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Private-equity commercial real estate, timberland, and farmland: Market integration and information transition dynamics

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Abstract: Using data from National Council of Real Estate Investment Fiduciaries (NCREIF), we examine market integration of commercial real estate and timberland/farmland assets via the Fama-MacBeth two-step approach under the intertemporal capital asset pricing framework. In addition, we study the information transition dynamics between those markets via the vector error correction model (VECM). We find evidence of market segregation and one-way information flow from the timberland/farmland market to the commercial real estate market. We conclude that commercial real estate and timberland/farmland assets are driven by different market fundamentals and that lagged timberland/farmland returns can help predict current commercial real estate returns. The only exception is during market downturns when commercial real estate and timberland/farmland markets are somewhat integrated and driven by some factors that are not specified in this study.

Key words: alternative assets, ICAPM, GARCH, risk premium, time series

1. Introduction

Commercial real estate usually consists of apartment, hotel, industrial, office and retail properties that are owned for the purpose of producing income. The commercial real estate market is large and denotes a significant portion of total US wealth. In addition, the timberland and farmland markets, as alternative real estate, have gained some market shares. In recent years, the respective market sizes for US commercial real estate, timberland and farmland are about \$6 trillion, \$0.8 trillion and \$2.7 trillion, compared with about \$30 trillion for US stock market (Burns et al. 2018; statista 2018; Waggle and Johnson 2009). All three markets have witnessed rapid development after the economic recession of the 1980s. With the collapse of the stock market and ample supply of foreclosed properties, golden opportunities for real estate investment emerged and profitable property investment was soon found to be achievable. As evidence, the average property value as indexed by NCREIF Property Index (NPI) has been more than doubled in the past 30 years, despite some downswing during the financial crisis of 2007-2008.

Timberland investments in the US concurred with the shift of ownership. On the supply side, forest products companies divested timberland holdings for more tax-efficient structures like timberland investment management organizations and real estate investment trusts. On the demand side, institutional investors included timberland in their portfolios for the diversification purpose. As a result, over 40 million acres, or equivalently \$41.6 billion, of timberland has changed hands in the past few decades (Hood et al. 2015). Since the late 1980s, the average timberland value as indexed by NCREIF Timberland Index (NTI) has increased fivefold and reached the peak of about \$2,400/acre in 2008. In most recent years, timberland value fell and flattened to about \$2,000/acre. Although farmland prices suffered from rising interest rates and higher energy prices in the early 1980s (Nickerson et al. 2012), high income and low interest rates resulted in rapid appreciation of farmland values since 2004. Coupled with capital influx from institutional investors, the average value of US farmland as indexed by NCREIF Farmland Index (NFI) was doubled and reached the peak of about \$3,000/acre in 2015. In most recent

years, farmland value exhibited some declining trend in response to falling farm income triggered by lower commodity prices.

Despite some common determinants such as economic growth, population density, household income and interest rate policy (Burns et al. 2018; Hardie et al. 2000; Hardie et al. 2001), timberland and farmland assets have major differences from commercial real estate. First, timber and agricultural crops are biological assets and growth and yield is a key contributor of their total returns (Mei et al. 2013). Second, timber and agricultural products markets are subject to different business cycles. For instance, timber and agricultural products prices, another return driver for timberland and farmland investments, are often affected by government policies, legislations and regulations such as Endangered Species Act, Energy Policy Acts, conservation programs and trade disputes and tariffs (e.g., Latruffe and Le Mouél 2009). In contrast, the key driver of commercial real estate returns is rental incomes. Third, all the three real estate assets benefit from value appreciation in the long run. However, unlike commercial or residential buildings, land itself is not depreciable. With population growth and urban sprawl, timberland and farmland have opportunities to be converted to higher and better uses. Fourth, the three real estate markets hold different positions along the supply chain. Timberland produces timber, which is converted to lumber and eventually used for constructions. Farmland produces food and energy feedstocks, which ultimately transform to production costs of commercial real estate. Fifth, timberland and farmland markets are much thinner than commercial real estate market. Only a small portion of land is for sale for a given time (Bigelow et al. 2016; Mei 2016). Lastly, private-equity timberland investment uses almost no loans whereas farmland and commercial real estate investments often use substantial financial leverage (Burns et al. 2018; Clayton et al. 2009; Mei 2017).

Market integration occurs when prices of related assets share similar trends over time. Given some similarities as well as some major differences, and inspired by previous research (e.g., Chaudhry et al. 1999; Glascock et al. 2000; Li et al. 2009; Ling and Naranjo 2015), we aim to test market integration and information transition dynamics between private-equity commercial real estate and

timberland/farmland assets in this study using the Fama-MacBeth two-step approach under the
intertemporal capital asset pricing framework and vector error correction model. We find evidence of
market segregation and one-way information flow from the timberland/farmland market to the
commercial real estate market. We conclude that commercial real estate and timberland/farmland are
driven by different market fundamentals and that lagged timberland/farmland returns can help predict
current commercial real estate returns.

The rest of this article is structured as follows. Next section reviews the literature with an
emphasis on those using NCREIF data. Sections 3 and 4 explain the data and methodology. Section 5
presents the empirical results and provides some discussions. The last section offers concluding remarks.

2. Literature Review

Many studies examined appraisal smoothing in NCREIF indices and proposed unsmoothing
methods for an improved risk estimation (e.g., Cheng and Liang 2000; Cho et al. 2003; Geltner 1989,
1991; Geltner et al. 2003; Newell and MacFarlane 1995). Another remedy for appraisal smoothing is to
use transaction-based indices (Fisher et al. 2007; Mei 2016). Corgel and deRoos (1999) demonstrated that
portfolio allocation to real estate was sensitive to recovery models used to correct appraisal smoothing in
NPI. Scholtens and Spierdijk (2010) and Mei (2016) illustrated that diversification contribution of
timberland was reduced when unsmoothed or transaction-based timberland returns were used in mixed-
asset portfolios. Although the smoothing effect in appraisal-based NCREIF data may result in biases
when compared with other assets, the smoothing effect becomes a systematic error within NCREIF
indices (Cheng and Liang 2000). Hence, we do not unsmooth NCREIF data in our analysis.

Some studies examined the market structure of private-equity real estate. Eppli and Shilling
(1995) found that US commercial real estate market adjusted slowly to changes in excess supply or
demand. Fisher and Young (2000) found that holding periods had been declining over time, which might

be related to market conditions and structural changes in the management of real estate assets. Cheng et al. (2008) found a nonlinear positive relationship between price and time on market, which helped to explain the “risk-premium puzzle” in real estate. Chaudhry et al. (1999) showed that NPI was cointegrated with return series of stocks, bonds and Treasury bills, while Shilton (2000) found little evidence of cointegration between NPI and American Council of Life Insurers commercial real estate underwriting data.

Some studies examined private-equity real estate from a portfolio’s perspective. Ziering and McIntosh (1999) found that larger properties had higher risk-return profile and lagging performance during recovery phase than small properties across a broad spectrum of property sizes. Shilton and Stanley (1995) found that investors concentrated their holdings within a small core of counties, while Graff and Young (1996) and Cheng and Liang (2000) showed that diversification across geographic locations and property types generated no significantly superior efficiency than naively diversified portfolios. In contrast, Mueller (1993) and Smith et al. (2005) showed that the addition of economic underpinnings enhanced portfolio efficiency. Mueller and Mueller (2003) and Chiang and Lee (2007) showed that both public and private real estate can improve the mean-variance Markowitz efficient frontier of a mixed-asset portfolio, whereas Craft (2001) claimed that assets highly correlated with pension liabilities should be weighted higher in pension plan portfolios and thus allocations to both public and private real estate had to be lower. However, when uncertainty was introduced, the efficient frontier became fuzzy and the weight vectors became even fuzzier (Liang et al. 1996).

Other studies examined real estate returns as proxied by NPI. Shilling (1993) investigated measurement errors in NPI as an errors-in-variables problem. Munneke and Slade (2000) addressed sample-selection bias in the construction of real estate indices within the context of the Phoenix area office market but found no significant effect for sample-selection bias correction. Pagliari et al. (2001) claimed that fundamental sources of return, i.e., initial earnings yield, dividend payout ratios, earnings growth, and shifts in capitalization rates, contributed to NPI’s cross-sectional and time-series variations.

David (2005) found that the consensus opinions on investment conditions contained in Real Estate Research Corporation's survey results were not useful in forecasting NPI. Hendershott and MacGregor (2005) argued that expectations of mean reversion of cash flows were not factored into asset pricing of NPI. Young (2005) proposed several modifications to current NCREIF formulas so as to expand our understanding of the performance of private-equity real estate. Lecomte and McIntosh (2006) demonstrated the feasibility of establishing NPI-based property futures and options.

To our best knowledge, only a few studies examined NPI, NTI and NFI altogether. Waggle and Johnson (2009) investigated the effects of including timberland, farmland and commercial real estate in a mixed-asset portfolio with stocks, government bonds and Treasury bonds under the mean-variance efficiency framework using both smoothed and unsmoothed returns and with both constrained and unconstrained scenarios. They found that timberland was included in almost all portfolios but farmland and commercial real estate were only included in low-risk portfolios. Kuethe et al. (2013) compared farmland's risk and return to those of alternative investments and found that NFI had relatively high mean returns, low volatility and low correlation with financial markets.

3. Data

NCREIF is a data service provider that serves the institutional commercial real estate investment community as a non-partisan collector, validator, aggregator, converter and disseminator of commercial real estate performance and benchmarking information. NPI, NTI and NFI are quarterly indices that track the performance of institutional commercial real estate properties, timberland properties, and farmland properties held in a fiduciary environment and for investment purposes only in the US. The respect start dates of the three indices are 1977Q4, 1987Q1 and 1991Q1. As of 2017Q4, NPI consisted of 7,527 properties with a value of \$560 billion, NFI consisted of 727 properties with a value of \$8.5 billion, and NTI consisted of 464 properties with a value of \$25.5 billion.

To delineate the performance by property types and geographical locations, NPI is separately reported by property type, i.e., apartment, hotel, industrial, office and retail properties, or by region, i.e., US East, Midwest, South and West. Based on property-level transaction data, NCREIF also reports a transaction-based property index (NTBI) using property level transaction data (Fisher et al. 2007). For completeness, we include NTBI in our analysis as well. NTI is separately available for US Lake States, Northeast, Northwest and South.¹ To gauge returns at the fund level, NCREIF also publishes timberland fund -and separate account index (TFSAI), properties under which are externally valued at least annually in accordance with uniform standards of professional appraisal practice. TFSAI is reported both gross and net of fees. To be consistent with other timberland indices, we use TFSAI gross data. Like NPI and NTI, NFI is available at the regional level for US Corn Belt States, Delta States, Lake States, Mountain States, Pacific Northwest, Pacific West and Southeast.² Fig. 1 plots the time-series of the NTBI, NPI, NTI and NFI from 1987 to 2017.

Based on the literature (e.g., Fama and French 1989; Parker and Julliard 2005; Plazzi et al. 2008; Yao and Mei 2015), in addition to market excess return (MKT) defined as market (S&P 500) return minus risk-free rate (1-month Treasury bill rate), state variables in the intertemporal capital asset pricing model (ICAPM) include term spread (TERM) defined as yield difference between 10-year and 3-month Treasury bonds, default spread (DEF) defined as yield difference between long-term BAA and AAA corporate bonds, private equity return represented by Cambridge Associates US private equity index (USPE), percentage change in inflation proxied by producer price index (PPI), and percentage change in gross domestic products (GDP).³ TERM is related to short-term business cycle as defined by National Bureau of Economic Research, DEF is related to long-term business episodes as well as the availability of

¹ NTI sub-indices for Lake States and Northeast are omitted from the analysis due to their much shorter reporting periods. Mei (2016) constructed a transaction based timberland index but that index starts in 2003 and is only available at an annual frequency due to lack of transactions in early years.

² NFI sub-indices for Corn Belt States and Lake States are omitted for similar reasons as for NTI sub-indices.

³ Consumption rate, Treasury bond rate, Fama-French factors, momentum, and liquidity have also been considered as state variables but eventually excluded from the model due to their insignificance as well as high correlations with other state variables.

debt financing, USPE captures the condition of the private equity market, PPI inflation rate reflects current economic activity, and GDP growth rate gauges the development of the overall economy. All return series are quarterly and run from 1987Q1 to 2017Q2 except for NFI and its regional indices.

Descriptive statistics of all variables are reported in Table 1. Based on previous research (e.g., Anson 2002; Asness et al. 2001), we also divide the whole sample into up and down market periods. An up market is when market excess return, i.e., S&P 500 minus risk-free rate (1-month Treasury bill rate), is nonnegative and a down market is when market excess return is negative. Of our study period, about 2/3 is classified as up market and 1/3 as down market. Over the whole sample period, respective average quarterly returns for commercial real estate and timberland/farmland are 2.0% and 2.7%. With higher mean returns, timberland/farmland indices also display higher risk. Across property types of NPI, office is inferior to others with a lower mean and a higher standard deviation. By region of NPI, East and West exhibit higher means as well as standard deviations than the rest. For the up market period, all the real estate indices show higher means but not necessarily higher standard deviations. For the down market period, all real estate indices have lower means but higher standard deviations. Regardless of market conditions, relative ranking of real estate indices remains the same.

For timberland, Northwest index shows a higher mean and standard deviation than other regional timberland indices for all periods examined. For farmland, Pacific West index shows a higher mean and standard deviation than other regional farmland indices for the whole sample and up market periods. For the down market period, Pacific West index has both the mean and standard deviation reduced and the reduction in risk is more significant. Overall, indices of commercial real estate, timberland and farmland follow the trend of the market. However, the reduction in risk in timberland and farmland in the down market period is more than that of commercial real estate.

Table 2 reports the correlations of return indices for up and down market periods. Regardless of market conditions, correlations within the same asset class remain high. For the up market period, commercial real estate and timberland/farmland returns are moderately correlated, whereas for the down

market period, the correlations are more negative. In general, timberland and farmland returns are more correlated for down market period. All these suggest that commercial real estate market and timberland/farmland market may be segregated.

For state variables, means of USPE, CPI and GDP decline noticeably together with MKT, while means of TERM and DEF increase slightly from the up market to down market period. All volatilities are much higher in the down market period except for TERM. These changes are consistent with the macroeconomic theory and within our expectations.

4. Methods

4.1. ICAPM framework

Discrete-time ICAPM is used for cross-sectional asset returns. Besides the market risk, risks of unfavorable shifts in the investment opportunity set should be incorporated into asset pricing. That is, an asset's expected return is a linear function of the market excess return and innovations in state variables which will be explicitly defined later. The conditional expected excess return can be expressed as

$$E(R_i) - R_f = \beta_{i,m} \lambda_m + \sum_{k=1}^K \beta_{i,k} \lambda_k \quad (2)$$

where $E(R_i)$ is the expected return of an asset i , R_f is the risk-free rate, λ_m is the market risk premium, λ_k is the price of risk for innovation in the state variable k , K is the total number of state variables, and subscript t indicates time. Beta loadings can be estimated by the following first-step regression:

$$R_{i,t} - R_{f,t} = \alpha_i + \beta_{i,m} (R_{m,t} - R_{f,t}) + \sum_{k=1}^K \beta_{i,k} \varepsilon_{k,t} + u_{i,t} \quad (3)$$

where $R_{i,t}$ and $R_{m,t}$ are historical returns of asset i and the market portfolio, $\varepsilon_{k,t}$ is the innovation in state variable k , and $u_{i,t}$ is the white noise.

4.2. Innovations in state variables

Innovations are unexpected shocks to state variables, which is defined as the difference between actual and expected returns conditional on the past information

$$\varepsilon_{k,t} = r_{k,t} - E(r_{k,t} | F_{t-1}) \quad (4)$$

where $r_{k,t}$ is the actual return of state variable k at time t , $E(r_{k,t} | F_{t-1})$ is the conditional mean of $r_{k,t}$ given the information set F_{t-1} available at time $t-1$. To obtain the dynamics of innovations in the state variables, we assume $\varepsilon_{k,t}$ follows a GARCH(1,1) with mean ARMA(1,1) model (Brennan et al. 2004; Campbell 1996; Dorfman and Park 2011; Petkova 2006)

$$\begin{aligned} r_{k,t} &= \mu_k + \phi_k r_{k,t-1} + \theta_k \varepsilon_{k,t-1} + \varepsilon_{k,t} \\ \varepsilon_{k,t} &= z_t \sqrt{h_{k,t}} \\ h_{k,t} &= \alpha_0 + \alpha_1 (\varepsilon_{k,t-1})^2 + \beta_1 h_{k,t-1} \end{aligned} \quad (5)$$

where μ_k , ϕ_k and θ_k are parameters in the mean ARMA(1,1) equation, z_t is an independent and identically distributed random variables with mean 0 and variance 1, $h_{k,t}$ is the conditional variance for the error term $\varepsilon_{k,t}$ given the information set F_{t-1} , and $\alpha_0 > 0$, $\alpha_1 \geq 0$, $\beta_1 \geq 0$ and $\alpha_1 + \beta_1 < 1$ are restrictions on the coefficients to be estimated. The maximum-likelihood method is applied to estimate the parameters in the GARCH model.

4.3. Fama-MacBeth two-step regression

According to equation (1), an asset's expected return depends on its exposure to the risk factors and the rewards of bearing such risks. To explore the implications of the ICAPM, the Fama-MacBeth two-step regression (Fama and MacBeth 1973), which is widely applied to analyze assets' cross-sectional returns, is used. In the first step, ordinary least squares approach is used to estimate equation (2) for each asset using innovations estimated from the GARCH model. Assets' beta loadings with respect to the

market excess returns and innovations in state variables are obtained. In the second step, actual excess returns of all cross-sectional assets are regressed on their beta loadings. In other words, the prices of risk factors are estimated using the following cross-sectional regressions

$$R_{i,t} - R_{f,t} = \lambda_{0,t} + \lambda_{m,t} \hat{\beta}_{i,m} + \sum_{k=1}^K \lambda_{e_{k,t}} \hat{\beta}_{i,e_k} + e_{i,t} \quad (6)$$

for $i = 1, 2, \dots, N$ and $t = 1, 2, \dots, T$, where N is the total number of assets, and T is the sample length, $\lambda_{0,t}$ is the intercept, $\hat{\beta}_{i,m}$ and $\hat{\beta}_{i,e_k}$ are beta loadings estimated in the first step, and $e_{i,t}$ is the error term. There is one regression across the N assets for each period, and there are T such regressions in total. This way, a time series for each risk premium is constructed. Then, averages are taken over the whole sample period as $\lambda_{e_k} = \sum_{t=1}^T \lambda_{e_{k,t}} / T$ for $k = 0, 1, 2, \dots, K$. To test the equality of parameter estimates, a seemingly unrelated regression estimator is used.

4.4. VAR and VECM

To examine how information flows among commercial real estate, timberland and farmland markets, a trivariate vector autoregressive (VAR) models is constructed

$$Y_t = u + \Phi_1 Y_{t-1} + \Phi_2 Y_{t-2} + \dots + \Phi_q Y_{t-q} + e_t \quad (7)$$

where Y_t is a 3×1 vector of endogenous variables, u is a 3×1 vector of intercepts, $\Phi_1, \Phi_2, \dots, \Phi_q$ are 3×3 matrices of parameters with diagonal elements denoting conditional momentum in NPI, NTI and NFI, and off-diagonal elements denoting feedback effects, and e_t is a vector of bivariate normal error terms. In order to ensure the stationarity of VAR, all eigenvalues of Φ need to have moduli less than one. The number of lags q is chosen by the Akaike information criterion and equation (6) is estimated via

iterated least squares.⁴ To augment the basis VAR model, we also include exogenous asset pricing factors to control for common sources of variation on all three markets.

If each component series in Y_t is integrated of order one, $I(1)$, some of the series may be cointegrated. The notion that m series are cointegrated means that although each of the m individual series is nonstationary, there exists at least one linear combination of these m series that is actually stationary. Engle and Granger (1987) investigated an error-correction representation theorem for a cointegrated system. A VECM corresponding to the above VAR is formulated as

$$\Delta Y_t = \mu_t + \Pi Y_{t-1} + \sum_{i=1}^{q-1} \Phi_i^* \Delta Y_{t-i} + \xi_t \tag{8}$$

where $\Pi = -I + \sum_{i=1}^q \Phi_i$ and $\Phi_i^* = -\sum_{j=i+1}^q \Phi_j$. The number of cointegrating relations is detected by the rank of the 3×3 matrix Π . Matrix Π can be decomposed into the product of two $3 \times m$ full-rank matrices α and β in the way that $\Pi = \alpha\beta'$, where α is the adjustment coefficient denoting the speed to restore equilibrium and β is the long-run parameter. The term $\beta'Y_{t-1}$ represents the stationary linear combination of m individual series, and the whole term ΠY_{t-1} is commonly known as the error correction term. Two tests in Johansen's (1991) multivariate cointegration analyses, the trace test and the maximum eigenvalue test, can be used to determine m , which is the number of cointegrating relations.

5. Results and Discussion

5.1. Results of ICAPM

⁴ For robustness check, we also use the Schwarz Bayesian information criterion and the likelihood ratio criterion for lag selection.

Innovations of the state variables estimated from the GARCH model are plotted in Fig. 2.⁵

Echoing the observation in Table 1, innovations in TERM and DEF are less volatile than those in USPE, PPI and GDP. Innovations in TERM show a sharp declining trend since 2015, which could be driven by a series of interest rises by the Federal Reserve Bank. Innovations of DEF are flat except for a spike around 2008. Innovations in USPE have most variations and follow economic cycles closely. Innovations in PPI and GDP share a similar trend as USPE but are less volatile. Overall, innovations in these state variables have captured the evolvement of the market.

Factor loadings from the first-step time series regression using the whole sample period are reported in Table 3. As a robustness check, both ICAPM and Fama-French three-factor model are used. The intercept is commonly known as alpha, a performance measure. For commercial real estate, quarterly alpha ranges from 1.1% to 1.5% for ICAPM and from 0.7% to 1.4% for Fama-French three-factor model; for timberland/farmland, quarterly alpha ranges from 0.6% to 3.0% for ICAPM and from 1.1% to 3.0% for Fama-French three-factor model. Therefore, private-equity commercial real estate, timberland/farmland assets exhibit positive abnormal returns on risk-adjusted basis and the average size of abnormal return for timberland/farmland assets is higher than commercial real estate. Market beta estimates are low for commercial real estate, timberland and farmland assets from both the asset pricing models, implying low systematic risk and diversification potential. Innovations in state variables have various impacts on commercial real estate and timberland/farmland. TERM innovations, in general, have significant impact on commercial real estate but not on timberland/farmland assets. On average, a 1% increase in unexpected shock in TERM leads to a 0.29% decrease in expected return of commercial real estate. DEF innovations, on the other hand, significantly impact expected returns of timberland/farmland assets but not commercial real estate. With a 1% increase in unexpected shock in DEF, the expected

⁵ We have also run an alternative EGARCH(1,1) model to capture the asymmetry effect of shocks. Factor loadings and risk premiums change slightly, however the expected returns remain almost unchanged and our major conclusions remain the same. Results are available from authors upon request. We thank the reviewer for this suggestion.

return of timberland/farmland increases by 3.07% on average. The expected returns of both commercial real estate and timberland/farmland are significantly impacted by USPE innovations. For commercial real estate, a 1% increase in unexpected shock in USPE leads to an average of 0.18% increase in expected return. The effect is almost doubled for timberland/farmland assets, with a value of 0.31%.

Factor loadings are also estimated for the up and down market periods as shown in Table 4. However, the impacts on alpha and market beta are trivial. For commercial real estate in the up market, innovations in DEF and USPE still show significant impacts. With a 1% increase in unexpected shocks of the aforementioned state variables, the average expected returns increase by 2.01% and 0.18%, respectively. In the down market, the significant impacts of innovations in DEF and USPE disappear. However, a 1% increase in TERM innovations leads to a significant 1.07% decrease in the expected return on average. For timberland/farmland assets, USPE innovations have significant impacts on both the up and down markets, with 0.31% and 0.29% increases in average expected returns corresponding to a 1% increase in the unexpected shocks.

Estimates of risk premium from the second-step cross-sectional regressions are reported in Table 5. Over the whole sample period, commercial real estate has significant positive premiums on all risk factors except for PPI. For example, if systematic risk increases by 0.01, quarterly commercial real estate return will increase by 0.35%; if default risk increases by 0.01, quarterly real estate return will increase by 0.005%. Timberland/farmland has significant positive premiums on MKT, TERM, USPE and GDP but significant negative premium on DEF. The F test and χ^2 test suggest that risk premiums across all risk factors as a whole differ in commercial real estate and timberland/farmland markets, an implication of market segregation. For the up market period, commercial real estate has significant positive premiums on TERM, DEF and PPI, but significant negative risk premiums on MKT and USPE, whereas timberland/farmland has significant positive premiums on TERM and DEF, but significant negative premiums on USPE and PPI. The F test and χ^2 test again suggest significant different risk premiums across all risk factors. For the down market period, no premiums are significant and commercial real

estate and timberland/farmland ought to be driven by other risk factors not included in this study. The F test and χ^2 test suggest that commercial real estate and timberland/farmland are somewhat integrated.

Given the estimates from the two-step regressions, expected returns based on ICAPM can be calculated (Table 6). On average, commercial real estate has an expected return of 2.0% per quarter while timberland/farmland has an expected return of 2.8% per quarter for the whole sample period. The two-sample t -test result shows that the difference is significant at the 1% level. The average expected return of timberland/farmland market is significantly higher than commercial real estate market in both the up and down markets. Comparing the average expected returns along economic cycles, result shows that higher expected return is obtained in the up market for both the commercial real estate and timberland/farmland assets.

5.2. Results of VECM

Results of the unit root test provide some evidence that NTI and NFI are not stationary. Furthermore, Johansen's cointegration trace test fails to reject the null hypothesis of one cointegration. So a VECM is estimated and results are shown in Table 7. For NPI, in addition to lags of itself at order 2 and 4, lag of NTI at order 1, and lags of NFI at order 1 and 2 have significant (at the 10% level or better) prediction power on NPI. Specifically, the signs on lags of NTI and NPI are positive while the signs on lags of NFI are negative. Coefficient on the error correction term is also significant, meaning a significant force to restore equilibrium when NPI deviates from the long-term trend. For NTI and NFI, only lags of themselves are significant and negative. Thus, there tends to be a one-way information transition from timberland/farmland market to commercial real estate market.

To control for asset pricing factors, MKT and innovations in state variables used in ICAPM are added as exogenous variables and VECM is estimated again (Table 8). In general, results are similar qualitatively to those of VECM without exogenous variables. For asset pricing factors, DEF is significantly negative on NPI and USPE is significantly positive on NTI at the 5% level or better. Thus,

commercial real estate market exhibits a strong cyclical pattern as the overall economy but with a lag. In other words, NPI tends to be significantly lower after a recession. Timberland market, on the other hand, is most sensitive to private equity market conditions. A 1% increase in USPE in the last quarter predicts a 0.28% increase in NTI, *ceteris paribus*.

6. Conclusions

Using NCREIF data, we examined the integration of commercial real estate and timberland/farmland markets via the Fama-MacBeth two-step approach under the ICAPM framework. In addition, we studied the information transition dynamics between those markets via the VECM method. We found some evidence of market segregation and a one-way information flow from the timberland/farmland market to the commercial real estate market. We conclude that commercial real estate and timberland/farmland are different real assets driven by different market fundamentals and that lagged timberland/farmland returns can help predict current commercial real estate returns. The only exception is during market downturns when commercial real estate and timberland/farmland markets are somewhat integrated and driven by some factors that are not specified in this study. We suspect that information flow between markets is related to their respective positions along the supply chain of manufacturing. Timberland and farmland markets are upstream of commercial real estate markets, providing raw materials (e.g., timber and fiber) that are used in the commercial real estate markets (e.g., construction and remodeling) (Li et al. 2019). Therefore, impact of factors that affect timberland and farmland assets may transit to downstream commercial real estate markets through forward linkages with some lag.

Timberland/farmland assets have higher expected returns as well as abnormal returns than commercial real estate regardless of business cycles, implying some superior performance. All real estate indices are closely correlated with US private-equity index, however, commercial real estate assets are

more sensitive to term spread whereas timberland/farmland assets are more sensitive to default risk. Term spread is able to track short-term fluctuations in business cycles (Fama and French 1989). Recessions correspond to positive shocks to term spread and expansions are associated with negative shocks to term spread. Therefore, our result implies that commercial real estate is more affected during business cycles than timberland/farmland market. The lead-lag relationships of commercial real estate and timberland/farmland returns persist whether asset pricing factors are included in the VECM model or not. This echoes the conjecture of the upstream stage of timberland/farmland markets to commercial real estate market. In other words, timberland/farmland markets may contain some fundamental determinants of the commercial real estate market.

As with any other time series analysis, our conclusions are only valid for the sample period under investigation. Additionally, it is well documented that private-equity indices are of much less frequency than those of public equity. The smaller sample size may result in lower explanatory power or less sophistication of the econometric models being used. For instance, we acknowledge that more advanced GARCH specifications may better capture the innovations in state variables should we have a larger sample size. Hence, these caveats should be kept in mind when interpreting our results. Future work can extend the analysis to public-equity markets.

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Table 1. Quarterly descriptive statistics of return indices.

	Whole sample							Up market			Down market		
	N	Mean	SD	Min	Max	Skewness	Kurtosis	N	Mean	SD	N	Mean	SD
<i>Real estate</i>													
NTBI	122	0.021	0.057	-0.172	0.178	-0.604	2.049	86	0.026	0.057	36	0.009	0.058
NPI	122	0.019	0.022	-0.083	0.054	-2.192	7.082	86	0.021	0.020	36	0.016	0.026
NPIapt	122	0.022	0.021	-0.087	0.063	-2.636	11.498	86	0.023	0.017	36	0.019	0.028
NPIoff	122	0.017	0.027	-0.093	0.066	-1.705	4.615	86	0.018	0.026	36	0.013	0.029
NPIind	122	0.021	0.022	-0.080	0.072	-2.060	6.388	86	0.023	0.020	36	0.017	0.027
NPIret	122	0.022	0.020	-0.063	0.078	-1.049	3.865	86	0.024	0.019	36	0.018	0.022
NPIe	122	0.020	0.024	-0.097	0.058	-2.192	7.678	86	0.021	0.021	36	0.016	0.030
NPImw	122	0.017	0.018	-0.067	0.040	-2.503	8.433	86	0.018	0.017	36	0.015	0.021
NPIs	122	0.018	0.019	-0.068	0.056	-1.824	5.375	86	0.020	0.018	36	0.013	0.022
NPIw	122	0.021	0.024	-0.082	0.056	-1.877	4.947	86	0.022	0.023	36	0.018	0.028
Avg		0.020	0.025						0.022	0.024		0.015	0.029
<i>Timberland/Farmland</i>													
NTI	122	0.029	0.039	-0.065	0.223	2.004	6.501	86	0.03	0.042	36	0.027	0.029
TFSAI	121	0.027	0.035	-0.045	0.202	1.915	5.726	85	0.028	0.037	36	0.024	0.028
NTIs	122	0.022	0.03	-0.052	0.151	1.301	2.881	86	0.022	0.031	36	0.024	0.030
NTInw	122	0.039	0.067	-0.125	0.362	2.621	9.144	86	0.042	0.077	36	0.031	0.036
NFI	106	0.028	0.031	0.000	0.228	3.749	18.709	75	0.031	0.034	31	0.021	0.017
NFIdel	106	0.024	0.019	0.001	0.097	1.928	3.511	75	0.025	0.021	31	0.022	0.014
NFI mou	106	0.025	0.022	-0.010	0.146	2.870	10.815	75	0.026	0.022	31	0.021	0.021
NFIpnw	105	0.018	0.034	-0.055	0.158	1.257	3.270	74	0.020	0.032	31	0.013	0.037
NFIpw	106	0.034	0.053	-0.018	0.414	4.401	26.189	75	0.039	0.061	31	0.021	0.022
NFIse	106	0.022	0.038	-0.093	0.224	2.177	10.577	75	0.026	0.043	31	0.013	0.018
Avg		0.027	0.037						0.029	0.040		0.022	0.025
<i>State variables</i>													
MKT	122	0.020	0.083	-0.244	0.207	-0.648	1.060	86	0.06	0.049	36	-0.076	0.066
TERM	122	0.018	0.011	-0.005	0.036	-0.224	-1.128	86	0.018	0.012	36	0.019	0.011
DEF	122	0.010	0.004	0.006	0.034	3.310	17.020	86	0.009	0.003	36	0.011	0.006
USPE	122	0.034	0.046	-0.154	0.178	-0.450	2.793	86	0.051	0.034	36	-0.009	0.044
PPI	122	0.005	0.017	-0.103	0.050	-2.068	13.616	86	0.005	0.013	36	0.006	0.024
GDP	122	0.025	0.024	-0.082	0.078	-1.057	3.417	86	0.027	0.020	36	0.021	0.032

Note: Real estate assets include NCREIF transaction-based property index (NTBI), NCREIF Property Index (NPI), NPI Apartment (NPIapt), NPI Office (NPIoff), NPI Industrial (NPIind), NPI Retail (NPIret), NPI East (NPIe), NPI Midwest (NPImw), NPI South (NPIs), NPI West (NPIw). Timberland/farmland assets include NCREIF Timberland Index (NTI), Timberland Fund & Separate Account Index gross (TFSAI), NTI South (NTIs), NTI Northwest (NTInw), NCREIF Farmland Index (NFI), NFI Delta regions (NFIdel), NFI Mountain regions (NFImou), NFI Pacific Northwest (NFIpnw), NFI Pacific West (NFIpw), and NFI Southeast (NFise). State variables in the ICAPM include market excess return (MKT) defined as S&P 500 minus risk-free rate (1-month Treasury bill rate), term spread (TERM) defined as yield difference between 10-year and 3-month Treasury bonds, default spread (DEF) defined as yield difference between long-term BAA and AAA corporate bonds, US private equity index by Cambridge Associates US (USPE), producer price index (PPI) and gross domestic product (GDP). All data run from 1987Q1 to 2017Q2 except for NFI, NFIdel, NFImou, NFIpw and NFise, whose respective start dates are 1991Q1 and NFIpnw, whose start date is 1991Q2. Up market is when MKT is nonnegative and down market is when MKT is negative.

1 **Table 2.** Correlations of return indices.

	NTBI	NPI	NPlapt	NPIoff	NPIind	NPIret	NPIe	NPImw	NPIs	NPIw	NTI	TFSAI	NTIs	NTInw	NFI	NFIdeI	NFI mou	NFIpnw	NFIpw
<i>Up market</i>																			
NPI	0.522																		
NPlapt	0.408	0.895																	
NPIoff	0.539	0.964	0.800																
NPIind	0.537	0.946	0.835	0.918															
NPIret	0.370	0.848	0.741	0.718	0.734														
NPIe	0.519	0.978	0.890	0.938	0.894	0.846													
NPImw	0.523	0.959	0.847	0.929	0.880	0.829	0.935												
NPIs	0.499	0.969	0.910	0.906	0.909	0.839	0.929	0.944											
NPIw	0.500	0.980	0.847	0.961	0.965	0.801	0.932	0.911	0.931										
NTI	-0.023	-0.076	0.070	-0.115	-0.090	-0.076	-0.055	-0.083	0.005	-0.120									
TFSAI	-0.065	-0.046	0.112	-0.075	-0.041	-0.088	-0.039	-0.086	0.020	-0.062	0.946								
NTIs	0.017	0.137	0.217	0.138	0.122	0.055	0.150	0.054	0.165	0.139	0.726	0.798							
NTInw	-0.055	-0.114	0.037	-0.175	-0.124	-0.079	-0.104	-0.088	-0.018	-0.169	0.899	0.785	0.402						
NFI	0.026	0.329	0.344	0.248	0.242	0.437	0.345	0.261	0.346	0.301	0.384	0.356	0.402	0.402					
NFIdeI	-0.029	0.252	0.264	0.213	0.136	0.311	0.282	0.191	0.254	0.226	0.300	0.317	0.312	0.293	0.745				
NFI mou	0.020	0.209	0.178	0.150	0.156	0.343	0.196	0.192	0.202	0.213	0.003	-0.012	0.060	-0.018	0.354	0.406			
NFIpnw	-0.115	0.026	0.010	-0.020	-0.016	0.203	0.049	-0.006	0.004	0.027	0.105	0.123	0.256	-0.023	0.283	0.356	0.225		
NFIpw	0.006	0.299	0.329	0.217	0.217	0.407	0.308	0.246	0.330	0.270	0.388	0.366	0.424	0.395	0.961	0.620	0.257	0.198	
NFIse	0.019	0.290	0.213	0.257	0.267	0.324	0.293	0.208	0.278	0.292	0.260	0.215	0.225	0.308	0.686	0.445	0.256	-0.038	0.589
<i>Down market</i>																			
NPI	0.356																		
NPlapt	0.357	0.971																	
NPIoff	0.356	0.989	0.943																
NPIind	0.289	0.985	0.961	0.976															
NPIret	0.369	0.930	0.878	0.891	0.880														
NPIe	0.363	0.993	0.970	0.979	0.969	0.934													
NPImw	0.376	0.979	0.945	0.969	0.962	0.924	0.963												
NPIs	0.372	0.987	0.961	0.972	0.971	0.925	0.975	0.970											
NPIw	0.315	0.992	0.956	0.987	0.989	0.905	0.977	0.965	0.969										
NTI	-0.263	-0.090	-0.053	-0.101	-0.084	-0.111	-0.105	-0.062	-0.083	-0.092									
TFSAI	-0.345	-0.098	-0.056	-0.108	-0.105	-0.094	-0.105	-0.100	-0.099	-0.085	0.886								
NTIs	-0.279	-0.114	-0.101	-0.107	-0.129	-0.106	-0.125	-0.092	-0.090	-0.119	0.868	0.944							
NTInw	-0.137	0.141	0.189	0.109	0.172	0.080	0.119	0.157	0.127	0.151	0.830	0.575	0.471						
NFI	-0.315	-0.314	-0.356	-0.285	-0.309	-0.296	-0.340	-0.309	-0.327	-0.270	0.430	0.543	0.548	0.155					
NFIdeI	-0.373	-0.498	-0.567	-0.449	-0.487	-0.480	-0.516	-0.514	-0.534	-0.436	0.402	0.520	0.507	0.126	0.852				
NFI mou	-0.241	-0.122	-0.156	-0.105	-0.088	-0.157	-0.133	-0.113	-0.102	-0.126	0.116	0.131	0.153	0.022	0.409	0.191			
NFIpnw	-0.320	-0.349	-0.361	-0.333	-0.356	-0.314	-0.371	-0.331	-0.310	-0.341	0.403	0.513	0.577	0.055	0.832	0.632	0.465		
NFIpw	-0.374	-0.140	-0.165	-0.119	-0.122	-0.158	-0.164	-0.151	-0.191	-0.075	0.365	0.514	0.425	0.213	0.883	0.750	0.228	0.617	
NFIse	0.247	0.292	0.285	0.271	0.295	0.304	0.280	0.286	0.336	0.269	0.066	-0.075	0.018	0.111	-0.322	-0.367	-0.169	-0.362	-0.436

Note: All definitions are same as for Table 1.

Table 3. Factor loadings from first-step time series regression using whole sample data.

	ICAPM							Fama-French three-factor			
	C	MKT	TERM	DEF	USPE	PPI	GDP	C	MKT	SMB	HML
<i>Real estate</i>											
NTBI	0.013	0.006	-0.28	-0.694	0.192	0.172	-0.031	0.010	0.109	-0.019	0.080
	2.180	0.060	-0.642	-0.273	1.065	0.469	-0.116	1.882	1.523	-0.156	0.896
NPI	0.013	-0.056	-0.315	0.424	0.184	0.13	0.171	0.010	0.044	-0.045	0.043
	6.033	-1.71	-2.028	0.468	2.868	0.994	1.793	4.987	1.595	-0.961	1.255
NPlapt	0.015	-0.058	-0.12	0.246	0.18	0.109	0.197	0.013	0.041	-0.032	0.046
	7.320	-1.873	-0.819	0.288	2.965	0.886	2.177	6.414	1.580	-0.725	1.404
NPlloff	0.012	-0.079	-0.459	0.015	0.236	0.087	0.173	0.007	0.055	-0.070	0.063
	4.332	-1.999	-2.433	0.014	3.021	0.551	1.488	2.889	1.636	-1.230	1.513
NPlind	0.015	-0.044	-0.486	0.631	0.156	0.131	0.192	0.012	0.046	-0.056	0.041
	6.885	-1.345	-3.118	0.695	2.415	1.001	2.005	5.709	1.654	-1.180	1.189
NPlret	0.014	-0.029	-0.106	1.168	0.134	0.194	0.123	0.014	0.026	-0.009	0.014
	6.465	-0.886	-0.685	1.292	2.081	1.486	1.289	6.778	0.967	-0.206	0.434
NPlle	0.014	-0.067	-0.334	0.369	0.190	0.179	0.254	0.011	0.043	-0.036	0.057
	6.048	-1.931	-2.035	0.386	2.790	1.294	2.515	4.713	1.446	-0.716	1.536
NPlmw	0.011	-0.037	-0.228	0.154	0.112	0.082	0.177	0.009	0.03	-0.029	0.026
	5.826	-1.324	-1.694	0.197	2.004	0.727	2.133	4.970	1.278	-0.727	0.892
NPls	0.011	-0.049	-0.128	0.057	0.193	0.037	0.055	0.009	0.040	-0.019	0.029
	5.313	-1.55	-0.856	0.066	3.111	0.293	0.592	4.705	1.549	-0.436	0.899
NPlw	0.015	-0.058	-0.442	0.805	0.202	0.146	0.173	0.012	0.052	-0.075	0.045
	6.162	-1.607	-2.586	0.809	2.849	1.014	1.646	5.169	1.724	-1.476	1.186
<i>Timberland/Farmland</i>											
NTI	0.021	-0.104	0.008	2.988	0.35	-0.101	0.096	0.021	0.026	-0.118	-0.013
	5.429	-1.822	0.029	1.888	3.116	-0.441	0.574	5.989	0.566	-1.509	-0.228
TFSAI	0.018	-0.099	-0.04	3.279	0.363	-0.136	0.056	0.019	0.029	-0.103	-0.029
	5.544	-1.924	-0.164	2.389	3.631	-0.684	0.387	6.175	0.712	-1.491	-0.566
NTIs	0.015	-0.131	-0.051	2.495	0.393	-0.191	-0.044	0.015	0.018	-0.163	-0.031
	5.126	-3.044	-0.252	2.096	4.648	-1.111	-0.351	5.439	0.513	-2.726	-0.688
NTInw	0.030	-0.066	-0.052	4.047	0.288	0.083	0.320	0.030	0.053	-0.109	0.036
	4.272	-0.632	-0.104	1.393	1.397	0.197	1.042	4.828	0.646	-0.785	0.354
NFI	0.018	-0.045	0.101	3.058	0.376	-0.326	-0.242	0.021	0.050	-0.018	-0.024
	5.542	-0.838	0.44	2.333	3.844	-1.709	-1.631	6.410	1.174	-0.252	-0.473
NFIdel	0.015	-0.017	0.173	1.931	0.176	-0.088	-0.179	0.018	0.014	0.003	-0.014
	7.119	-0.478	1.149	2.255	2.757	-0.704	-1.840	8.629	0.534	0.071	-0.451
NFImou	0.013	0.090	0.200	2.996	0.008	0.550	-0.225	0.017	0.047	0.002	0.005
	5.253	2.273	1.174	3.086	0.105	3.896	-2.045	7.148	1.494	0.04	0.132
NFIpnw	0.006	0.098	-0.209	5.083	0.083	-0.049	-0.168	0.011	0.041	-0.016	-0.047
	1.721	1.566	-0.792	3.374	0.736	-0.225	-0.979	3.072	0.854	-0.198	-0.828
NFIpw	0.025	-0.110	0.089	3.198	0.626	-0.844	-0.227	0.026	0.089	-0.053	-0.029
	4.395	-1.194	0.224	1.411	3.698	-2.563	-0.882	4.748	1.220	-0.44	-0.337
NFIsse	0.015	-0.106	-0.285	1.583	0.469	0.138	-0.328	0.015	0.056	-0.038	-0.020
	3.689	-1.594	-0.999	0.974	3.869	0.583	-1.778	3.802	1.075	-0.442	-0.332

Note: *t*-stat under parameter estimate. C for intercept. All other definitions are same as for Table 1.

1 **Table 4.** Factor loadings from first step time series regression using up and down market periods.

	Up market							Down market						
	C	MKT	TERM	DEF	USPE	PPI	GDP	C	MKT	TERM	DEF	USPE	PPI	GDP
<i>Real estate</i>														
NTBI	0.022	-0.109	-0.400	2.047	0.167	0.051	0.098	0.009	0.124	1.624	-4.950	0.011	0.150	-0.375
	2.094	-0.809	-0.875	0.609	0.809	0.101	0.278	0.425	0.513	1.008	-1.114	0.024	0.235	-0.743
NPI	0.016	-0.098	-0.205	2.033	0.197	-0.108	0.052	0.015	-0.044	-1.438	-0.270	0.091	0.369	0.229
	4.395	-2.160	-1.319	1.779	2.806	-0.632	0.434	2.297	-0.553	-2.677	-0.182	0.570	1.732	1.359
NPlapt	0.017	-0.094	-0.012	2.252	0.197	-0.112	0.034	0.020	-0.043	-1.259	-0.808	0.110	0.267	0.276
	5.475	-2.410	-0.089	2.294	3.275	-0.764	0.332	2.802	-0.505	-2.186	-0.509	0.647	1.168	1.530
NPloff	0.013	-0.121	-0.354	1.400	0.272	-0.196	0.069	0.016	-0.007	-1.678	-0.608	0.048	0.403	0.210
	2.888	-2.074	-1.779	0.956	3.029	-0.893	0.452	2.035	-0.081	-2.740	-0.360	0.268	1.661	1.092
NPlind	0.019	-0.102	-0.373	2.335	0.163	-0.108	0.072	0.017	-0.016	-1.547	-0.097	0.047	0.366	0.258
	5.339	-2.275	-2.431	2.073	2.357	-0.641	0.609	2.537	-0.195	-2.813	-0.064	0.288	1.676	1.494
NPlret	0.017	-0.063	-0.002	2.790	0.115	0.016	0.018	0.013	-0.107	-1.046	0.472	0.169	0.359	0.168
	4.618	-1.324	-0.013	2.353	1.586	0.090	0.142	2.069	-1.449	-2.111	0.345	1.155	1.827	1.082
NPlc	0.016	-0.096	-0.216	2.009	0.202	-0.065	0.129	0.013	-0.106	-1.566	-0.264	0.116	0.460	0.325
	4.286	-2.034	-1.336	1.690	2.762	-0.364	1.035	1.773	-1.202	-2.659	-0.162	0.668	1.970	1.762
NPlmw	0.014	-0.074	-0.146	1.115	0.101	-0.104	0.088	0.012	-0.053	-1.028	0.112	0.111	0.258	0.229
	4.238	-1.775	-1.030	1.072	1.583	-0.666	0.810	2.239	-0.807	-2.328	0.092	0.853	1.475	1.658
NPls	0.015	-0.116	-0.039	1.504	0.207	-0.209	-0.043	0.012	0.016	-0.901	-0.510	0.016	0.312	0.122
	4.492	-2.646	-0.263	1.368	3.066	-1.272	-0.371	1.822	0.206	-1.730	-0.355	0.106	1.511	0.746
NPlw	0.017	-0.100	-0.312	2.645	0.222	-0.090	0.042	0.021	-0.023	-1.835	-0.203	0.096	0.354	0.216
	4.213	-1.965	-1.795	2.074	2.837	-0.469	0.316	2.928	-0.271	-3.236	-0.129	0.569	1.573	1.216
<i>Timberland/Farmland</i>														
NTI	0.028	-0.195	0.034	3.202	0.282	-0.253	0.164	0.028	-0.026	0.017	3.001	0.445	-0.064	-0.065
	3.891	-2.098	0.109	1.377	1.975	-0.726	0.671	3.278	-0.252	0.025	1.576	2.181	-0.234	-0.303
TFSAI	0.024	-0.182	0.044	3.761	0.312	-0.246	0.112	0.028	-0.046	-0.409	2.941	0.476	-0.147	-0.119
	3.970	-2.160	0.156	1.889	2.519	-0.830	0.536	3.293	-0.456	-0.611	1.594	2.407	-0.554	-0.568
NTIs	0.016	-0.143	-0.078	2.067	0.349	-0.404	-0.074	0.024	-0.120	-0.041	3.638	0.618	-0.147	-0.110
	3.171	-2.216	-0.357	1.282	3.522	-1.671	-0.439	2.667	-1.118	-0.057	1.842	2.919	-0.517	-0.490
NTInw	0.048	-0.291	0.112	5.617	0.163	0.013	0.514	0.037	0.080	-0.537	2.258	0.259	0.089	0.014
	3.511	-1.649	0.186	1.272	0.600	0.019	1.112	3.360	0.606	-0.605	0.922	0.987	0.252	0.049
NFI	0.016	-0.054	0.131	2.644	0.446	-0.612	-0.395	0.014	-0.005	-0.191	4.568	0.206	0.027	-0.035
	2.517	-0.634	0.464	1.252	3.337	-1.970	-1.670	2.785	-0.067	-0.541	4.743	1.857	0.201	-0.289
NFIdel	0.013	0.005	0.183	1.234	0.185	-0.062	-0.132	0.016	-0.024	-0.190	2.292	0.177	-0.067	-0.203
	3.203	0.089	1.011	0.910	2.152	-0.312	-0.872	3.496	-0.356	-0.589	2.609	1.749	-0.537	-1.809
NFImou	0.012	0.091	0.178	2.587	0.030	0.624	-0.226	0.007	0.123	0.518	3.320	-0.135	0.551	-0.098
	2.776	1.569	0.927	1.800	0.332	2.948	-1.403	0.940	1.089	0.949	2.231	-0.788	2.613	-0.519
NFIpnw	0.009	0.102	-0.308	1.962	-0.007	-0.198	0.006	0.004	-0.015	0.263	8.583	0.433	0.159	-0.259

	1.325	1.136	-1.067	0.906	-0.053	-0.612	0.025	0.326	-0.088	0.319	3.822	1.678	0.498	-0.904
NFIpw	0.021	-0.137	0.200	3.349	0.790	-1.442	-0.579	0.019	0.002	-0.874	5.219	0.196	-0.128	0.169
	1.889	-0.932	0.409	0.918	3.418	-2.684	-1.416	2.953	0.019	-1.975	4.324	1.408	-0.748	1.098
NFIse	0.017	-0.156	-0.288	5.186	0.509	0.106	-0.579	0.011	-0.038	0.691	-1.221	0.273	0.004	-0.184
	2.138	-1.529	-0.846	2.035	3.158	0.284	-2.028	1.791	-0.412	1.557	-1.007	1.958	0.023	-1.188

Note: *t*-stat under parameter estimate. C for intercept. All other definitions are same as for Table 1.

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Table 5. Risk premiums from second step cross-sectional regression.

	Real estate		Timberland/Farmland	
	Estimate	<i>t</i> -stat	Estimate	<i>t</i> -stat
<i>Whole sample</i>				
C	0.000	0.017	0.023	3.939
MKT	0.351	8.212	0.238	5.966
TERM	0.009	6.560	0.013	2.753
DEF	0.005	8.583	-0.006	-3.368
USPE	0.133	7.993	0.104	8.502
PPI	-0.037	-4.617	0.003	0.929
GDP	0.070	7.515	0.056	6.613
<i>Up market</i>				
C	0.002	0.820	0.019	2.928
MKT	-0.140	-4.662	-0.101	-1.580
TERM	0.006	2.249	0.033	5.544
DEF	0.003	4.858	0.005	6.339
USPE	-0.030	-3.192	-0.116	-2.005
PPI	0.018	3.773	-0.026	-2.755
GDP	0.005	0.704	-0.052	-1.833
<i>Down market</i>				
C	-0.010	-0.319	0.012	2.918
MKT	0.157	0.497	-0.016	-0.189
TERM	0.006	0.356	-0.016	-1.616
DEF	0.002	0.412	-0.002	-1.632
USPE	0.131	0.655	0.017	1.268
PPI	0.032	0.353	0.035	1.051
GDP	0.042	0.529	-0.002	-0.090
<i>Integration test</i>				
	Whole	Up	Down	
Theil's <i>F</i> test	35.75	22.38	1.74	
	(0.000)	(0.001)	(0.259)	
Wald χ^2 test	165.40	133.07	9.86	
	(0.000)	(0.000)	(0.131)	

Note: C for intercept. All other definitions are same as for Table 1.

Table 6. Expected returns based on ICAPM.

	Whole sample	Up market	Down market
<i>Real estate</i>			
NTBI	0.021	0.026	0.009
NPI	0.019	0.021	0.015
NPIapt	0.022	0.022	0.017
NPIoff	0.016	0.018	0.014
NPIind	0.021	0.023	0.015
NPIret	0.022	0.024	0.017
NPIe	0.020	0.022	0.015
NPImw	0.018	0.019	0.016
NPIs	0.018	0.021	0.012
NPIw	0.021	0.022	0.016
Avg	0.020	0.022	0.015
<i>Timberland/Farmland</i>			
NTI	0.030	0.029	0.021
TFSAI	0.028	0.030	0.026
NTIs	0.022	0.023	0.022
NTInw	0.038	0.042	0.031
NFI	0.028	0.035	0.020
NFIdeI	0.026	0.025	0.021
NFI mou	0.027	0.028	0.021
NFIpnw	0.020	0.022	0.016
NFIpw	0.036	0.040	0.024
NFIse	0.024	0.027	0.017
Avg	0.028	0.030	0.022
2-sample t-test	3.572	3.259	4.077

Note: All definitions are same as for Table 1.

Table 7. VECM results without exogenous variables.

	NPI		NTI		NFI	
	Estimate	<i>t</i> -stat	Estimate	<i>t</i> -stat	Estimate	<i>t</i> -stat
ECT	-0.281	-4.357	0.058	0.298	0.120	0.971
C	0.002	2.000	-0.001	-0.361	-0.001	-0.348
NPI _{t-1}	0.117	1.283	0.228	0.824	-0.054	-0.309
NTI _{t-1}	0.069	1.888	-0.800	-7.185	-0.042	-0.586
NFI _{t-1}	-0.186	-3.230	-0.024	-0.139	-0.752	-6.793
NPI _{t-2}	0.254	2.927	-0.127	-0.483	0.139	0.828
NTI _{t-2}	0.059	1.285	-0.354	-2.538	0.027	0.305
NFI _{t-2}	-0.130	-2.052	-0.150	-0.781	-0.729	-5.988
NPI _{t-3}	0.126	1.390	0.426	1.557	0.098	0.566
NTI _{t-3}	0.052	1.122	-0.254	-1.823	0.042	0.477
NFI _{t-3}	-0.109	-1.750	-0.244	-1.290	-0.689	-5.729
NPI _{t-4}	0.257	2.889	-0.095	-0.351	0.175	1.025
NTI _{t-4}	-0.008	-0.212	-0.109	-0.987	0.014	0.198
NFI _{t-4}	-0.049	-0.847	0.140	0.805	0.156	1.404

Note: ECT for error correction term and C for intercept. Endogenous variables in the VECM are NCREIF Property Index (NPI), NCREIF Timberland Index (NTI) and NCREIF Farmland Index (NFI).

Table 8. VECM results with exogenous variables.

	NPI		NTI		NFI	
	Estimate	t-stat	Estimate	t-stat	Estimate	t-stat
ECT	-0.071	-1.250	-0.091	-0.348	0.073	0.436
C	0.003	2.889	-0.001	-0.143	-0.002	-0.667
NPI _{t-1}	-0.134	-1.993	0.350	1.131	-0.030	-0.150
NTI _{t-1}	0.046	1.808	-0.834	-7.107	-0.049	-0.653
NFI _{t-1}	-0.143	-3.465	0.029	0.155	-0.754	-6.189
NPI _{t-2}	0.021	0.327	-0.108	-0.358	0.147	0.761
NTI _{t-2}	-0.001	-0.037	-0.371	-2.473	0.031	0.322
NFI _{t-2}	-0.084	-1.832	-0.108	-0.509	-0.738	-5.452
NPI _{t-3}	-0.001	-0.011	0.438	1.503	0.101	0.539
NTI _{t-3}	0.018	0.583	-0.255	-1.763	0.044	0.473
NFI _{t-3}	-0.109	-2.484	-0.159	-0.784	-0.680	-5.245
NPI _{t-4}	0.161	2.623	0.027	0.094	0.230	1.266
NTI _{t-4}	-0.008	-0.325	-0.119	-1.062	0.012	0.172
NFI _{t-4}	-0.037	-0.942	0.174	0.953	0.127	1.086
MKT _{t-1}	0.004	0.291	-0.091	-1.402	-0.011	-0.255
TERM _{t-1}	0.068	1.068	-0.100	-0.341	0.163	0.868
DEF _{t-1}	-2.777	-6.502	1.183	0.602	0.976	0.775
USPE _{t-1}	-0.022	-0.821	0.280	2.275	0.089	1.133
CPI _{t-1}	0.056	1.027	-0.101	-0.398	-0.103	-0.634
GDP _{t-1}	0.066	1.601	-0.136	-0.713	0.001	0.004

Note: ECT is error correction term and C is intercept. Endogenous variables in the VECM are NCREIF Property Index (NPI), NCREIF Timberland Index (NTI) and NCREIF Farmland Index (NFI). Exogenous asset pricing control variables are innovations in market excess return (MKT) defined as S&P 500 minus risk-free rate (1-month Treasury bill rate), term spread (TERM) defined as yield difference between 10-year and 3-month Treasury bonds, default spread (DEF) defined as yield difference between long-term BAA and AAA corporate bonds, US private equity by Cambridge Associates US (USPE), producer price index (PPI) and gross domestic product (GDP).

Fig 1. Time-series of NCREIF Transaction-based Index (NTBI), NCREIF Property Index (NPI), NCREIF Timberland Index (NTI) and NCREIF Farmland Index (NFI).

Fig 2. Innovations of state variables obtained from GARCH-M model.