In another paper (Washburn and Binkley 1989b), we derive the CAPM relationship for rates of change in period-average asset values. We show that neither of these previous approaches is correct. Each procedure systematically mismeasures the model's explanatory variables. This biases the estimates of CAPM parameters.

The precise form of the CAPM for period-average values depends on the averaging process. Given the process for averaging stumpage prices, the forestry CAPM can be accurately estimated by relating annual-average forestry returns to one of three alternative measures of annual-average market and risk-free returns: (i) the geometric mean of the thirteen twelve-month returns that can be calculated from values of the risk-free asset and market portfolio at the conclusion of each month during two calendar years, (ii) the arithmetic mean of these same thirteen returns, or (iii) the rate of change in the annual arithmetic mean of market and risk-free asset value calculated from values at the conclusion of each month. (The CAPM betas reported in Tables 1, 2, and 4 were estimated with the third measure of average market and risk-free returns.) In essence, period-average forestry returns should be related to period-average market and risk-free returns.

Figure 2 compares the three alternative beta estimates for the national forest bid prices. The choice among the three measures of average market and risk-free returns has little effect on the parameter estimates. The figure also compares the corrected betas those obtained using first and second calendar year returns. In general, using first calendar year returns causes an upward bias in beta estimates. The bias is often negligible for the softwoods but severe for the hardwoods. Use of second calendar year returns biases beta estimates downwards. The downward bias is relatively small for the hardwoods, but is large for the commercially important softwood species. Figure 3 makes the same comparison for the Louisiana prices. It shows the same general pattern, although for both softwoods and hardwoods, the bias caused by using first calendar year market and riskless returns is less severe than that caused by using second calendar year returns.

To summarize, measurement of market and risk-free returns over the second calendar year (e.g. Redmond and Cubbage 1988; Harris, Redmond, and Cubbage 1988; Zinkhan 1988; Zinkhan and Mitchell 1988) substantially underestimates the systematic risk of forest assets. Measurement of the explanatory variables over the first calendar year (e.g. Binkley and Washburn 1988a, 1988b) overestimates the systematic risk. The bias for commercially important softwood species, however, tends to be much smaller when market and risk-free returns are measured over the first calendar year than when they are measured over the second calendar year.
FIGURE 2.--A comparison of CAPM betas estimated by relating rates of change in the average annual price of sawtimber stumpage sold on national forests to alternative measures of market and risk-free rates of return. An asterisk (*) indicates that the estimate is statistically different from zero at the 0.10 level of confidence.
FIGURE 3.—A comparison of CAPM betas estimated from rates of change in the average annual price of sawtimber stumpage sold on private land in Louisiana to alternative measures of market and risk-free rates of return. An asterisk (*) indicates that the estimate is statistically different from zero at the 0.10 level of confidence.
Stumpage Market Efficiency

The CAPM implicitly assumes that markets for forest assets are informationally efficient; that is, that the expected future value of the asset is equal to its current value capitalized at its equilibrium rate of return:

\[ P_{t+1} = P_{t} \exp[R_{t} + \beta (E_{m,t} - R_{f,t})]. \]  (4)

We can equivalently express the efficiency condition in terms of the asset's rate of return:

\[ E_{i,t} - R_{f,t} - \beta (E_{m,t} - R_{f,t}) = 0. \]  (5)

If we condition the expectations operator on "weak-form" information–past departures of actual from equilibrium rates of return–in ex post form the condition becomes:

\[ R_{i,t} - R_{f,t} - \beta (R_{m,t} - R_{f,t}) = \epsilon_{t}. \]  (6)

where the expected value of \( \epsilon_{t} \) equals zero and \( \text{cov}(\epsilon_{t}, \epsilon_{t+j}) \) equals zero for all \( j \) not equal to \( t \). In other words, departures of actual from equilibrium rates of return are white-noise. A testable implication of equation (6) is that departures from equilibrium rates of return are serially independent. That is, past departures from equilibrium can not be used to identify current departures. A finding of significant serial dependence is cause to reject a joint hypothesis that markets for forest assets are efficient and that equilibrium rates of return conform to the specified model (Fama 1976), in this case the CAPM. If markets for forest assets are inefficient, then the CAPM is not an appropriate framework to measure their risk.

Lacking historical data on returns for actual forest assets, we tested the weak-form efficiency of markets for southern pine sawtimber stumpage (Washburn and Binkley 1989a). We used two variants of the single-index market model of equilibrium return rather than the CAPM. The market model postulates a linear relationship between equilibrium returns on individual assets and the value of a common market factor, or index, that affects the return on all assets. We selected two alternative indices–returns for the stock market (\( R_{m} \)) and the rate of inflation (\( R_{\text{inf}} \)):

Stock-based market model

\[ R_{i,t} = \alpha + \beta R_{m,t} + \epsilon_{t}, \]  (7)

Inflation-based market model

\[ R_{i,t} = \alpha + \beta R_{\text{inf},t} + \epsilon_{t}, \]  (8)

where \( \epsilon_{t} \) is a random error. The stock-based market model provides essentially the same test of efficiency as the CAPM (Brenner 1979). Using the inflation-based model along with the stock-based model tests the robustness of the efficiency results to the model of equilibrium return.

The market models were estimated using ordinary least squares regression of the rates of change in monthly-, quarterly-, and annual-average stumpage prices on rates of change in corresponding period-average values of the S&P 500 or the CPI. An interesting outcome of this procedure was a finding that rates of change in stumpage price are uncorrelated with the realized inflation rate. This counters the common view that timber is a good inflation hedge.

The weak-form efficiency of stumpage markets was evaluated by testing for serial dependence in the residual errors. To compensate for the spurious serial dependence induced by
period averaging, the hypothesis of serial independence was a correlation coefficient of 0.25 at the first lag and zero at all subsequent lags.

The results of the analysis are summarized in Table 5. They are robust with respect to the model of equilibrium rate of return, but vary with the time interval for measuring departures from equilibrium rates of stumpage price change. On annual and quarterly bases, departures from equilibrium rates were serially independent, indicating that stumpage markets are weak-form efficient. On a monthly basis, however, markets for southern pine sawtimber stumpage do not pass this test. A departure from the equilibrium rate of change over one month tends to be followed by a departure in the opposite direction during the next month. This short-run inefficiency suggests that a CAPM for forest assets based on short-run, monthly data is inevitably misspecified. It also suggests that there may be economic gain from short-term harvest flexibility or "playing the market" if the adjustment costs are small.

TABLE 5--Results of weak-form efficiency tests of markets for southern pine sawtimber stumpage

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Note: E indicates that weak-form efficiency is not rejected and I indicates that weak-form efficiency is rejected. Blanks indicate that no data were available to test the model. Monthly and quarterly prices were obtained from Timber Mart South (1987), annual prices from various state reports.
The issues discussed in this paper pose important econometric problems for applying the CAPM (along with portfolio theory and other pricing models) to forest assets. Lack of accurate records describing historical timberland returns forces analysts to construct time series based on assumptions about stumpage, growing stock, and bare land values. Different assumptions produce different measures of the return and risk of timberland investments. Because data on stumpage prices are more extensive than data on growing stock and bare land values, CAPM results probably are more reliable for assets that consist primarily of mature stumpage than for those with large bare land or growing stock components. Furthermore, if the bulk of the variation in the return for forest assets results from changes in stumpage price, it is possible to obtain reasonable estimates of asset risk, the CAPM beta. However, lacking good data on growing stock value, bare land value, and the cost of holding forest assets, it is difficult to estimate accurately asset performance as measured by the CAPM alpha. Hence, the measures of the historic risk of timberland investments are more reliable than are the estimates of past risk-adjusted performance.

Once a method for measuring historical forestry returns has been selected, another set of problems arise for estimating the CAPM equation. The primary source of confusion has been the reporting of stumpage prices as period averages, which has caused past researchers to mismeasure market and risk-free returns. This errors-in-variables problem has biased estimates of CAPM parameters.

Despite the significance of these problems, past efforts at applying portfolio theory and asset pricing models to timberland investments provide useful information for investment analysts. Two basic results emerge from past work. First, timberland investments can diversify a portfolio of traditional financial assets. Second, timberland investments have low systematic risk and therefore comparatively low returns are adequate to justify ownership of forest assets.

Several lines of research are important to strengthen these results. Our current efforts are proceeding on four fronts.

First, the lack of information on the actual market value of bare land and growing stock impedes accurate estimation of the return for forest assets. As noted earlier, we are conducting a survey of southern forestland appraisers to obtain their perceptions of these values. We are also designing an hedonic analysis of actual forestland sales in the South to measure directly the current market values of bare land and different ages of growing stock. To the extent that we can obtain data on past sales, the hedonic analysis will also indicate how actual market values have changed over time.

Second, our work to the present has concentrated on southern pine assets, partly due to the availability of data and partly because of the importance of the region to nontraditional investors. However, analysis of rates of stumpage price change suggests that there are substantial geographic differences in the return and risk of timberland investments. As shown in Table 2, the CAPM beta calculated from the rate of change in the cut price of Douglas-fir stumpage sold from national forests in the Pacific Northwest is 0.342, nearly double the beta for southern pine sawtimber stumpage in Louisiana of 0.229. Furthermore, the rate of change in the price of spruce sawtimber stumpage in Maine over a similar observation period produces a negative CAPM beta of about -0.3. These initial results merit further attention. What are the consequences of using Forest Service cut prices as proxies for market values of stumpage in the West? Do the negative betas for rates of change in sawtimber stumpage price in Maine mean that timberland investments in this region are superior performers, or do lower rates of growth for timber in Maine offset the lower risk.
Third, we are investigating the use of models for pricing financial options to value forest assets. Depending upon the stochastic processes for variables such as stumpage price, timber growth, and operating costs, holding young timber can be viewed as ownership of either a forward contract or an option for delivery of stumpage at some future date (Washburn 1987; Zinkhan 1989). In this framework, it is possible to estimate a theoretical capital value for growing stock or bare land with the risk-free rate of interest without specifying either the required rate of return (or discount rate) for timber capital, or the expected rate of future stumpage price change. Eliminating these parameters from the valuation problem has obvious advantages for empirical applications.

Finally, the validity of the traditional CAPM is arguable (Roll 1977; Ross 1978). Several alternative pricing models have been developed, including intertemporal CAPM's (Merton 1973; Breeden 1979), inflation-adjusted CAPM's (Friend, Landskroner, and Losq 1976), the Arbitrage Pricing Theory (APT; Ross 1976), and the new equilibrium theory (Ibbotson, Diermeier, and Siegel 1984). These alternative models have not yet been applied to forest assets. Given the common view that timberland is a good hedge against inflation, an inflation-adjusted CAPM (which assumes that investors are concerned with real rather than nominal returns) would seem to be promising. As noted earlier in our description of the tests for stumpage market efficiency, rates of change in stumpage price are not related to realized inflation. However, further analysis indicates that timber returns are inversely related to the anticipated component of inflation and directly to the unanticipated component. The implications of these relationships for measures of forest risk deserve more attention.

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