Lumber Futures and Timberland Investment

Authors

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Abstract

Using 20 years of data, we derive a pricing model for timberland market values. We examine the relationship between lumber futures, capitalization rates, anticipated inflation, anticipated construction, and timberland value. Using an ordinary least squares regression model and Johansen's (1988) cointegration technique, we find that timberland market values have a long-run significant positive equilibrium relationship with lumber futures and building permits. Capitalization rates have a significant negative relationship as expected. In the short run, unanticipated shocks in the independent variables provide a permanent change in timberland market values.

From 1985 to 2007, institutions increased their investments in timberland from approximately $69 million (Draffan, 2006) to approximately $40 billion (Hancock, 2008). Driven by the Employee Retirement Income Security Act (ERISA) of 1974, which required much greater portfolio diversification for institutional investments, timberland provided institutions with diversification opportunities when forest product companies collectively decided to divest themselves of their vast timberland holdings to raise new capital in the 1980s. Today, timberland is widely held by pension funds, insurance companies, real estate investment trusts, timberland investment management organizations, and other institutions. As an example, until recently, the Harvard Endowment invested approximately 10% of its portfolio in timberland (Draffan, 2006).

Timberland, as an asset class, exhibits unique characteristics. Unlike typical commercial property, which derives its value from expected rental income, timberland serves as both a factory and a storage facility for raw lumber products. For many investors, the harvesting of timber for lumber products is the sole reason for owning and managing these large tracts of land (Cascio and Clutter, 2008). Besides the lumber itself, these products also include pulp and paper, plywood, fiberboard, and other specialty materials. For others such as institutional investors, timberland provides an opportunity to diversify and minimize risk in their investment portfolios.

In this study we develop and test a pricing model for timberland. Since the sale of lumber is the income component of timberland, we use lumber futures in our model. The study also links the construction and development sector of the real estate industry to timberland value. Lumber is used in most construction projects and we examine this relationship through building permits. Lastly, since timberland is a long-term investment, we examine whether anticipated inflation influences its value. The study covers the period 1988 to 2008.

We find that timberland value has a positive long-run equilibrium relationship with six-month lumber futures prices and building permits. Capitalization rates of timberland (as proxied by their risk premiums) are negatively related to timberland value over the long-run as expected. Anticipated inflation has a negative relationship with timberland value, however this appears to be due to multi-collinearity between the variables. Through the variance decompositions, building permit issuance explains the largest percentage of shocks to the market values of timberland in the short term. Impulse responses by timberland to one standard deviation shocks and innovations of timberland market values and the other variables suggest that short-term shocks cause a permanent change in timberland value. Thus shocks affecting lumber futures and timberland capitalization rates result in a permanent change in timberland market prices.

Literature Review and Hypotheses

Pricing models for various investments such as stocks, bonds, commodities, and timberland have been examined extensively in prior research. Consistent with finance theory, Redmond and Cubbage (1988) note that the value of a parcel of timberland should equal the present value of the expected future cash flows from the sale of timber produced by that tract of land. But as demonstrated by Schiller with other assets, this relationship is inconsistent with the observations of real markets. Shiller (1979) shows that bond yield volatility is too large when based only on changes in the term structure of interest rates. Similarly, Schiller (1981) evaluates the classic valuation model for stocks and finds that stock price volatility is too large to be explained solely by the present value of future dividends.

Pricing models of timberland have been proposed by past researchers with varying degrees of success. Redmond and Cubbage (1988) apply the Capital Asset Pricing Model (CAPM) to timberland in Louisiana and find a beta of −0.23. Zinkhan (1988) and Zinkhan and Mitchell (1988) similarly find betas of −0.21 and −0.20, respectively, for southern pine forests. Binkley and Washburn (1988) measure portfolio returns of similar forest property and find a small but positive beta of 0.25. Washburn and Binkley (1990) examine portfolios of sawtimber and find similar positive betas with the exception of small negative betas for eastern hardwoods, oaks, and maples. Cascio and Clutter (2008) estimate regional betas ranging from −0.137 to 0.349 for the Northeast, Pacific Northwest, Southern, and National NCREIF Timberland Indexes.

Lumber Futures

Recently, housing futures began trading on the Chicago Mercantile Exchange (CME). One of the primary functions of a futures market is that of price discovery. By having derivative contracts available, the market is able to more easily remove pricing errors. Thus, additional information is provided about the true price of the underlying security by having more instruments trade on that security (Stoll and Whaley, 1993). Prior research indicates that futures markets tend to have quicker price reaction and higher information share than the underlying cash markets due to higher levels of liquidity that facilitate ease of trading and reduced transaction costs relative to the underlying cash market (Koutmos and Tucker, 1996). Most importantly, futures markets have been shown to be credible predictors of future asset prices and are better at predicting returns than cash indexes (Martikainen, Perttunen, and Puttonen, 1995). Futures markets are used by different market participants including both hedgers and market makers. Hedgers are market participants that use the futures markets to mitigate the risk of adverse price changes in many commodities and financial assets. Market makers are typically speculators that attempt to profit from the random arrival of buys and sells and thus earn the spread for their inventory activities.

Most prior research on the futures markets has centered on commodities such as oil, cattle, and petroleum or financial assets such as stock and bonds. While basis or location and the cost of carrying issues exist, futures contracts still accurately track an underlying cash market through settlement on an index or through a delivery process. Although lumber futures have received little research attention, Tomek and Gray (1970) find that for commodities that can be stored, like lumber, futures prices are generally accurate forecasters of spot prices. This reflects the cost of carry model for pricing futures. This model is a no arbitrage pricing approach where a futures position can be replicated by borrowing funds, buying the commodity today, and storing it until the future delivery date. The futures price must equal the sum of the current cash price for the commodity, the cost of borrowing the funds, and the storage cost, to prevent an arbitrage scenario. Since the futures contract is designed by the exchange to serve hedgers' needs, the value of the lumber futures contracts should reflect the value of the lumber as harvested from the timberland. Basically timberland prices should be driven by the value of harvested timber, the cost of capital used to purchase the land, and inflation as part of the storage cost.

While there is no research on the relationship between lumber futures prices and timberland value, lumber futures have been investigated. Rucker, Thurman, and Yoder (2005) perform event studies on lumber futures and find that housing starts significantly affect the price of lumber futures. The effects of housing starts on lumber futures are absorbed by the market in one day. Canadian and Japanese trade policy events negotiated by the United States International Trade Administration (ITA) or the United States International Trade Commission (ITC) are absorbed by the lumber futures market in three days. Endangered Species Act

(ESA) court rulings have longer market absorption times, taking over a week in some cases. Further, Karali and Thurman (2008) find that housing starts provide important information to lumber markets. Unanticipated errors (shocks) in the forecasts of housing starts result in a price movement by lumber futures nearing expiration. Also, as lumber inventories and time to delivery increase, the shocks have much less impact. However, lumber futures should provide us with a window into the cash flows that the market place anticipates will be derived from timberland in the future. As a result, we hypothesize that the price of timberland should be positively related to lumber futures.

Capitalization Rates

Another factor in developing timberland valuations is the capitalization rate. Jud and Winkler (1995) note that capitalization rates have an important role in the valuation of real property as it converts an expected income stream into the asset's value. Further, Chichernea, Miller, Fisher, Sklarz, and White (2008) suggest that capitalization rates provide important information on the equilibrium behavior of real estate prices, as well as expected trends in supply. The authors argue that if markets are efficient, then capitalization rates should be ''ex ante'' indicators of changes in construction costs and market rents. We believe timberland is no different from other property types in regards to property valuation. We hypothesize that capitalization rates for timberland should vary inversely with timberland values.

Anticipated Inflation

Wurtzebach, Mueller, and Machi (1991) indicate that inflation is an important factor in the prediction of real estate values by the long-term investor. They argue that institutions such as pension funds and insurance companies purchase a variety of assets to manage inflation risk and protect against inflation's negative effects. Anticipated inflation is plausibly an important factor in the growth of timberland market values. There have been some studies examining inflation's effect on real estate value such as Hinkelmann and Swidler (2008) and Plazzi, Torous, and Valkanov (2008). Results have been mixed. We hypothesize that timberland values should react positively with anticipated inflation.

Building Permits

The housing sector has traditionally used the lion's share of lumber produced by U.S. timberland. Building permits are used as a measure of future construction activity. We use building permits in our study because, as Somerville (2001) notes, building permits are the first sign of intent to build as they are the granting of permission by the local authority. In addition, permits may be needed for more than the creation of a single structure as these permits are used for remodeling, as well as additions to an existing structure. Furthermore, building permits can be estimated and seasonally adjusted more reliably than housing starts according to Teplin (1978). Lastly, Goodman (1986) notes there is less sampling error in building permit data in comparison to housing starts. Our hypothesis is that timberland market values are positively related to the increasing issuance of building permits.

Data

The National Council of Real Estate Investment Fiduciaries (NCREIF) tracks total returns from a large, geographically diverse sample of U.S. timberland which, as of June 30, 2008, was composed of over 10 million acres valued at $18,151,800,000. Quarterly total timberland returns are given by NCREIF and market values in this analysis are computed from these quarterly returns. NCREIF calculates these returns and includes operating income from the sale of timber products, as well as capital appreciation. The income is known as EBITDDA, earnings before income tax, depreciation, depletion, and amortization, and is the timberland equivalent of net operating income (NCREIF, 2008). Capitalization rates are based on the net operating income of the timberland. The capital appreciation component in the timberland returns is based on market value appraisals of the timberland. The timberland market values in the study are computed on a price per acre basis. We calculate a July 2008 market value estimate by dividing the portfolio market value by the portfolio acreage. The appreciation returns that signify the change in appraisal market values over time are used to compute prior market values.

Data on futures contracts are from RC Research, Inc. from Price-Data and verified with data from the Chicago Mercantile Exchange (CME). Lumber futures contracts are based on 110,000 board feet of random length 2x4's, grade 1 or 2. Deliverable specifications exist for moisture content, packaging, quality, and size to insure that the contract closely complies with cash market practices. Contracts carried into expiration are settled by physical delivery to the buyer's destination with standard terms added for shipping expenses. The exchange lists six expiration months for the commodity (January, March, May, July, September, and November) and extends thirteen months into the future. The tick size is $0.10 per board foot or $11 per contract. These contracts expire on the last trading day prior to the 16^{th} calendar day of the maturity month and are deliverable on any business day for the remainder of that month.

Matching the dates used in the NCREIF Timberland Index and futures lumber prices has some limitations. First, we can only use data for January 1 and July 1 in each year since these are the only times during the year when the NCREIF index corresponds reasonably well with lumber futures contract expirations. Second, due to holidays and weekends, futures contract closing prices are frequently unavailable on January 1 or July 1. Therefore, we use futures prices for the last business day closest to these dates. Thus, we are limited to six-month observation periods and a maximum of forty-one six-month observations (Jan. to July, and July to Jan., each year). While this is a limited sample size for the time span involved, Perron and Shiller (1985) argue that increasing the number of observations may not necessarily increase the statistical power.

We assume that the timberland values, as measured by NCREIF, suffer from smoothing. Smoothing is the dampening of measured risk in appraisal-based indices that results from the appraisers' partial adjustments at the disaggregate level and temporal aggregation when constructing the index at the aggregate level (Geltner, 1993). We adjust for smoothing using Geltner's (1993) methodology. This is shown by the following equation:

$$k^*_t = \frac{k_t - (1 - \alpha)k_{t-1}}{\alpha}, \qquad (1)$$

where k_t is the appraisal based return in year t and k^*t is the actual return after the correction procedure. We use the factor of 0.40 for the correction similar to Geltner (1993) and Pagliari, Scherer, and Monopoli (2005). Second, NCREIF acknowledges that full capital appreciation is not readily available until the fourth quarter of a given year in its timberland index since not all properties are reappraised every quarter (Washburn, 2004). Therefore, in lieu of desmoothing the data and as a robustness check, we reanalyze the original semi-annual using a seasonal dummy variable, similar to Chaudhry, Myer, and Webb (1999), to correct for any seasonality that may occur in the original timberland market value in our other set of tests.

Additionally, we realize that capitalization rates may cause spurious regression results in our pricing model due to the market value calculation contained in their denominator. In the empirical analysis, timberland market values are the dependent variable, while capitalization rates are an explanatory variable. We include a proxy for the capitalization rates to control for the spurious relation possibility. It can be argued that theoretically the capitalization rate for timberland can be proxied by the risk premium in the following expression:

$$R_p = R_t - R_{10\text{-}TBond}, \qquad (2)$$

where R_t is the income return for timberland, $R_{10\text{-}TBond}$ is used as a proxy for the long-term investor's risk-free rate, and R_p is the risk premium. Ciochetti and Shilling (2007) indicate the variation in property cap rates is caused by risk premiums and not interest rates.

The study uses anticipated inflation figures from the Livingston Survey of the Federal Reserve Bank of Philadelphia (2008). The Livingston Survey provides the longest running inflation estimates by economists in the U.S., dating back to 1946. We use these estimates as they are actual forecasts by economists for use in the business community. The survey provides several estimates such as 6-month or 12-month projections of anticipated inflation. Also each estimate is made by multiple economists. We use the means of the 12-month economic estimations. The mean factors in all the economists' forecasts and 12-month estimates allow for a longer time period suitable for an investment like timberland.

Building permits are obtained from the United States Census Bureau (2008). The Census Bureau collects data monthly from all permit gathering districts throughout the U.S. For our sample we use the total number of building permits issued during the month immediately preceding the quarter or semi-annual starting day. The monthly totals provide investors with an indication of potential future real estate development. The building permit data are seasonally adjusted and shown as an annual rate by the Census Bureau.

Methodology

We use the following general model to explain timberland market values:

$$Timb = f(CR, Fut, Infl, Home), \tag{3}$$

where *CR* is the capitalization rate proxy for timberland (risk premium), *Fut* is the lumber futures price, *Infl* is anticipated inflation, and *Home* is the anticipated amount of new home construction.

We begin testing this model by simple ordinary least squares regression of the form:

$$LnT_v = \alpha + \beta_1 T_c + \beta_2 lnL_f + \beta_3 I_a + \beta_4 lnB_p + \varepsilon_t, \tag{4}$$

where T_v is the natural logarithm of market values of timberland at the beginning of the time period (180 days), T_c is the capitalization rate for timberland during the immediately preceding time period, L_f is the natural logarithm of the 6-month lumber futures price at the beginning of the time period, I_a is the 12-month forecast of anticipated inflation made at the beginning of the time period, B_p is the natural logarithm of the number of building permits issued during the preceding month, α is the constant, and ε_t is the error term.

However, Granger and Newbold (1974) and Phillips (1986) show that ordinary least squares regression on non-stationary variables may produce spurious regressions. Therefore, cointegration techniques are employed to find long-run equilibrium relationships between the time series variables. We begin by testing for the stationarity of the variables with the Augmented Dickey Fuller (ADF) and the Phillips-Perron (PP) Tests. For use in cointegration analysis, each time series variable must be integrated to the order of I(1) or stationary in their first differences. In other words, they need to contain no more than one unit root. The natural log of the market values of timberland, building permits, and futures prices for lumber are used to prevent heteroscedasticity of the residuals in the data, but the figures used are shown with the original data to provide a clear and dynamic view of their actions over time. Capitalization rates and unanticipated inflation are not transformed in this manner as they are percentage rates.

Unit root tests are simple regression models that depend on certain assumptions. The ADF and PP tests that do not include a time trend, but include a drift term are based on the alternate hypothesis of a time series variable is stationary around a fixed mean (Campbell and Shiller, 1987) is shown by the following model:

$$y_t = \alpha + py_{t-1} + \varepsilon_t, \tag{5}$$

where α is the constant or drift term, py_{t-1} is the coefficient and regressor, and ε_t is the error term.

Series that are stationary around a time trend are shown by the following:

$$y_t = \alpha + \delta t + py_{t-1} + \varepsilon_t, \tag{6}$$

where δt is the time trend in the model.

Next, we test the research hypothesis of the study with the maximum likelihood in error correction model used by Johansen (1988) and Johansen and Juselius (1990). Gonzalo (1994) recommends that this method be used on small samples after examining differing cointegration techniques as it has the smallest bias in median and sample dispersion. This technique is shown by the following model:

$$\Delta X_t = \mu + \Gamma_1 \Delta X_{t-1} + ... + \Gamma_{k-1} \Delta X_{t-k+1} + \Pi X_{t-k} + \Phi D_t + \varepsilon_t, \tag{7}$$

where X_t is the vector of p $I(1)$ variables, μ is a $p \times 1$ vector of intercepts, $\Gamma 1$, Γk, Π, and Φ are $p \times p$ matrices of coefficients, D_t is a seasonal dummy variable for two of the four tests, ε_t is the $p \times 1$ error term that is assumed to be normally and independently distributed with a mean of zero and a variance matrix of Ω, and Δ is the first difference operator. There are three possible cases to show whether the matrix Π has information on long-run equilibrium relationships between the series. For our hypothesis of long-run relationships between the variables to be correct, the rank of the matrix of the coefficients X_{t-k} has to have a finite value $< p$. Each of the coefficients given by the model will have an appropriate sign for any negative or positive relationship after the dependent variable is separated from the other terms in the vector. The models include a linear trend in the data. Also, we determine if the differences of each of the independent variables does not have a zero mean and all of the variables are allowed to drift around an unrestricted intercept term in the cointegrating equation (CE) and test vector autoregressive model (VAR).

The equation providing information on the long-run relationship is shown as a vector error correction model (VECM) as the vectors in this equation are considered stationary even though the variables are non-stationary. Further extensions of the cointegration analysis are shown after the construction of the VECM. Additionally, we have provided tests for short-run dynamics in the model with direct impulse responses and variance decompositions of the variables similar to Kolari, Fraser, and Anari (1988) and Ling and Naranjo (2006). These results help to give meaningful insights into the results and conclusions of the study.

Results

Summary statistics for the timberland values are reported in Exhibit 1. The market value for timberland steadily rises in value over the test period from approximately \$350 per acre to over \$1,750 per acre. Exhibit 2 shows lumber futures prices range from a minimum of \$180 (1988) to a maximum of \$437 (1994) per contract. The capitalization rates for timberland have generally declined over the test period, as shown in Exhibit 3, from approximately 13% in 1988 to less than 3% in 2008. The risk premium for timberland capitalization rates follows a somewhat similar pattern, falling from over 5% to −2% in recent years. Yearly anticipated inflation also drifted lower during most of the sample period, ranging from approximately 6% in 1989 to 2% in 2003, rising back to 3% in 2008. Building permits rose for most of the 20-year test period, but with a dramatic drop beginning in the second quarter of 2005 to the present time corresponding to the collapse of the housing bubble.

Exhibit 4 presents the results of the ordinary least squares regressions. The capitalization rate as proxied by the risk premium, lumber futures prices, and anticipated inflation are statistically significant when using the raw data and when we desmooth the data. Building permits are not statistically significant in either case. It is somewhat surprising that we find that the coefficients associated with anticipated inflation are negative. In the case of anticipated inflation, we believe we face a multi-collinearity issue.[1] Panel B shows the variance inflation factors

Exhibit 1 | Summary Statistics (1988–2008)

Variable	Mean	Std. Dev.	Min.	Max.
Market Value ($ per Acre Timberland)	984	338	338	1,753
Capitalization Rate (Risk Premium)	−0.06	1.3	−1.8	5.9
Capitalization Rate (Timberland)	6.1	2.3	2.8	13.3
Futures Prices ($ per Lumber Contract)	286	61	179	437
Building Permits in Thousands	1,506	328	861	2,263
Anticipated Inflation in CPI	3.3	0.9	1.4	5.8

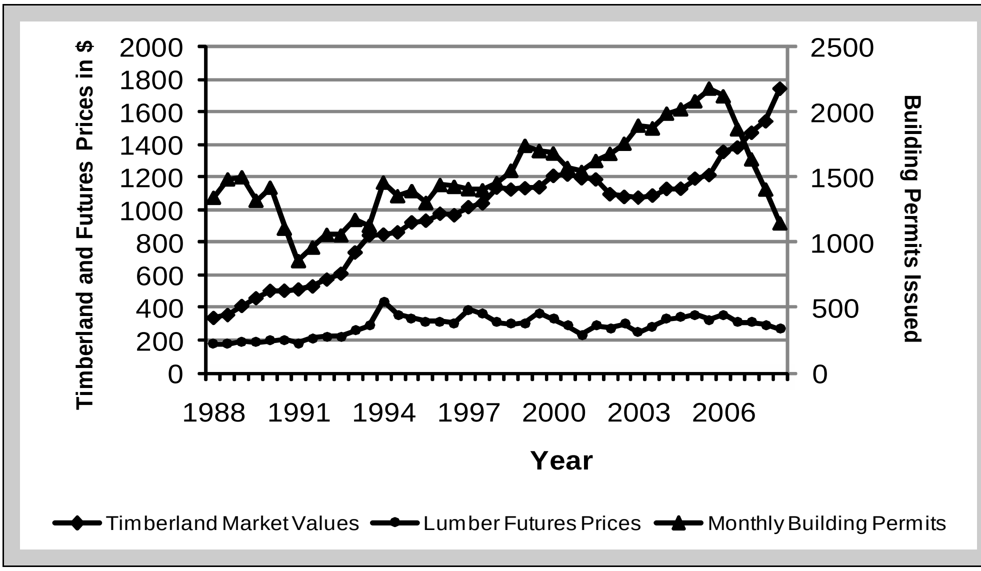
Notes: Timberland values, capitalization rates, and capitalization rate risk premiums are based on quarterly data taken from the NCREIF Timberland Index. Futures prices for lumber are daily closing prices on the first day of each quarter from the Chicago Mercantile Exchange. Anticipated inflation are yearly economic projections in December and June in the Livingston Survey of the Philadelphia Federal Reserve Bank. Building permits are quarter end monthly totals granted by the governing authorities. Market values for timberland are dollars per acre. Anticipated inflation is the change in the consumer price index and capitalization rate risk premiums are percentage rates.

(VIF) for all of the variables. A common rule-of-thumb is that variables with a VIF of 5 or above are a cause for concern, as the square root of 5 equals the difference in the standard errors of the regression coefficient as compared to being uncorrelated with the other independent variables. Smaller data sets may have a multi-collinearity problem with a VIF of 2.5.[2] Anticipated inflation shows a VIF above 3.0 in all cases. Therefore, we have eliminated this variable from further testing.

Panel C of Exhibit 4 presents the regression results excluding anticipated inflation from the model. Lumber futures, building permits, and the proxy for capitalization rates are significant at the 5% level or better. The signs of each of the coefficients are as expected. The VIF of each variable shown in Panel D is less than 1.4, showing little sign of any multi-collinearity between these three variables. The R^2 value is 0.7 and above for all models; however, the Durbin Watson statistics are very low. This suggests serial correlation in the economic time-series data. Significance levels and standard errors of the regression coefficients are often inaccurate and unreliable when encountering this problem.

Due to the apparent presence of serial correlation, we continue with time-series econometric methodology. Exhibit 5 shows the results of the augmented Dickey-Fuller test (ADF) and the Phillips-Perron test (PP). The market value of timberland, capitalization rates, lumber futures prices, building permits, and anticipated inflation each contain a unit root at the 5% level using the models with an intercept term. The first differences of each of the variables reject the null hypothesis of a unit root.

Exhibit 2 | NCREIF Timberland Market Values per Acre
CME Lumber Futures Prices, and Building Permits (1988–2008)

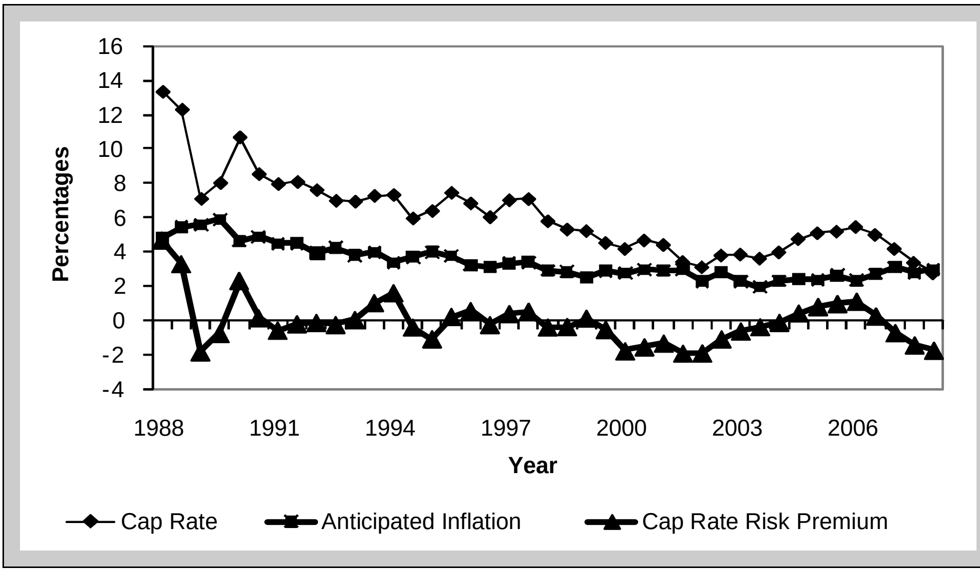


Notes: Timberland market value is measured in dollars per acre provided by NCREIF. The lumber futures prices are measured in dollars per contract taken from the semi-annual closing prices of the Chicago Mercantile Exchange. Building permits are seasonally adjusted monthly estimates before the beginning of the quarter. These are obtained from the U.S. Census Bureau.

Exhibit 6 presents the results of the Johansen trace tests to determine the number of cointegrating vectors in the semi-annual data. An optimal lag length of two is chosen for the models after performing several information criterion tests such as the Akaike Information Criterion, Schwartz Criterion, and Final Prediction Error Criterion on a VAR equation of the time series variables. According to Cheung and Lai (1993), Johansen's procedure tends to overestimate the number of cointegrating vectors when using too many lags with small samples. Johansen (1995) agrees that using too many lags causes parameters to grow rapidly and criterion can be used to find an adequate combination of lag length and parameters. Since we have semi-annual data, two lags should be an appropriate lag length.[3]

The multivariate cointegration models on the original timberland market value semi-annual data indicate one cointegrating equation in the vector. The equations are significant at the 5% level in the trace and maximum eigenvalue tests shown in Panel A of Exhibit 6. Panel B shows the normalized coefficients for the data. As expected, there is a negative relationship between capitalization rates and timberland prices. The futures price for lumber and building permits are positively related to timberland values. Each variable is significant at the 1% level when forecasting them in the VECM. These models are not shown in this report, but significance levels are shown on the normalized cointegrating coefficents.[4]

Exhibit 3 | Anticipated Inflation, Capitalization Rates, and Risk Premium for Timberland from 1988 to 2008



Notes: Capitalization rates are derived using net operating income and market values for timberland from NCREIF. Anticipated inflation is taken from the consumer price index of the mean estimates of economists at the Livingston Survey of the Federal Reserve Bank in Philadelphia, Pennsylvania. Risk premiums are derived from the NCREIF income return for timberland minus the 10-year Treasury Bond rate.

Panel C of Exhibit 6 shows the desmoothed timberland market value semi-annual data. Again, both trace and maximum eigenvalue tests show one cointegrating relationship at the 5% level. The normalized coefficients shown in Panel D are slightly smaller than the ones provided by the original market value estimates. All variables are significant at the 1% level in this model. The added volatility from desmoothing the dependent variables as compared to using a seasonal dummy variable changes the coefficients only slightly. As expected, there is no change in the signs of the relationships when desmoothing the data.

Due to the data specification, the coefficient's economic interpretation is relatively straightforward. A lumber futures' coefficient of 1.229 can be interpreted as a 1.23% change in timberland market values per acre when a 1.00% change in lumber futures occurs. For example, if a lumber futures contract trends 1% higher from a price of $200 to approximately $202, then a corresponding acre of timberland would increase from a price of $1,000 per acre to approximately $1,012 an acre, holding everything else constant. Similarly, a 1.00% change in the risk premium (cap rate) changes the timberland market values per acre by 24.8%. If the risk premium decreases from 2% to 1%, then a timberland per acre

Exhibit 4 | OLS Regression Analysis on the Pricing Model for the Market Value of Timberland

	Cap Rate–Risk Premium	Lumber Futures Price	Building Permits	Anticipated Inflation	R^2	Durbin-Watson
Panel A: Multivariate Regressions with Anticipated Inflation						
Semi-annual Original Market Value Timberland	−7.485*** (1.947)	0.529*** (0.149)	−0.013 (0.152)	−25.702*** (4.318)	0.882	0.704
Semi-annual Desmoothed Market Value Timberland	−7.795*** (1.989)	0.541*** (0.151)	0.003 (0.155)	−24.815*** (4.371)	0.874	0.645
Panel B: Variance Inflation Factors						
Semi-annual Original Market Value Timberland	1.195	2.080	1.907	3.147		
Semi-annual Desmoothed Market Value Timberland	1.188	2.052	1.903	3.073		
Panel C: Multivariate Regressions Excluding Anticipated Inflation						
Semi-annual Original Market Value Timberland	−11.710*** (2.537)	1.039*** (0.170)	0.473*** (0.179)		0.764	0.868
Semi-annual Desmoothed Market Value Timberland	−11.834*** (2.522)	1.030*** (0.169)	0.477*** (0.178)		0.706	0.803

Exhibit 4 | (continued)

OLS Regression Analysis on the Pricing Model for the Market Value of Timberland

	Cap Rate–Risk Premium	Lumber Futures Price	Building Permits	Anticipated Inflation	R^2	Durbin-Watson
Panel D: Variance Inflation Factors						
Quarterly Original Market Value Timberland	1.050	1.366	1.338			
Quarterly Desmoothed	1.048	1.366	1.337			

Note: Standard errors for the regression coefficients are shown in the parentheses. The sample size in the semi-annual data models is 41. The regression equations are shown by the following: $LnT_v = \alpha + \beta_1 T_c + \beta_2 lnL_f + \beta_3 I_a + \beta_4 lnB_p + \varepsilon_t$. and $LnT_v = \alpha + \beta_1 T_c + \beta_2 lnL_f + \beta_3 lnB_p + \varepsilon_t$.

*Significant at the 10% level.

**Significant at the 5% level.

***Significant at the 1% level.

Exhibit 5 | ADF and PP Test Results for Stationarity of the Variables

Variable	Lags	ADF Test	Critical Values	Bandwidth	PP Test	Critical Values
MV Timber. Desmoothed	0	−2.134	−2.936	1	−2.071	−2.936
MV Timberland	0	−2.582	−2.936	1	−2.399	−2.936
Cap Rate–Risk Premium	9	−2.036	−2.960	2	−4.811	−2.936
Futures Price	0	−2.366	−2.936	9	−2.225	−2.936
Building Permits	2	−1.720	−2.941	3	−1.614	−2.936
Anticipated Inflation	1	−1.967	−2.938	22	−1.433	−2.936
Δ MV Timber, Desmoothed	1	−2.764	−2.941	0	−4.778	−2.938
Δ MV Timberland	0	−3.915	−2.938	2	−3.955	−2.938
Δ Cap Rate–Risk Premium	8	−3.504	−2.960	7	−6.573	−2.938
Δ Futures Price	0	−6.991	−2.938	12	−7.310	−2.938
Δ Building Permits	1	−2.951	−2.941	2	−5.078	−2.938
Δ Anticipated Inflation	0	−9.397	−2.938	5	−9.910	−2.938

Notes: MacKinnon asymptotic critical values are shown at the 5% level. The data are semi-annual. The test includes the intercept. Lags are determined by the Schwartz Information Criterion (SIC) for the Augmented Dickey Fuller (ADF) test, while the Phillip-Perron (PP) test bandwidth is determined by the Newey-West procedure with a Bartlett kernel. Δ.is the first difference operator. Unit root tests were performed with the trend term as a check, but were not shown for the sake of brevity.

Exhibit 6 | Johansen's Multivariate Models and Normalized Cointegrating Coefficients—Semi-annual Data

Ho:	Eigenvalue	Trace Statistic	5% Critical Value	Prob.**
Panel A: Trace and Maximum Eigenvalue Tests–Original Data				
r = 0	0.533	49.273	47.856	0.036
r ≤ 1	0.318	20.322	29.797	0.401
r ≤ 2	0.116	5.747	15.494	0.725
Ho:	Eigenvalue	Max–Eigen Statistic	5% Critical Value	Prob.**
r = 0	0.533	28.950	27.584	0.033
r ≤ 1	0.318	14.574	21.131	0.319
r ≤ 2	0.116	4.706	14.264	0.778
Market Value Timberland	Cap. Rate–Risk Premium	Lumber Futures Price	Building Permits	
Panel B: Normalized Cointegrating Coefficients				
1.000	26.926***	−1.293***	−0.860***	
	(4.222)	(0.136)	(0.133)	
Ho:	Eigenvalue	Trace Statistic	5% Critical Value	Prob.**
Panel C: Trace and Maximum Eigenvalue Tests—Desmoothed Data				
r = 0	0.519	48.426	47.856	0.044
r ≤ 1	0.329	20.597	29.797	0.383
r ≤ 2	0.131	5.39	15.494	0.766
Ho:	Eigenvalue	Max–Eigen Statistic	5% Critical Value	Prob.**
r = 0	0.519	27.829	27.584	0.046
r ≤ 1	0.329	15.206	21.131	0.274
r ≤ 2	0.131	5.350	14.264	0.697
Desmoothed MV Timb.	Cap. Rate–Risk Premium	Lumber Futures Price	Building Permits	
Panel D: Normalized Cointegrating Coefficients				
1.000	24.767***	−1.229***	−0.841***	
	(3.763)	(0.124)	(0.122)	

Exhibit 6 | (continued)

Johansen's Multivariate Models and Normalized Cointegrating Coefficients—Semi-annual Data

Notes: The test assumes no exogenous variables, but a seasonal dummy variable is used in the test on the original data. 2 lags are used in the test. Standard errors for the normalized cointegrating coefficients are shown in parenthesis. Lutkepohl, Saikkonen, and Trenkler (2001) give preference to the trace test in Johansen's cointegration procedure when using small sample sizes such as the subject study.
*Significant at the 10% level.
**Significant at the 5% level.
***Significant at the 1% level.

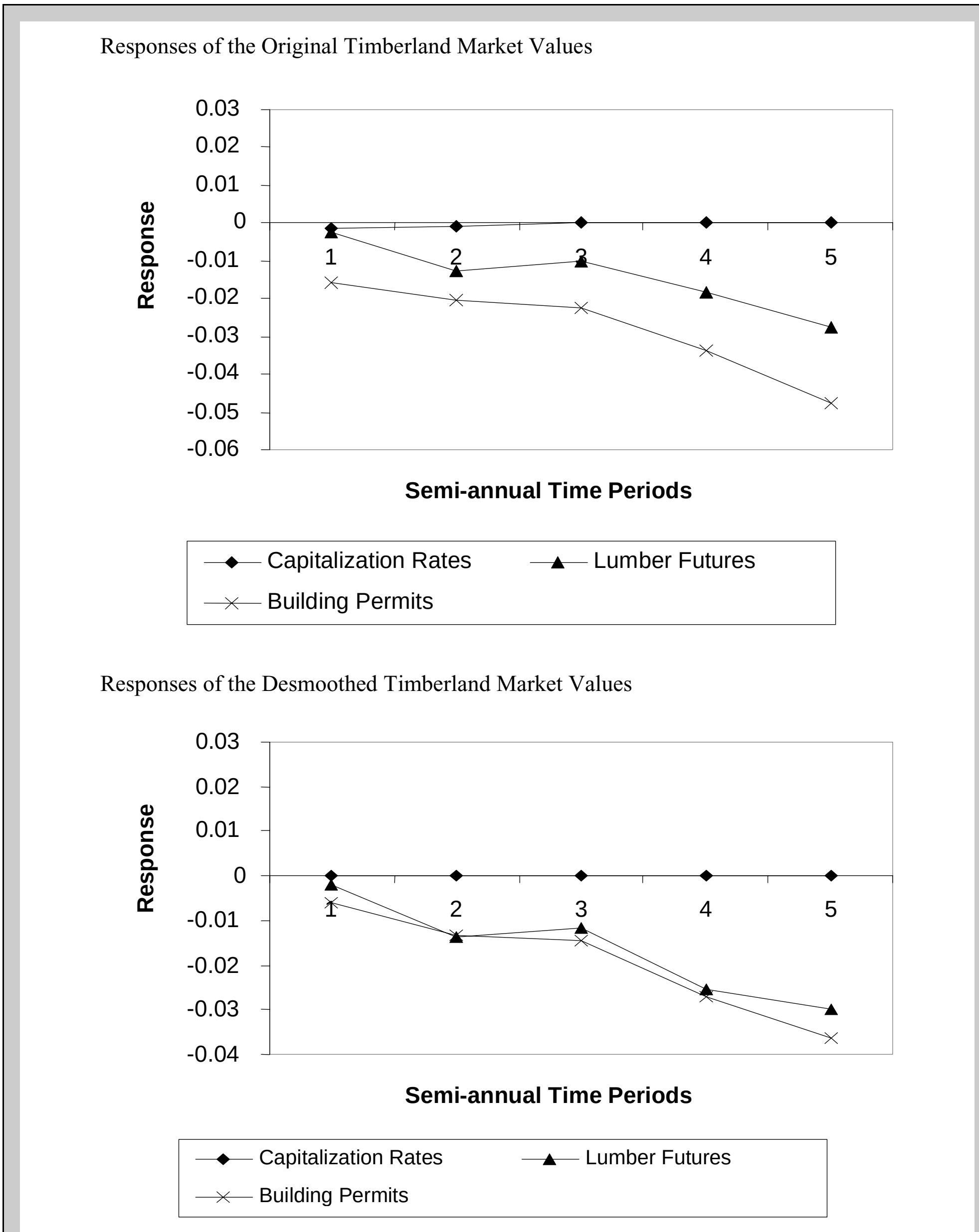
value of $1,000 would increase approximately $248 to $1,248 an acre. Finally, a 1.00% increase in building permits issued would increase timberland market values by 0.84%.

Exhibit 7 | Variance Decomposition of Timberland Value in the Multivariate Model

Period	Market Value Timberland	Lumber Futures Price	Building Permits	Cap. Rate
Panel A: Market Value for Original Timberland—Semi-annual Data				
1	84.126	0.265	13.681	1.928
2	84.229	1.778	11.980	2.013
3	83.451	1.716	11.479	3.354
4	77.075	3.001	14.077	5.847
5	70.541	4.277	18.043	7.140
Panel B: Market Value for Desmoothed Timberland—Semi-annual Data				
1	95.798	0.477	1.382	2.344
2	87.876	4.748	3.363	4.013
3	87.268	4.610	3.516	4.606
4	80.744	7.431	5.671	6.154
5	77.216	8.319	7.840	6.626

Notes: These results are based upon the VEC model. The forecast horizon is 2.5 years. Cholesky Ordering: Building Permits, Timberland Capitalization Rates, Futures Price for Lumber, Market Values of Timberland.

Exhibit 8 | Impulse Responses for Timberland Market Values in the Multivariate Model over a 2.5-Year Forecast Horizon



Note: These results are based upon the vector error-correction model. These are the responses of timberland to one standard deviation shocks in cap rates for timberland, lumber futures prices, and building permits. The forecast horizon is 2.5 years using semi-annual periods.

Short-run Dynamic Relationships

Variance decompositions of timberland over a 2.5-year forecast horizon are performed to see the impact of its shocks on the other time-series variables in the VECM. Ordering of the variables was performed and the shocks were orthogonalized by Cholesky decomposition in which the covariance matrix of the resulting residuals is lower triangular. In other words, each variable appearing first in the order will only affect the others that enter afterwards. In the model, the most exogenous variables such as anticipated inflation are shown first, while timberland is shown last as it is the variable being explained in the decomposition.

In Exhibit 7, Panels A and B show the decomposition of the errors of the variables. Building permit issuance tends to explain the most forecast error variance in the original timberland prices over the time period. Lumber futures prices predict little the first six months, but increases as the time horizon grows. Capitalization rates tend to have a more level impact on timberland prices over time. The aggregate of the variables predict 22%–29% of the squared forecast error over the time period.

Impulse response functions show the direction of responses of timberland values to one standard deviation shocks in the residuals of the time-series variables. Response functions for timberland in the multivariate models are shown in Exhibit 10. Generally, the response of timberland market values to a shock in cap rate risk premium is very small. An unanticipated positive shock in lumber futures prices causes a negative change in timberland market values in the short run. This is surprising and contrary to the long-run equilibrium effect between the two variables. A shock to building permit issuance has a similar response. Finally, the results of the impulse response functions suggest that most shocks to the variables do not dampen over the 2.5-year forecast horizon. The shocks are not absorbed and corrected in the short term. This suggests a permanent change in the market values of timberland as a result of the unanticipated shocks on the independent variables.

Conclusion

In this research we offer a model for timberland valuation as a function of lumber futures, capitalization rates, anticipated inflation, and anticipated construction. We use ordinary least squares regression analysis (OLS) to test the model. As hypothesized, capitalization rates as proxied by timberland risk premiums are negatively related to timberland prices and six month lumber futures prices have a positive relationship. Anticipated inflation has surprising negative coefficient and a multi-collinearity issue appears to be present. After excluding anticipated inflation, monthly building permit issuance is found to have a positive relationship with timberland market values.

As a robustness check due to concerns about serial correlation in the data, we further test the model using Johansen's cointegration technique. In general, the cointegration results support the findings of the OLS regression analysis as lumber futures and anticipated construction (as proxied by building permits) are positively and significantly related to timberland value in the long run. Timberland risk premiums (as proxied for capitalization rates) have an inverse long-run equilibrium relationship with timberland market values. Further checks including desmoothing the timberland market values and excluding anticipated inflation from the analysis show similar results.

In the short term, shocks to the variables show a permanent structural impact on timberland values. Monthly building permit issuance tends to predict more of the squared forecast error in timberland prices than the other variables in the pricing model. Changes in timberland capitalization rates have a more level and permanent impact on timberland value, while lumber futures impact on timberland increases over the time horizon. Contrary to the positive long-run equilibrium effect, unanticipated shocks in lumber futures prices have a negative reaction with timberland market values.

Endnotes

[1] An anonymous reviewer noted that our explanatory variables seemed closely related. We attempt to solve this problem by examining for multi-collinearity in our regressions. Suppression can also occur when adding predictors to a regression model and may change the coefficient signs or allow direct effects to be larger than zero-order effects. See Johansen (2007) for more detail on correlations and time-series data.

[2] See http://www.researchconsulting.com/multicollinearity-regression-spss-collinearity-diagnostics-vif.asp.

[3] Lagrange Multiplier (LM) tests are used to check for serial correlation in all of the cointegration tests.

[4] Vector error correction models and further robustness checks on unit root tests, variance decompositions, impulse response functions, and other less restrictive Johansen tests and their results can be provided upon request.

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