Cointegration and Price Discovery between Equity and Mortgage REITs

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Abstract. **This study analyzes the relationship between equity and mortgage real estate investment trust (REIT) stock prices by performing cointegration tests and causality tests, and estimating an error correction model. Evidence is found that a stable long-run linear relationship exists based on their common reactions to changes in market returns, interest rates and other additional factors. Geweke causality test results indicate a causal relationship running from EREIT stock prices to MREIT stock prices. This may reflect the quicker response of equity REIT stock prices to changes in some fundamentals, including real estate returns. In addition, the results suggest overall linear dependence (total linear causality) and instantaneous linear feedback between changes in EREIT and MREIT stock prices. The results of the error correction model not only indicate a significant increase in the explanatory power of the model compared with the vector autoregression model but also reveals how the price discovery processes in REIT security markets maintain the long-run equilibrium.**

Introduction

The dimensions of the literature regarding real estate investment trusts (REITs) have expanded greatly in recent decades. Three major topics are investment decisions, financing decisions and the relationship between return and risk (Corgel, McIntosh and Ott, 1995). On the issue of return and risk, some studies are devoted to the comparison of returns and risks between equity and mortgage REITs (EREITs and MREITs). For example, in their study of REIT performance over the period 1970–93, Han and Liang (1995) find that EREITs outperform MREITs. Liang, McIntosh and Webb (1995) also point out that the variability of risk components of MREITs was considerably greater than that of EREITs during 1970s and 1980s. Khoo, Hartzell and Hoesli (1993) report a reduction in the standard deviation of equity REITs from 1970 through 1989. Giliberto (1991) indicates that the volatility of EREITs starts to increase in 1990. In their study of pricing interest rate risk for MREITs, Liang and Webb (1995) conclude that the market risk of MREITs is largely interest rate risk which is not diversified away. Chen and Tzang (1988) find that both EREITs and MREITs are sensitive to changes in interest rates. Yet, Mengden (1988) argues that MREITs are more sensitive to changes in short-term interest rates than are EREITs.

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The empirical relationship between REITs returns and bank stock returns is examined by He, Myer and Webb (1996). They suggest that MREITs are a more relevant factor in terms of explaining bank stock returns and risks than are EREITs.

However, one important issue, the price dynamics between EREITs and MREITs, has attracted little attention. To both academicians and practitioners, it is beneficial to examine the price dynamics between the two major types of REITs. The price dynamics reveals how price discovery processes in the REIT security markets maintain long-term equilibrium, thus deepening the understanding of price relationships between EREITs and MREITs.

Although EREITs make their investments mainly on real estate properties, while MREITs put their investment focus on mortgages, both have common responses to some fundamentals. For example, the sensitivities of both to changes in market returns and interest rates are widely reported in the literature. In addition, they may have similar reactions to other important factors, such as changes in real estate returns. These similar reactions make their stocks different from other types of stocks. Changes in real estate returns, reflected in changes in property value, not only directly affect EREIT returns, but also have direct impact on the value of mortgage loans that use real properties as collateral. Accordingly, changes in real estate returns can significantly affect the returns and risks for both EREIT and MREIT stocks. In cointegration tests employed in this study, any common reactions of EREIT and MREIT stock prices to changes in market returns and interest rates are explicitly excluded; this ensures that cointegration is based on factors other than market returns and interest rates, such as real estate returns. This is accomplished by regressing changes in equity/mortgage REIT stock prices against changes in market returns and interest rates and using residuals from the regression in cointegration tests. In their recent study about the volatility of REIT returns, He and Webb (1997) provide evidence that most variations in EREIT and MREIT returns can be explained by the stock market factor, the bond market factor and the unsecuritized real estate market factor (the median sales price of new houses sold).

These common reactions will determine a cointegrating relationship between stock prices for EREITs and MREITs. If stock prices of EREITs and MREITs are cointegrated, a stable long-run relationship between the two time series is implied, that is, both variables cannot wander arbitrarily far away from each other. Among cointegrated time series, certain types of Granger-causal relationships may exist. Given any kind of one-way or two-way linear feedback between two time series, an analysis of price discovery is helpful to explore how a long-run equilibrium between the two variables can be reached. Schreiber and Schwartz (1986) define price discovery as the process in which markets try to reach equilibrium prices. An error correction model can explore equilibrium price adjustments between two market segments (Harris, McInish, Shoesmith and Wood, 1995).

In order to examine the cointegration and price discovery between stock prices for EREITs and MREITs, this study performs the Johansen (1988) cointegration tests to

examine if there is a stable long-run relationship between EREITs and MREITs, conducts causality tests to determine what kinds of feedback exist between them and estimates an error correction model to analyze the equilibrium price adjustments between them.

The remainder of this article is organized as follows. The second section describes the data and explains the econometric models for testing cointegration, causal relationships and price discovery. The third section discusses the results from all tests performed. The final section is the conclusion.

Data and Methodology

The sample period is from January 1972 to December 1995. This period includes the increased volatility of EREITs reported by Giliberto (1991). The inclusion of this change in the volatility of EREITs may provide a unique opportunity to discover the true relationship between EREIT and MREIT stock prices. EREITs invest 75% or more of their total assets on real estate properties. MREITs use 75% or more assets to acquire mortgages. Monthly stock price indexes for different types of REITs are provided by the *1995 NAREIT Industry Statistics* (by the National Association of Real Estate Investment Trusts, Inc.).

According to Engle and Granger (1987), two nonstationary time series are cointegrated if they are both stationary in their first differences. Cointegration implies that there is a bounded, linear combination of the levels of the two variables. However, Dickey, Jansen and Thornton (1991) argue that the Engle-Granger cointegration test is sensitive to the choice of dependent variables; therefore, the results of the test may not be consistent. A more robust test is Johansen's (1988) multivariate cointegration test (Gonzalo, 1989) as follows:

$$\Delta X_t = \Gamma_1 \Delta X_{t-1} + \ldots + \Gamma_{k-1} \Delta X_{t-k-1} + \Gamma_k \Delta X_{t-k} + \mu + \varepsilon_t, \tag{1}$$

where: X_t = An $n \times 1$ vector of the variables;
$\quad\Gamma$ = An $n \times n$ coefficient matrix;
$\quad\mu$ = An $n \times 1$ constant vector; and
$\quad\varepsilon_t$ = An $n \times 1$ vector of white noises with mean zero and finite variance.

The number of cointergration vectors is represented by the rank of the coefficient matrix Γ. The likelihood ratio test for the hypothesis that there are at most r cointegration vectors is called the Trace Test statistic:

$$Trace\ Test = -T \sum_{i=r+1}^{p} \ln(1 - \tilde{\lambda}_i), \tag{2}$$

where T is the sample size and $\tilde{\lambda}_{r+1}, \ldots, \tilde{\lambda}p$ are the $p - r$ smallest squared canonical correlations.

Another restricted maximum likelihood ratio test is referred to as the Maximal Eigenvalue Test statistic:

$$Maximal\ Eigenvalue\ Test = -T \ln (1 - \tilde{\lambda}_{r+1}), \tag{3}$$

where $\tilde{\lambda}_1^*, \ldots, \tilde{\lambda}_r^*$ are the r largest squared canonical correlations. The maximal eigenvalue test produces more clear cut results than the trace test, because the later does not use the information that the eigenvalues have been found not to differ significantly from zero (Johansen and Juselius, 1990).

If there is a cointegrating vector between EREIT and MREIT stock prices, the stationarity of these two time series is implied. However, it may merely represent the common responses of these two variables to changes in market returns and interest rates. To rule out these potential common response in cointegration tests, the residuals from the following ordinary least squares model are used to replace EREIT and MREIT stock prices:

$$\tilde{R}_t = \alpha_0 + \alpha_1 \tilde{M}_t + \alpha_2 \tilde{I}_t + \tilde{\omega}_t, \tag{4}$$

where $\tilde{R}_t$ are stock prices for EREITs and MREITs, $\tilde{M}_t$ represents market returns proxied by New York Stock Exchange value-weighted return index, $\tilde{I}_t$ represents changes in yields on long-term United States government bonds and $\tilde{\omega}_t$ are residuals. This study utilizes yields on long-term U.S. government bonds obtained from various issues of the *Federal Reserve Bulletin*. During the sample period, the Federal Reserve System changed measures of long-term U.S. government bonds twice, therefore, this study made appropriate adjustments.

If two time series, such as the stock prices of EREITs (X) and MREITs (Y) are cointegrated, Geweke (1982) proposes the following canonical representations to test the causal relationships between the two variables:

$$X_t = \alpha + \sum_{i=1}^{r} \beta_i X_{t-i} + \xi_{1t} \qquad\qquad Var(\xi_{1t}) = \sigma_{\xi 1}^2 \tag{5}$$

$$X_t = \alpha + \sum_{i=1}^{r} \beta_i X_{t-i} + \sum_{j=1}^{s} \gamma_j Y_{t-j} + \xi_{2t} \qquad Var(\xi_{2t}) = \sigma_{\xi 2}^2 \tag{6}$$

$$X_t = \alpha + \sum_{i=1}^{r} \beta_i X_{t-i} + \sum_{i=0}^{s} \gamma_j Y_{t-j} + \xi_{3t} \qquad Var(\xi_{3t}) = \sigma_{\xi 3}^2 \tag{7}$$

$$X_t = \alpha + \sum_{i=1}^{r} \beta_i X_{t-i} + \sum_{j=-p}^{s} \gamma_j Y_{t-j} + \xi_{4t} \qquad Var(\xi_{4t}) = \sigma_{\xi 4}^2 \tag{8}$$

Each of these canonical representations has an approximate asymptotic chi-square distribution. To determine the optimal lag/lead lengths for r, s and p, the Shibata

(1976) criterion and Hsiao's (1979) procedure are used. The maximum likelihood (*ML*) measures of linear causality from Y_t to X_t (denoted as $F_{y \to x}$), from X_t to Y_t (denoted as $F_{x \to y}$), contemporaneous linear causality between Y_t and X_t (denoted as $F_{y \cdot x}$) and total linear causality between Y_t and X_t (denoted as $F_{y,x}$) are as follows:

$$F_{y \to x} = \ln(\sigma^2_{\xi 1}/\sigma^2_{\xi 2}) * n \sim \chi^2(d) \tag{9}$$

$$F_{x \to y} = \ln(\sigma^2_{\xi 3}/\sigma^2_{\xi 4}) * n \sim \chi^2(d) \tag{10}$$

$$F_{y \cdot x} = \ln(\sigma^2_{\xi 2}/\sigma^2_{\xi 3}) * n \sim \chi^2(1) \tag{11}$$

$$F_{y,x} = \ln(\sigma^2_{\xi 1}/\sigma^2_{\xi 4}) * n = F_{y \to x} + F_{x \to y} + F_{y \cdot x} \sim \chi^2(2d + 1) \tag{12}$$

where n = the number of observations, χ^2 = the chi-square statistic and d = the difference in degrees of freedom between the paired models.

Assuming that the time series for stock prices of MREITs (*X*) and stock prices of EREITs (*Y*) are cointegrated, a movement away from the implied long-run equilibrium in one period will result in a proportion of the disequilibrium being corrected in the next period, according to the Granger Representation Theorem (Granger, 1969, 1986; and Engle and Granger, 1987). Therefore, this process is called error correction. Engle and Granger (1987) argue that cointegration is equivalent to error correction. Because price discovery is the process of maintaining equilibrium prices among different markets, it can be examined by estimating an error correction model. To this end, the following simple bivariate Error Correction Model (ECM) is utilized:

$$\Delta X_t = \alpha_1 + \gamma_1(X_{t-1} - \beta_1 Y_{t-1}) + \sum_{i=1}^{k1} \mu_{1i} \Delta X_{t-i} + \sum_{i=1}^{k2} \theta_{1i} \Delta Y_{t-i} + \varepsilon_t. \tag{13}$$

Equation (13) relates current changes in stock prices for MREITs to the lagged changes in both EREIT and MREIT stock prices and the degree to which the lagged levels of their stock prices are outside of their equilibrium relationship that is represented by $(X_{t-1} - \beta_1 Y_{t-1})$, an error correction term. The coefficient of the error correction component, γ_1, measures the rate at which disequilibria are corrected.

This study uses a likelihood ratio procedure, based on a chi-square statistic, for the unconstrained vector autoregression (VAR) model in levels to determine the optimal length of lag for the error correction model. This begins with a lag length of $p = 6$ set uniformly across the equations in the system and moving to shorter lengths, which are tested as restrictions against the longer lengths. The process is stopped when the chi-square statistic becomes significant. The optimal length of lag is found to be 3.

In order to ascertain whether the addition of error correction terms to the VAR model increases the explanatory power of the ECM, the following *F*-Statistic (Kmenta, 1986) is calculated:

$$\frac{(SSR_Q/SST) - (SSR_K/SST)}{1 - (SSR_Q/SST)} * \left[\frac{n - Q}{Q - K}\right]$$

$$= \left[\frac{R_Q^2 - R_K^2}{1 - R_Q^2}\right] * \left[\frac{n - Q}{Q - K}\right] \sim F(Q - K, n - Q) \tag{14}$$

where: SSR = Regression sum of squares;
SST = Total sum of squares;
R^2 = Coefficient of determination;
n = Number of observations;
K = Number of explanatory variables plus a constant term;
Q = Number of explanatory variables plus a constant term; and $Q > K$.

Empirical Results

The descriptive statistics show that EREITs outperformed MREITs. The mean monthly stock return for EREITs over the period of January 1972 through December 1995 was 0.4%. During the same period, MREITs experienced in a negative average monthly stock return of −0.4%. The risk measures, in terms of standard deviation and coefficient of variation, are higher for MREITs than EREITs. For example, the standard deviation for MREITs is 5.5% vs. 4.0% for EREITs and the coefficient of variation for MREITs is −12.31 vs. 10.67 for EREITs. These results are consistent with the early findings in the REIT literature (Mengden, 1988; Giliberto, 1991; Khoo, Hartzell and Hoesli, 1993; Han and Liang, 1995; and Liang, McIntosh and Webb, 1995).

Results from the Augmented Dickey-Fuller unit root tests indicate that EREIT and MREIT stock price indexes are $I(1)$ (see Exhibit 1). The Dickey-Fuller cointegration tests provide significant (at the 1% level) evidence that stock prices for EREITs and MREITs are cointegrated (Exhibit 2). Exhibit 3 contains the results of the Johansen cointegration tests. In the maximal eigenvalue test, the null hypothesis that there is no cointegrating relationship between stock prices for EREITs and MREITs, $R = 0$,

Exhibit 1
Augmented Dickey-Fuller Unit Root (ADF) Tests

	On the Level		First Differenced	
Variable	Lags	ADF	Lags	ADF
EREIT	9	2.3	4	7.6***
MREIT	16	3.4*	0	45.5***

***Significance at the 1% level.
EREIT = The stock return index on equity REITs.
MREIT = The stock return index on mortgage REITs.

Exhibit 2
Dickey-Fuller Cointegration Tests

Y	X	Trend	No Trend
EREIT	MREIT	4.9***	4.9***
MREIT	EREIT	4.6***	4.7***

***Significant at the 1% level.
EREIT = The stock return index on equity REITs.
MREIT = The stock return index on mortgage REITs.

is tested against the alternative that one cointegrating vector exists between these two variables, $R = 1$. The null hypothesis is rejected at the 1% significance level. The trace test produced the same results. Overall, the results of both the trace and maximal eigenvalue tests, along with the Dickey-Fuller cointegration test, indicate one cointegrating vector between stock prices for EREITs and MREITs. A cointegrating vector indicates that there is one linear combination for which the variance is bounded, that is, a stable long-run relationship between these variables. When the residuals from Equation (4) are used to replace stock prices for EREITs and MREITs, the results of the trace and maximal eigenvalue tests, once again, at the 1% significance level, indicate one cointegrating vector between the two variables. This result clearly suggests that EREIT and MREIT stock prices have common responses to some fundamentals additional to changes in market returns and interest rates. One possible additional factor is changes in real estate returns (such as changes in rental revenue and property value).

The results from Geweke (1982) causality tests are summarized in Exhibit 4. The results do not support the hypothesis that changes in MREIT stock prices Granger-cause changes in EREIT stock prices. However, the results (significant at the 1% level) suggest that there is a causal relationship running from EREIT stock prices to

Exhibit 3
Johansen Cointegration Tests

Y	X	Trace Test		Max. Eigenvalue	
EREIT	MREIT	$R = 0$	164.9***	$R = 0$	88.3***
ERSD	MRSD	$R = 0$	159.7***	$R = 0$	90.8***

***Significant at the 1% level.
EREIT = The stock return index on equity REITs.
MREIT = The stock return index on mortgage REITs.
ERSD = The residuals from Equation (4) for equity REITs.
MRSD = The residuals from Equation (4) for mortgage REITs.

Exhibit 4
Results of Geweke Causality Tests

	Geweke's Measures
$F_{y \to x}$	0.41
$F_{x \to y}$	20.53***
$F_{y \cdot x}$	80.16***
$F_{y,x}$	101.09***
Panel A: Shibata Criterion	
r	11
s	1
p	3
Panel B: Significant Lags/Leads	
x (Eq. 5)	$-1, -2, -3, -4, -5, -6, -7, -8, -9, -10, -11$
x (Eq. 6)	$-1, -2, -3, -4, -5, -6, -7, -8, -9, -10, -11$
y (Eq. 6)	$-1, -2, -3, -4, -5, -6, -7, -8, -9, -10, -11$
x (Eq. 7)	$-1, -2, -3, -4, -5, -6, -7, -8, -9, -10, -11$
y (Eq. 7)	$0, 1$
x (Eq. 8)	$-1, -2, -3, -4, -5, -6, -7, -8, -9, -10, -11$
y (Eq. 8)	$0, 1$
y^{lead} (Eq. 8)	$-1, -2, -3$

The dependent variable (x) is EREIT and the independent variable (Y) is MREIT.
***Significant at the 1% level.
EREIT = The return index on equity REITs.
MREIT = The return index on mortgage REITs.
$F_{y \to x} = y$ causes x.
$F_{x \to y} = x$ causes y.
$F_{y \cdot x} =$ Contemporaneous causality.
$F_{y,x} =$ Total causality present in the system.
$r =$ Number of dependent variable lags based on Shibata Criterion.
$s =$ Number of independent variable lags based on Shibata Criterion.
$p =$ Number of independent variable leads based on Shibata Criterion.
Significant Lags/Leads indicate which dependent and independent lag/lead coefficients are significant at the 5% level. A negative sign ($-$) before the number for the lag/lead means the coefficient is negative.

MREIT stock prices for up to three months. This result may indicate that EREIT stock prices respond to changes in some fundamentals, including real estate returns, more quickly than MREIT stock prices. Furthermore, the significant (at the one percent level) results of the causality tests do suggest the overall linear dependence (total linear causality) and instantaneous linear feedback between changes in EREIT and MREIT stock prices. In addition, all eleven coefficients of lags are significantly negative for EREIT stock prices. However, for MREIT stock prices the number of

significant coefficients of lags is only two. These results indicate the impact of EREIT stock prices on MREIT stock prices. The contemporaneous Granger causality suggests that changes in EREIT or MREIT stock prices can simultaneously affect changes in the other.

Exhibit 5 presents the estimation results of the VAR first difference model and ECM. An ECM essentially is a VAR model including an error correction term. However, the addition of an error correction term to a VAR model can significantly increase the explanatory power of the ECM. The R^2 for the VAR model is .402, but it increases to .498 for the ECM. This increase is significant at the 1% level with an F-Statistic of 53.44. The Durbin-Watson D-Statistic is closer to two for the ECM than the VAR model: 2.02 vs. 2.15. The coefficient of the error correction term is significant at the one percent level. These results suggest that the error-correcting price adjustments occur in the REIT security markets to maintain the long-run equilibrium and these adjustments account for a large share of the explained variation in the estimated models.

The results also reveal the price adjustment processes between EREIT and MREIT stock prices. As an example, suppose in period $t - 1$ the return index for EREITs decreases to 2% while the MREIT return index increases to 1%; that is, the return index for MREITs is 1% lower than that for EREITs. The error correction term is,

Exhibit 5
Estimation Results for the Dependent Variable, ΔMREIT

Independent Variables	VAR First Difference Model	Error Correction Model
ΔMREIT ($t - 1$)	−0.82(−11.6***)	−0.50(−6.4***)
ΔMREIT ($t - 2$)	−0.55(−6.5***)	−0.38(−4.7***)
ΔMREIT ($t - 3$)	−0.21(−2.9***)	−0.14(−2.1**)
ΔEREIT ($t - 1$)	0.20(2.1**)	0.67(6.1***)
ΔEREIT ($t - 2$)	−0.01(−0.1)	0.38(3.2***)
ΔEREIT ($t - 3$)	−0.20(−2.1**)	0.04(0.4)
γ_1[MREIT$_{t-1}$ − (−1.2)*EREIT$_{t-1}$]		−0.48(−7.3***)
Constant	0.00(0.1)	0.00(<0.1))
ΔMREIT (F-Stat)	45.96***	14.05***
ΔEREIT (F-Stat)	4.19***	14.72***
DW	2.15	2.02
R^2	0.402	0.498

The significance of difference between R^2s (F-Stats) is 53.4***. t-Stats are in parentheses.
**Significant at the 5% level.
***Significant at the 1% level.
MREIT = The return index on MREITs.
EREIT = The return index on equity REITs.
DW = Durbin-Watson D-Statistic in OLS models.

therefore, equal to 3.4% $[1 - (-1.2*2)]$. In period t, the MREIT return index decreases by 1.6%$[3.4\%*(-0.5)]$. If the EREIT return index increases to 2.5% in period $t - 1$, while the MREIT index decreases to -3.5%, then the error correction term is -0.5%. In period t, the MREIT index increases by 0.2%. It is important to understand that the error correction term is not a causal relationship measure. The size of the error correction term can be affected by changes either in MREIT stock prices or EREIT stock prices or both. The error correction term represents the stable long-run relationship between two time series.

Conclusion

This study finds that the average monthly stock return over the period January 1972 through December 1995 is higher for EREITs than MREITs. However, the risk measures, in terms of standard deviation and coefficient of variation, are higher for MREIT stock prices than EREIT stock prices. This is consistent with the results of previous studies (Mengden, 1988; Giliberto, 1991; Khoo, Hartzell and Hoesli, 1993; Han and Liang, 1995; and Liang, McIntosh and Webb, 1995).

The results of the Dickey-Fuller and Johansen cointegration tests suggest a stable long-run linear relationship between EREIT and MREIT stock prices. This relationship reflects their common responses to changes in market returns and interest rates, as well as other additional fundamental factors. One of such factors is changes in real estate returns. Although the results of the Geweke causality tests provide no evidence to support the hypothesis that changes in MREIT stock prices Granger-cause changes in EREIT stock prices, the results do indicate a causal relationship running from EREIT stock prices to MREIT stock prices. This finding may reflect the quick reaction of equity REIT stock prices to changes in some fundamentals, including real estate returns. The results of the Geweke causality tests also suggest the overall linear dependence (total linear causality) and instantaneous linear feedback between changes in EREIT and MREIT stock prices. This implies that changes in EREIT or MREIT stock prices can simultaneously cause changes in the other.

The error correction term (*i.e.*, the adjusted differences between MREIT and EREIT stock prices) not only significantly increases the explanatory power of the error correction model, but also reveals the price discovery processes between stock prices for EREITs and MREITs. The results indicate that price discovery processes or error-correcting price adjustments occur in the REIT security markets to maintain the long-run equilibrium.

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