Random Walks and Market Efficiency: Evidence from International Real Estate Markets

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Abstract This study performs tests of the random walk hypothesis for international commercial real estate markets utilizing stock market indices of real estate share prices for three geographical regions: Europe, Asia and North America. The augmented Dickey-Fuller and Phillips-Perron unit root tests and Cochrane variance ratio test find that each of these markets (as well as associated broader stock markets) exhibits random walk behavior. Moreover, a non-parametric runs test provides support for weak-form market efficiency in the real estate markets. In addition, Johansen-Juselius co-integration analysis reveals that all three markets appear co-integrated and share a common long-run stochastic trend. Results of co-integration analyses and vector error correction models suggest that diversification benefits through international real estate securities can only be achieved in the short run.

Introduction

As the random walk hypothesis has important implications for the portfolio management, the hypothesis has been tested for many segments of the United States and other international markets. This study relates to the random walk hypothesis in the context of international real estate securities markets.

The study of real estate markets has drawn considerable interest since the late 1970s. Both the pricing and performance of domestic real estate assets have been extensively examined.[1] While there have been numerous studies of the domestic real estate markets, there have been relatively few studies that have investigated the international commercial real estate markets. This is despite the increased recognition that the shares of listed international real estate companies may offer diversification opportunities for real estate investors. Moreover, the market for these shares has grown more than twelve-fold during the last decade and half. According to Eichholtz, Veld and Vestbirk (1999), this was already more than

$350 billion in size at the beginning of 1999, divided about equally among Europe, North America and the Far East. The relative lack of studies on international real estate markets is in part due to the quality and availability of international real estate returns data as well as the markets' development relative to international stock markets. However, potential diversification benefits of investing in international real estate markets warrant further examination.

Among the studies that have examined the international commercial real estate markets for diversification benefits include: Asabere, Kleiman and McGowan (1991), Ziobrowski and Curcio (1991), Eichholtz, Koedijk, Huisman and Schuin (1998), Myer, Chaudhry and Webb (1997), Liu and Mei (1998) and Case, Goetzmann and Rouwenhorst (1999). Asabere, Kleiman and McGowan find that international real estate should enhance portfolio efficiency for U.S. investors. Ziobrowski and Curcio provide evidence to suggest that U.S. real estate did not significantly improve diversification benefits for investors in United Kingdom and Japan. Eichholtz, Koedijk, Huisman and Schuin examine the extent to which international real estate returns are driven by continental factors. If returns in a particular country are driven by a continental factor, a high correlation exists between the returns in that country and the returns in other countries in the same continent. Eichholtz, Koedijk, Huisman and Schuin find strong continental factors in Europe and North America. However, real estate returns for the Asia/Pacific region are not driven by continental factors. These results suggest potential international diversification opportunities for real estate portfolio managers in the Europe, North American and Asian/Pacific regions. Case, Goetzmann and Rouwenhorst on the other hand, argue that the correlations among international real estate markets in the 1987–1997 period are surprisingly high, given the degree to which real estate markets are segmented. They attribute a substantial amount of the correlation across world property markets to the effects of changes in GNP.

Liu and Mei (1998) examine the extent to which monthly returns on real estate-related securities for six countries over the 1980–1991 period are predictable. They find that the predicted portion of the returns on both stocks and real estate securities are small. They conclude that investing in international real estate-related securities provides additional diversification benefits over and above that associated with international stocks.

Myer, Chaudhry and Webb (1997) examine the stochastic time series properties of *appraisal-based* commercial real estate wealth indices for three countries (United States, Canada and the United Kingdom) and for several property types (aggregate, office, retail and industrial). They find evidence of random walks (based on unit-root tests) for all series except industrial property. They also find evidence of co-integration (a long-term stable relationship) among the real estate indices across the three countries, diminishing potential diversification benefits.

With respect to international real estate markets, none of the previous studies has examined the random walk hypothesis,[2] and the co-integration among series utilizing stock price indices, although Myer, Chaudhry and Webb (1997) have done so using *appraisal-based* data for three countries. The appraisal process leads to smoothing and intertemporal correlation in appraisal-based series.[3] This study extends Myer, Chaudhry and Webb's research in a number of ways. First, it utilizes stock price-based data, rather than appraisal-based price data, to examine random walks (employing two unit root tests, and a variance ratio test), and to conduct co-integration analyses (utilizing the Johansen-Juselius procedure, and vector error correction models) for international commercial real estate markets. Second, it employs a much larger sample (consisting of thirty countries divided into three geographical areas: Europe, Asia and North America). Third, the random walk hypothesis is also tested for broader stock markets corresponding to the three real estate markets. Finally, it tests for weak-form efficiency in the real estate markets utilizing a non-parametric runs test.

The findings of this study support random walks, and co-integration in the long-run for the European, Asian and North American real estate markets. The results of co-integration analyzes and vector error correction models imply that investors in international real estate can derive benefits from diversification in the short-run, but not in the long-run. The study also concludes that broader equity markets in the three geographical areas follow random walks as well.

The remainder of the article is organized as follows. The next section discusses the data and methodology. The following section presents the empirical findings. The last section is the conclusion.

Data and Methodology

Data

This study utilizes stock market indices on real estate share prices obtained from Global Property Research (GPR).[4] GPR real estate stock index series is employed for three geographical configurations: Europe (EUR), Asia and the Far East (referred to simply as Asia or ASI) and North America (NAM). To construct the GPR indices, GPR follows property companies in thirty-five countries (thirty of the thirty-five countries belong to the three areas covered in this study).[5] Countries included in the GPR Index are those for which listed property investment companies of sufficient size exist. Although other publicly listed and property-related companies, such as developers or construction companies, exist in more than the thirty-five countries, their returns, in GPR's judgment, do not reflect real estate returns as directly, even if parts of their assets consist of real estate. Also, GPR only includes equity investors above a certain market capitalization. In order to qualify for inclusion in the indices, a minimum of 75% of revenues must come from equity real estate investments, and firms must have had a market capitalization of more than 50 million U.S. dollars. The sample includes monthly data from 1983:12 to 1997:12. All returns data are first converted into levels and then into natural logarithms.

In order to provide a better understanding of the data utilized in this study, statistics summarizing the characteristics of the returns data in Exhibits 1 and 2 are provided. Exhibit 1 provides a summary of returns and associated risk on real estate equity for the three regions covered in this study. Exhibit 2 provides a correlation matrix of returns for the three regions.

An examination of Exhibit 1 reveals that the average real estate return varied considerably—while risks and returns experienced by Europe and North America were not too far apart, Asia far exceeded them with respect to the monthly average return as well as the standard deviation. The correlation matrix provided in Exhibit 2 yielded an interesting picture regarding pairwise co-movements among these regions. All three correlation coefficients are moderately large and in a rather tight range—0.295, 0.328 and 0.365, respectively. These were all statistically significant at the 1% level.[6]

Methodology

Tests of the Random Walk Hypothesis and Co-integration Analysis. Two techniques were used to analyze the univariate time series properties of the real estate data to determine whether or not the individual series follow random walks: unit root tests and variance ratio test. Co-movements among time series were they analyzed using the co-integration analysis to examine if the series have a stable long-term relationship.

Following Meyer, Chaudhry and Webb (1997), the unit root technique was used to analyze the univariate time series properties of the real estate data to determine whether or not the random walk hypothesis holds. Examples of studies that utilized the unit root methodology to test for random walks in international equity markets include Huang (1995) and Long, Payne and Feng (1999).

First, a standard augmented Dickey-Fuller (1979) unit root tests (ADF) employing Equation (1) was estimated with the lag length determined by Akaike's

Exhibit 1 | Real Estate Equity Returns: Summary Statistics (1983:12–1997:12)

Region	Average	Max.	Min.	Std. Dev.
Europe	0.89	12.73	−9.75	3.97
Asia	1.54	47.40	−26.69	8.59
N. America	0.94	13.94	−19.85	4.38

Notes: The table is based on Global Property Research data for the three geographical areas. The term "average" refers to the arithmetic mean. The values are percentages per month.

Exhibit 2 | Real Estate Equity Returns: Correlation Matrix (1983:12-1997:12)

Region	Europe	Asia	N. America
Europe	—	0.365	0.295
	—	(5.05)	(4.08)
Asia	0.365	—	0.328
	(5.05)	—	(4.54)
N. America	0.295	0.328	

Note: The table is based on Global Property Research data for the three geographical areas. *t*-Statistics are in the parentheses.

information criterion. Moreover, the lag length chosen was sufficient to eliminate serial correlation in the error terms.

$$\Delta X_t = \alpha + \beta T + (\rho - 1)X_{t-1} + \Sigma_{i=1}^{n} \phi_i \Delta X_{t-i} + \varepsilon_t, \quad (1)$$

where X_t is the respective time series; T is a linear time trend; Δ is the first-difference operator; and ε_t denotes the error process with zero mean and constant variance. The null hypothesis of a unit root (*i.e.*, difference stationary) is $(\rho - 1) = 0$ against the alternative hypothesis, $(\rho - 1) < 0$. An alternative unit root test proposed by Phillips and Perron (1988) has the desirable feature that it allows for a weaker set of assumptions concerning the error process, specifically, the presence of dependence and heterogeneity in the error term. The presence of a unit root was tested using the Phillips-Perron (PP) procedure as follows:

$$X_t = \alpha + \beta(t - T/2) + \rho X_{t-1}\ \nu_t, \quad (2)$$

where X_t is the respective time series; $(t - T/2)$ is a time trend where T is the sample size; and ν_t is the error term. The null hypothesis is that the time series is nonstationary, $\pi = 1$, against the alternative hypothesis that the time series is stationary around a deterministic trend, $\rho < 1$.[7]

The variance ratio test has been employed in a number of studies as an alternative method to test the random walk hypothesis (see, Lo and MacKinlay, 1988; Urrutia, 1995; and Long, Peng and Feng, 1999).[8] Given that a time series can be decomposed into a temporary and permanent component, the Cochrane (1988) variance ratio test estimates the size of the random walk or permanent component in the time series. Cochrane provides a method of measuring the degree of persistence in a time series, known as the variance ratio test, which is defined as follows:

$$V_k = 1 + 2\,\Sigma_{j=1}^{k}[1 - j/(k + 1)]r_j, \tag{3}$$

where r_j is the jth order sample autocorrelation coefficient of the first difference of the logarithm of the respective real estate indices, and k is the number of autocorrelations included in the calculation of V_k.

A variance ratio of about one or higher indicates the presence of a stochastic trend (*i.e.*, unit root). The variance ratio equals one for a pure random walk. If the time series is trend stationary, the variance ratio approaches zero as k approaches infinity. Thus, if the real estate index is stationary around a deterministic trend, shocks to the index will not be persistent and estimates of the variance ratio will be close to zero. However, the variance ratio is not strictly bounded by zero and one. Variance ratios of less than one imply that some negative serial correlation is present, while a variance ratio of greater than one implies positive serial correlation. For the random walk hypothesis to hold, the null hypothesis that the variance ratio is equal to one should not be rejected.

Before employing the variance ratio test, the size of k must be determined. Lo and MacKinlay (1988) recommend that the power of the variance ratio test is preserved, compared to standard unit root tests, when k is less than one-half of the sample size. The data set in this study has 168 observations, 1983:12 to 1997:12, so the variance ratios for $k = 12, 24, 36, 48, 60, 72$ and 84 can be computed.[9] Lo and MacKinlay provide a Z-Statistic to test the null hypothesis of a random walk. Following Lo and MacKinlay and the assumption of homoscedasticity, the asymptotic variance of the V_k statistic is given as follows:[10]

$$\Phi_k = [2(2k - 1)(k - 1)]/3kT, \tag{4}$$

where k is the difference horizon and T is the sample size. The V_k statistics asymptotically approaches normality and can be used to test the null hypothesis of a pure random walk ($V_k = 1$) as follows:

$$Z_k = (V_k - 1)/\Phi_k^{1/2}. \tag{5}$$

Co-integration Analysis and Vector Error Correction Models. A well-known method of testing for potential diversification benefits has been to utilize the co-integration methodology to examine the presence of long-term stable relationship among returns (see, for example, Chan, Gup and Pan, 1992; and Ben-Zion, Choi and Hauser, 1996). Following Richards (1995), this study examines whether or not international real estate markets defined by geographical regions are co-integrated using the Johansen-Juselius (1990) procedure. The Johansen-Juselius procedure examines the long-run time series properties of the respective real estate markets as it captures the tendency of these markets to remain aligned with each other over long periods of time while allowing for short-run departures (*i.e.*, daily fluctuations in market prices and returns) to occur. Granger (1986) argues that prices determined in efficient markets cannot be co-integrated and thus predictable. Sephton and Larsen (1991), Dwyer and Wallace (1992) and Richards (1995) advise against such inferences with respect to market efficiency unless dividends and interest rate differentials are unimportant.[11] The presence of co-integration between real estate markets means that these markets are correlated over long time horizons. Although it is still possible to derive portfolio diversification internationally in the short run, it is not possible in the long run in the presence of co-integration.

If the respective real estate markets are integrated of order one, then the Johansen-Juselius co-integration analysis is performed to examine the long-run properties of these time series. The Johansen-Juselius procedure is used to determine the number of co-integrating vectors based on the following vector autoregression (VAR) model:

$$\Delta X_t = \mu + \Gamma_l \Delta X_{t-1} + \cdots + \Gamma_{k-l} \Delta X_{t-k-1} + \Pi X_{t-k} + \varepsilon_t, \qquad (6)$$

where X_t is a vector of non-stationary (in levels) variables; $\Gamma_i = -I + \Pi_1 + \cdots + \Pi_t$; $\Pi = I - \Pi_1 - \cdots - \Pi_k$; and ε_t is a vector of error terms with zero mean and constant variance. The Π matrix contains information about the long-run relationship among the variables in the vector. If the pxp Π matrix has rank zero, $r = 0$, then all elements of X_t are non-stationary. Thus, there are no co-integrating relationships among the variables. A full-rank Π matrix, $r = p$, implies a convergent system of difference equations, so that all variables are stationary. In the intermediate case, $r < p$, there are r nonzero co-integrating vectors among the elements of X_t and $p - r$ common stochastic trends. The Π matrix can be factored into $\alpha\beta'$ where α is a pxr matrix of the vector error correction parameters and β is a pxr matrix of co-integrating vectors. The co-integration vector can be found as a eigenvector, λ, via a maximum likelihood procedure by solving the following eigenvalue problem:

$$|\lambda S_{kk} - S_{ko} S_{oo}^{-1} S_{ok}| = 0, \qquad (7)$$

where S_{oo} is the residual moment matrix from an ordinary least squares regression of ΔX_t on $\Delta X_{t-1} + \cdots + \Delta X_{t-k-1}$; S_{kk} is the residual moment matrix from an ordinary least squares regression of X_{t-k} on ΔX_{t-k-1}; and Sok is the cross product moment matrix.

Johansen-Juselius (1990) provide two tests to determine the number of co-integrating vectors: the maximum eigenvalue and trace tests. First, the maximum eigenvalue test is based on the null hypothesis that the number of co-integrating vectors is r against the alternative $r + 1$ co-integrating vectors, and is given by:

$$\lambda_{max}(r, r + 1) = -T \ln(1 - \lambda_{r+1}). \tag{8}$$

The maximum eigenvalue test statistic, λ_{max}, equals zero when all $\lambda_i = 0$. The further the eigenvalues are from zero the more negative is $\ln(1 - \lambda_{r+1})$ thus the larger the λ_{max} statistic. To test the hypothesis that there are at most r co-integrating vectors, the trace test is employed as follows:

$$\lambda_{trace}(r) = -T \Sigma_{r+1}^{p} \ln(1 - \lambda_i), \tag{9}$$

where $\lambda_{r+1}, \ldots, \lambda_p$ are the smallest eigenvalues (characteristic roots). The null hypothesis is that the number of cointegrating vectors is less than or equal to r against a general alternative. The test statistic, λ_{trace}, equals zero when all $\lambda_i = 0$. As in the case of the maximum eigenvalue test, the further the eigenvalues are from zero the more negative is $\ln(1 - \lambda_i)$ and thus the larger the λ_{trace}. statistic.

A Test of Weak-form Efficiency: Non-parametric Runs Test

A simple non-parametric runs test was utilized to examine the weak-form efficiency of returns in the various real estate markets. The runs test has been previously utilized in several studies of market efficiency (see, for example, Lo and MacKinlay, 1988; and Long, Payne and Feng, 1999). In employing the runs test, the number of runs, r, of positive and negative returns (n_1 and n_2, respectively) are counted. If both n_1 and n are greater than 20, the sampling distribution of r approximates normality. The distribution of r then has the mean or expected value of:

$$\mu_r = [(2n_1n_2)/(n_1 + n_2)] + 1, \tag{10}$$

and a standard deviation of:

$$\sigma_r = [2n_1n_2(2n_1n_2 - n_1 - n_2)]/[(n_1 + n_2)^2(n_1 + n_2 - 1)]. \quad (11)$$

The test statistic for the null hypothesis that the returns (for any particular real estate index) are *random*, implying weak-form efficiency, is given by the *Z*-Statistic as follows:

$$Z_r = (r - \mu_r)/\sigma_r. \quad (12)$$

Empirical Results

Random Walk Hypothesis and Co-integration Analysis

Results of Unit Root Tests. Exhibit 3 displays the results of the ADF and PP unit root tests. Abbreviations EUR, ASI, NAM, RE and STK stand for Europe, Asia, North America, Real Estate and Stock Market, respectively. The ADF and PP tests fail to reject the null hypothesis of a unit root for each of the real estate and stock market indices in levels, suggesting that the respective real estate and stock market indices are integrated of order one, I(1). First-differences of the log level of the

Exhibit 3 | Unit Root Tests for Real Estate & Stock Markets (1983:12–1997:12)

	Log Levels		Log First-Differences	
Variable	ADF	PP	ADF	PP
ASI (RE)	−1.480	−1.485	−13.600[a]	−13.583[a]
EUR (RE)	−1.480	−1.431	−13.923[a]	−13.943[a]
NAM (RE)	−2.269	−2.053	−9.880[a]	−9.768[a]
ASI (STK)	−1.221	−1.380	−9.186[a]	−11.704[a]
EUR (STK)	−1.969	−1.656	−9.587[a]	−15.003[a]
NAM (STK)	−1.725	−2.101	−9.451[a]	−8.071[a]

Notes: MacKinnon (1991) critical values for the ADF and PP unit root tests:
[a] 1%, 4.015
[b] 5%, 3.437
[c] 10%, 3.143

respective real estate and stock market indices are stationary. The unit root results thus provide support for the random walk hypothesis for all three markets (Europe, Asia and North America), both for real estate and the broader stock markets.

The unit-root test results are similar to those by Myer, Chaudhry and Webb (1997) for international commercial real estate, Huang (1995) for Asian stock markets and Long, Payne and Feng (1999) for the Shanghai equity exchange.

Variance Ratio Test. The Cochrane variance ratio tests for both real estate and broader stock markets are reported in Exhibit 4. For the European property index, EUR, the variance ratios are greater than one across all difference horizons, k. However, they are statistically equal to one in all cases, except for $k = 36$, at the 5% level of significance. In the case of Asia, ASI, the null hypothesis of the variance ratio being equal to one is not rejected at the 5% level for all difference horizons, k. Finally, for North America, the difference horizon $k = 12$ provides the only variance ratio for which the null hypothesis is rejected at the 5% level of significance. For all three real estate market indices the variance ratios gradually decline as the difference horizon lengthens. The results of the variance ratio tests for these indices show that, barring a few exceptions, the variance ratio is statistically indistinguishable from one in a vast majority of cases.

Exhibit 4 | Cochrane Variance Ratio (V_k) Tests for Real Estate and Stock Markets 1983:12–1997:12

	ASIRE	EURRE	NAMRE	ASISTK	EURSTK	NAMSTK
k	V_k	V_k	V_k	V_k	V_k	V_k
12	1.311	1.276	1.569	1.515	1.205	0.700
	(1.078)	(0.956)	(1.974)[b]	(1.787)[c]	(0.709)	(−1.039)
24	1.725	1.736	1.581	2.241	1.353	0.584
	(1.719)[c]	(1.745)[c]	(1.378)	(2.945)[a]	(0.839)	(−0.986)
36	1.939	2.063	1.511	2.778	1.095	0.519
	(1.799)[c]	(2.037)[b]	(0.979)	(3.407)[a]	(0.182)	(−0.921)
48	1.777	2.104	1.439	2.614	0.886	0.276
	(1.283)	(1.824)[c]	(0.725)	(2.132)[b]	(−0.188)	(−1.196)
60	1.431	2.060	1.489	2.132	1.038	0.302
	(0.635)	(1.561)	(0.720)	(1.665)[c]	(0.055)	(−1.028)
72	0.998	1.955	1.049	1.601	1.054	0.260
	−0.002	1.280	0.066	0.806	0.072	−0.993
84	0.797	1.576	0.643	1.423	0.860	0.356
	(−0.252)	(0.715)	(−0.443)	(0.524)	(−0.174)	(−0.798)

Notes: *Z*-Statistics are in parentheses. Critical values for the *Z*-Statistics are as follows:
[a] 1%, 2.575
[b] 5%, 1.960
[c] 10%, 1.645

For the European and North American broader stock markets, the null hypothesis that the variance ratio is equal to one is not rejected at the 5% level of significance across all time horizons (k). However, the null hypothesis is rejected for the Asian stock markets at the 5% level for $k = 24$, 36 and 48. These findings based on variance ratio tests generally support the prior empirical results, employing the ADF and PP unit root tests, that both real estate and stock markets in the three geographical areas broadly support the random walk hypothesis.

The results of the variance ratio tests are in line with both Huang (1995) and, Long, Payne and Feng (1999). However, they are opposite to the results obtained by Lo and MacKinlay (1988), and Poterba and Summers (1988) for the U.S. stock markets, and by Urrutia (1995) for the Latin American stock markets.

Co-integration and Vector Error Correction Results. Exhibit 5 displays the results of the Johansen-Juselius co-integration tests for the real estate indices. As before, abbreviations EUR, ASI, NAM, RE and STK stand for Europe, Asia, North America, Real Estate and Stock Market, respectively. In addition, prefixes ''L'' and ''ΔL'' indicate that the variable is ''expressed in levels,'' and in ''change in levels,'' respectively.

For two out of three bivariate models, EUR-ASI (RE) and EUR-NAM (RE), presented in Panels A and B of Exhibit 5, both the λ_{max} and λ_{trace} statistics indicate one co-integrating vector for each of the models. However, λ_{max} and λ_{trace} statistics for the ASI-NAM (RE) model in Panel C fail to reject the null hypothesis of no co-integration. In Panel D, the results of all three real estate markets taken together are presented—they reveal one co-integrating vector. Thus, there is evidence to suggest that all three real estate markets share a common stochastic trend in which departures from this long-run equilibrium will be temporary.

Exhibit 6 reports the results of the corresponding vector error correction models for those models exhibiting co-integration.[12] In Panel A (EUR-ASI (RE)), there is no short-run relationship between the European and Asian real estate markets—coefficients of both $\Delta LASI_{t-1}$ in the $\Delta LEUR_t$ regression, and of $\Delta LEUR_{t-1}$ in the $\Delta LASI_t$ regression are statistically insignificant at the 5% level. The error correction terms (ER) in both the $\Delta LEUR$ and $\Delta LASI$ equations are statistically significant at the 5% level, implying a stable long-run relationship between these two time series. Moreover, based on the error correction terms, there is a slightly faster adjustment towards long-run equilibrium occurring in the Asian real estate markets. Similarly, results presented in Panel B (EUR-NAM(RE)) suggest there is no short-run relationship between the European and North American real estate markets—coefficients of both $\Delta LNAM_{t-1}$ in the $\Delta \mathrm{LEUR}_t$ regression, and of $\Delta LEUR_{t-1}$ in the $\Delta LNAM_t$ regression are statistically insignificant at the 5% level. However, the error correction term in the $\Delta LEUR_t$ regression is significant at the 5% level whereas it is insignificant at this level in the $\Delta LNAM_t$ regression. In Panel D (EUR-ASI-NAM(RE)), the results in large part mirror the finding associated with the bivariate models. In the $\Delta LEUR_t$ regression, coefficients of both $\Delta LASI_{t-1}$ and $\Delta LNAM_{t-1}$ are insignificant at the 5% level. Similarly, in the

Exhibit 5 | Johansen-Juselius Co-integration Tests (RE)
1983:12–1997:12

	Null	Alternative	Statistic	95%CV	90%CV
Panel A: EUR-ASI (RE)					
l_{max}	$r = 0$	$r = 1$	21.681[a]	15.870	13.810
	r £ 1	$r = 2$	5.757	9.160	7.530
l_{trace}	$r = 0$	$r = 1$	27.438[a]	20.180	17.880
	r £ 1	$r = 2$	5.757	9.160	7.530
Panel B: EUR-NAM (RE)					
l_{max}	$r = 0$	$r = 1$	20.747[a]	15.870	13.810
	r £ 1	$r = 2$	4.103	9.160	7.530
l_{trace}	$r = 0$	$r = 1$	24.851[a]	20.180	17.880
	r £ 1	$r = 2$	6.108	9.160	7.530
Panel C: ASI-NAM (RE)					
$_{max}$	$r = 0$	$r = 1$	10.460	15.870	13.810
	r £ 1	$r = 2$	1.473	9.160	7.530
l_{trace}	$r = 0$	$r = 1$	11.933	20.180	17.880
	r £ 1	$r = 2$	1.473	9.160	7.530
Panel D: EUR-ASI-NAM (RE)					
l_{max}	$r = 0$	$r = 1$	23.314[a]	22.040	19.860
	r £ 1	$r = 2$	7.316	15.870	13.810
	r £ 2	$r = 3$	1.719	9.160	7.530
l_{trace}	$r = 0$	$r = 1$	32.349[b]	34.870	31.930
	r £ 1	$r = 2$	9.035	20.180	17.880
	r £ 2	$r = 3$	1.719	9.160	7.530

Notes: Two lags were used in the Johansen-Juselius co-integration procedure based on Akaike's information criteria. The co-integration tests were estimated under the assumption of unrestricted intercepts and no trend in the VAR model (see Pesaran and Smith, 1999:67). Critical values for the co-integration tests are from Osterwald-Lenum (1992).
[a] Significant at the 5% level.
[b] Significant at the 10% level.

$\Delta LASI_t$ and $\Delta LNAM_t$ regressions, coefficients of the remaining two geographical areas are insignificant at the 5% level. These imply a lack of short-run relationship among the real estate indices for the three geographical areas. Moreover, the error correction terms in the $\Delta LEUR_t$ and $\Delta LASI_t$ regressions are significant at the 5% level whereas the term is insignificant at this level in $\Delta LNAM_t$ regression. The results of vector error correction models largely support the finding that while there is no short-run relationship among the three geographical real estate series considered, a long-run relationship appears to exist among these areas.

The finding of the existence of a long-run relationship among international real estate markets are similar to that of Myer, Chaudhry and Webb (1997) for the U.S., Canadian and U.K. real estate markets based on appraisal-based data. This finding is however in sharp contrast with that of Chan, Gup and Pan (1992) that finds no co-integration (based on both pairwise and higher-order co-integration tests) for the U.S. and five major Asian stock markets.

Exhibit 6 | Vector Error Correction Models (Real Estate Markets)

1983:12–1997:12

Panel A: EUR-ASI(RE)

$$DLEUR_t = \underset{(-1.21)}{-0.096DLEUR_{t-1}} + \underset{(0.08)}{0.003DLASI_{t-1}} - \underset{(-4.73)^{a}a}{0.178EC_{t-1}}$$

$$EC_t = 0.525LEUR_t - 0.270LASI_t - 1.243$$

$F = 8.45$ [.000][a] LM = 16.39 [.174] RESET = 2.26 [.132] HET = 1.16 [.281]

$$DLASI_t = \underset{(1.69)^{c}}{0.291DLEUR_{t-1}} - \underset{(-1.52)}{0.132DLASI_{t-1}} - \underset{(-2.33)^{b}}{0.193EC_{t-1}}$$

$$EC_t = 0.525LEUR_t - 0.270LASI_t - 1.243$$

F = 2.86 [.060][c] LM = 15.85 [.198] RESET = 1.31 [.252] HET = 0.168 [.682]

Panel B: EUR-NAM(RE)

$$DLEUR_t = \underset{(-0.60)}{-0.047DLEUR_{t-1}} - \underset{(-1.94)^{c}}{0.137DLNAM_{t-1}} - \underset{(-4.66)^{a}}{0.177EC_{t-1}}$$

$$EC_t = 0.279LEUR_t - 0.277LASI_t - 0.113$$

F = 7.32 [.001][a] LM = 14.19 [.289] RESET = 0.319 [.572] HET = 0.917 [.338]

$$DLNAM_t = \underset{(-.467)}{-0.042DLEUR_{t-1}} + \underset{(3.23)^{a}}{0.261DLNAM_{t-1}} - \underset{(-1.59)}{0.069EC_{t-1}}$$

$$EC_t = 0.279LEUR_t - 0.277LASI_t - 0.113$$

F = 5.28 [.006][a] LM = 7.30 [.837] RESET = 0.079 [.779] HET = .065 [.799]

Panel C: ASI-NAM(RE)

No Co-integration Detected

Exhibit 6 | (continued)

Vector Error Correction Models (Real Estate Markets)

1983:12–1997:12

Panel D: EUR-ASI-NAM (RE)

$$DLEUR_t = -0.069DLEUR_{t-1} + 0.026DLASI_{t-1} - 0.136DLNAM_{t-1} + 0.185EC_{t-1}$$
$$(-0.86) \quad (0.66) \quad (-1.92)^c \quad (4.94)^a$$

$$EC_t = -0.504LEUR_t + 0.230LASI_t + 0.076LNAM_t + 0.971$$

F = 6.86 [.000][a] LM = 17.46 [.133] RESET = 0.108 [.742] HET = .479 [.489]

$$DLASI_t = 0.261DLEUR_{t-1} - 0.134DLASI_{t-1} + 0.097DLNAM_{t-1} - 0.173EC_{t-1}$$
$$(1.47) \quad (-1.52) \quad (0.62) \quad (2.10)^b$$

$$EC_t = -0.504LEUR_t + 0.230LASI_t + 0.076LNAM_t + 0.971$$

F = 1.82 [.145] LM = 16.6 [.164] RESET = 2.53 [.111] HET = 1.53 [.216]

$$DLNAM_t = -0.073DLEUR_{t-1} + 0.048DLASI_{t-1} + 0.246DLNAM_{t-1} + 0.067EC_{t-1}$$
$$-(0.78) \quad (1.05) \quad (3.01)^a \quad (1.55)$$

$$EC_t = -0.504LEUR_t + 0.230LASI_t + 0.076LNAM_t + 0.971$$

F = 4.20 [.007][a] LM = 8.21 [.768] RESET = 0.460E-3 [.983] HET = 0.067 [.796]

Notes: EC_t is respective error correction term; F is the overall F-Statistic for the error correction model; LM is the Breusch-Godfrey, Lagrange multiplier test statistic for serial correlation; RESET is Ramsey's specification test statistic; and HET is test of heteroscedasticity based on the regression of squared residuals on squared fitted values. The LM, RESET and HET test statistics are distributed as chi-square. *t*-Statistics are in parentheses and *p*-values are in brackets.
a Significant at the 1% level.
b Significant at the 5% level.
c Significant at the 10% level.

Weak-form Efficiency

Exhibit 7 provides the results of the non-parametric runs test for the real estate markets. For all three geographical configurations, EUR, ASI and NAM, the *Z*-Statistic is statistically insignificant at the 5% level. This result supports the hypothesis that the real estate markets are weak-form efficient, and it is consistent with the finding (based on the unit-root and variance-ratio tests) that returns in the three real estate markets follow random walks.

Unfortunately, since weak-form efficiency has not been previously tested for international real estate markets, the findings cannot be compared in that context.

Exhibit 7 | Non-parametric Runs Test for Real Estate Markets
1983:12-1997:12

Variable	Observed # of Runs, r	Expected # of Runs, r	n_1 (# of Negative Returns	$n2$ (# of Positive Returns)	Z-Statistic
EUR	81	79.24	106	62	1.200
ASI	82	82.67	98	70	1.725[a]
NAM	72	78.70	107	61	0.334

Note:
[a]Critical value is 10%, 1.645.

However, the runs test finding supports the results of Long, Payne and Feng (1999) for Shanghai equity markets, and of Urrutia (1995) for stock markets in four emerging Latin American countries. It should be noted that while the finding of random walks based on variance ratio tests, of weak-form efficiency based on runs test are consistent, Urrutia's findings are not—his variance ratio tests rejected the random walk hypothesis.

Conclusion

This study conducts tests of the random walk hypothesis for international commercial real estate markets utilizing stock market indices of real estate share prices for three geographical regions: Europe, Asia and North America (comprising a total of thirty countries). It employs two different techniques to test the hypothesis—unit-root tests (augmented Dicky-Fuller (ADF), and Phillips-Perron (PP) tests), and the Cochrane variance ratio test. The unit-root and variance ratio tests are conducted for broader stock markets for the three areas as well. Moreover, a co-integration analysis (the Johansen-Juselius co-integration procedure and vector error correction models) of the long-run relationship among the three real estate markets is conducted. The study also utilizes a non-parametric runs test to examine the weak-form efficiency in international commercial real estate markets. The ADF and PP unit root tests, and Cochrane variance ratio test demonstrate that both real estate and broader stock markets in Europe, Asia and North America exhibit random walk behavior. Moreover, Johansen-Juselius co-integration analysis reveals that the paired real estate markets of Europe-Asia and Europe-North America are co-integrated, whereas the paired real estate markets of Asia-North America are not co-integrated. Finally, all three real estate markets appear to be co-integrated and share a common long-run stochastic trend, implying a stable long-run relationship among the three geographical areas.

The results of the vector error correction models for those models exhibiting co-integration largely confirm the existence of a long-run relationship and the lack of a short-run relationship among the European, Asian and North American real estate markets. These findings imply that investors in international real estate can derive benefits from diversification in the short-run, but not in the long-run. The findings of random walks, and co-integration in the long-run are consistent with the results utilizing appraisal-based data for a much smaller sample of international real estate markets (Myer, Chaudhry and Webb, 1997).

Results of the non-parametric runs test support the hypothesis that international commercial real estate markets are weak-form efficient. This is consistent with the finding of a random walk behavior of these markets based on unit-root and variance ratio tests. Also, the empirical results of co-integration analysis and error correction models are not inconsistent with the finding of random walks (market efficiency) based on unit-root, and variance ratio tests, and the finding of weak-form market efficiency based on runs tests—as pointed out by Richards (1995), one should not infer that efficient markets cannot be co-integrated unless dividends and interest rate differentials are unimportant.

This study contributes to the empirical literature on market efficiency in general, and on international commercial real estate in particular. This article provides evidence that supports the random walk hypothesis both in international real estate markets considered and associated broader stock markets. However, since the real estate markets have a stable long-run relationship, investors in international real estate can derive benefits from diversification in the short-run, but not in the long-run.

Endnotes

1 In the context of broader stock markets, there have been a number of studies that have examined whether the U.S. and other international markets follow a random walk. See, for example, Fama (1965), Lo and MacKinlay (1988), Huang (1995) and Long, Payne and Feng (1999).

2 Often market efficiency tests focus on whether returns follow a random walk process. Implications of the random walk hypotheses include that (a) returns are not predictable in the short or long term and (b) that the variance of the sample is linearly related to the sampling interval. See LeRoy (1989) for a discussion of efficient markets hypothesis, random walks and martingale/fair game models. For a detailed discussion of the random walk hypothesis, see Chapter 2 of Campbell, Lo and MacKinlay (1997).

3 Newell and Webb (1996) find that the degree of appraisal smoothing and intertemporal correlation for the appraisal-based real estate series of five countries (United States, Canada, United Kingdom, Australia and New Zealand) was significant over the 1985–1993 period.

4 The web address for Global Property Research is: www.gpr.nl.

5 Out of the thirty-five countries followed by GPR, thirty belong to the three geographical areas. The geographic break-up is as follows: Europe (Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Italy, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom), North America (Canada, Mexico and the United

States), Far East (Australia, Hong Kong, India, Indonesia, Japan, Malaysia, New Zealand, Philippines, Singapore, Sri Lanka, Taiwan and Thailand). The remaining five countries are: Argentina, Brazil, Venezuela, Israel and South Africa. For an updated list of countries covered currently, visit: www.gpr.nl.

[6] The null hypothesis that the correlation between two regions, ρ_{xy}, is equal to zero is tested using the *t*-statistic calculated as: $t = [(r_{xy}\sqrt{(n-2)}]/[\sqrt{(1-r_{xy}^2)}]$ where n is the number of observations and r_{xy} the sample correlation coefficient.

[7] The lag structure embedded in the Phillips-Perron test statistics is chosen to match the autocovariances of the residuals under the null hypothesis. See Phillips and Perron (1988) for details.

[8] See Seck (1996) in the case of real estate markets and citations therein.

[9] According to Campbell and Mankiw (1987), the variance ratio test exhibits downward bias. Thus, the measurement of persistence should be corrected by multiplying the variance ratio by $[T/(T-k)]$, where T is the number of observations.

[10] Seck (1996) also employed the assumption of homoscedasticity in the calculation of standard errors. The results are similar when heteroscedastic-corrected standard errors are used.

[11] In response to the argument by Granger (1986), Richards (1995: 634–35) states that ''the assertion that predictability of prices is contrary to market efficiency applies strictly only to non-interest- or non-dividend-bearing assets, such as precious metals.'' Also see Richards (1995, 635, Footnote 3) for an example illustrating how co-integration of stock prices (without dividends) might be theoretically feasible in an efficient market.

[12] A vector error correction (VEC) model is a vector autoregression (VAR) that builds in co-integration by incorporating the error correction term.

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