Stationarity and Co-Integration in Systems with Three National Real Estate Indices

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***Abstract*. This study examines the stochastic properties of the commercial real estate wealth indices for three countries (the U.S., Canada and the U.K.) and for several property types (aggregate, office, retail, and industrial). Each of the indices is tested for a unit root and all series are found to be nonstationary. Furthermore, all indices also indicate the presence of both drift and trend. The results are strongest when the indices are tested in real and exchange rate-adjusted form. Application of Johansen's model indicates that the system for the three countries shows evidence of co-integration for the aggregate, retail, office, and industrial properties. Again, the evidence is the strongest when the indices are tested in real and exchange rate-adjusted form. Hence, it is conceivable that inflationary expectations may be the factor that provides the common linkage between commercial real estate across national boundaries.**

Introduction

Several studies have examined the time-series properties of commercial real estate returns and compared them to the returns on financial assets (see, for example, Ross and Zisler, 1991; Myer and Webb, 1993a, 1993b). It has been established that real estate return series exhibit serial correlation and non-normality. However, there are only a few studies that have examined the wealth indices themselves and no studies that have examined real estate wealth indices across national boundaries. An examination of such indices can be useful for discerning long-run relationships that are not obvious when time series are differenced (returns calculated). One probable reason for the limited examination of this issue thus far is the nonstationarity that time-series data often exhibit and a lack of data (see for example Myer, Chaudhry and Webb, forthcoming). If a time series is nonstationary, most widely used statistical tests cannot be applied, since the linear properties of a series measured at equal intervals (namely, its conditional mean, variance and temporal autocorrelation) are time variant. However, formal tests have been developed for testing a series for stationarity and statistical tests have been developed that adjust for nonstationary time series.[1] For instance, Granger (1981) indicates a series that is integrated of order zero (implies stationarity) after differencing, may have linear combinations that are stationary without differencing. Such series are said to be co-integrated.

The purpose of this study is to examine and compare the time-series properties of the

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U.S., Canadian and the U.K. commercial real estate wealth indices. Also of interest is the long-run relationship by property type across national boundaries. First, each of the national time series is tested for nonstationarity, with and without drift and trend components. Then systems are formed for each of the four property types (aggregate, office, retail, and industrial) across the three countries under examination. These systems are then examined for evidence of nonstationarity. An additional test is also performed to estimate the number of co-integrating vectors for each of the real estate systems (Johansen test).

The remainder of this study is organized as follows. Section two presents the methodology for testing stationarity (with and without drift and trend) and co-integration tests. Section three discusses the data. The empirical results are presented in the fourth section, and section five summarizes the results of this study.

Methodology

As discussed in Engle and Granger (1987), a series is said to be integrated of order d ($I(d)$) if it is nonstationary, but when differenced d times, it has a stationary, invertible, ARMA representation. A system consisting of two or more series is said to be co-integrated if the individual time series comprising the system are integrated of order one, but have a linear combination that is stationary (or integrated of order zero).

Unit Root Tests

The ADF (Augmented Dickey-Fuller) test for stationarity of a time series, Y_t, begins with the estimation of the following regression equation when no linear trend is considered:

$$\Delta Y_t = \alpha_0 + \alpha_1 Y_{t-1} + \sum_{j=1}^{p} \gamma_j \Delta Y_{t-j} + \varepsilon_t \, . \tag{1}$$

When a linear trend is considered (1) becomes as follows:

$$\Delta Y_t = \alpha_0 + \alpha_1 Y_{t-1} + \alpha_2 t + \sum_{j=1}^{p} \gamma_j \Delta Y_{t-j} + \varepsilon_t \, . \tag{2}$$

If $\alpha_1 = 0$, then the series is said to have a unit root and is nonstationary. Hence, if the hypothesis, $\alpha_1 = 0$, is rejected for one of the above two equations it can be concluded that the time series does not have a unit root and is integrated of order zero (stationary). The parameters α_0 and α_2 are to test for the presence of drift and trend components, respectively, in the time series. However, it is pertinent to note that the distributions of the ordinary t- and F-statistics computed for the regressions do not have the expected distributions. Hence, the critical values for testing various hypotheses have been estimated using Monte Carlo simulations by Davidson and MacKinnon (1993).

An alternative to the ADF test is the PP (Phillips-Perron) test. The advantage of employing the PP test is that, rather than including the lagged values of ΔY_t as independent variables, the PP test corrects the standard errors of the t-values using the Newly and West (1987) correction.

Tests for Co-Integration

Testing for co-integration implies stationarity for linear combinations of the subject time series. Hence, application of the ADF and PP tests on the residuals from a co-integrating regression provide a test of co-integration. Thus, if there are N series, $Y_{t1} \ldots Y_{tN}$, the co-integrating regression is given by:

$$Y_{t1} = \beta_0 + \sum_{j=2}^{N} \beta_j Y_{tj} + u_t \ , \tag{3}$$

or

$$Y_{t1} = \beta_0 + \beta_1 t + \sum_{j=2}^{N} \beta_j Y_{tj} + u_t \ , \tag{4}$$

if the trend is included. The residuals from these regressions are then tested for the presence of a unit root using the ADF and PP tests. If the test rejects the presence of a unit root, it is concluded that the time-series system is co-integrated.

Another, powerful test for determining co-integrating relationships in time-series systems was recently introduced by Johansen (1988). This test considers the following AR representation for a vector, Y, which is made up of n variables:

$$Y_t = c + \sum_{i=1}^{s-1} \phi_i Q_{it} + \sum_{i=1}^{k} \pi_i Y_{t-i} + \varepsilon_t \ , \tag{5}$$

where each of the series that comprise Y are $I(0)$, Q_{it} are seasonal dummies, and c is a constant.[2]

This system can be rewritten in error-correction form as:

$$Y_t = c + \sum_{i=1}^{s-1} \phi_i Q_{it} + \sum_{i=1}^{k-1} \Gamma_i \Delta Y_{t-i} + \Pi Y_{t-k} + \varepsilon_t \ , \tag{6}$$

which is essentially a vector representation of equation (4) with seasonal dummies added. This system will have the same degree of integration on both sides only if $\Pi=0$ (the series are not co-integrated) or $\Pi Y_{t-\mathrm{k}}$ is $I(0)$, which implies co-integration. The rank of matrix Π gives the number of co-integrating vectors and if Π is decomposed as $\Pi=\alpha\beta'$, β provides the number of co-integrating vectors and α is the scaling factor. Hence, Johansen (1988) provides a maximum likelihood method of estimating this vector and performing cointegration tests.

Data

Data for the four property-type indices (aggregate, office, retail, and industrial) were taken from the Russell-NCREIF Property Index for the U.S. and Canada, while the U.K. property indices were obtained from Investment Property Database (IPD). Exchange rate data were compiled from the *Wall Street Journal,* while CPI data were obtained from *International Financial Statistics.* This study covers the period from the first quarter 1987 through the third quarter 1992.

Empirical Results

Time series for each of the three countries and the four property types were tested for the presence of a unit root employing both the ADF and PP methods. The number of lags chosen was the maximum significant number (at the 95% level) which was derived from the partial autocorrelations of each of the time series. Tests for co-integration were performed on the residuals of each system of equations for the four property types in the three countries under study. Critical values for the ADF and PP tests are based upon Davidson and MacKinnon (1993). For Johansen's test, the critical values were obtained from Johansen and Juselius (1990).

Stationarity, Trend and Drift

Exhibits 1 and 2 contain the ADF and PP results using the nominal series for each of the four property types. ADF tests for the nominal series suggest that, except for industrial

Exhibit 1
Augmented Dickey-Fuller (ADF) Tests for Commercial Real Estate Indices of the U.S., Canada and the U.K.: Nominal Values

		No Trend		With Trend		
Series	Nlags	$\alpha1=0$	$\alpha0=\alpha1=0$	$\alpha1=0$	$\alpha0=\alpha1=\alpha2=0$	$\alpha1=\alpha2=0$
			Total			
U.S.	1	−2.151	2.525	−.0035	3.173	4.518
Canada	1	−2.392	3.903	.062	2.865	3.265
U.K.	2	−3.057*	4.679*	−2.513	3.106	4.651
			Office			
U.S.	1	−.222	.336	.026	3.347	4.568
Canada	1	−2.224	3.457	.029	2.514	2.801
U.K.	3	−2.542	3.231	−1.542	2.253	3.378
			Retail			
U.S.	1	−2.511	3.841*	.295	3.285	4.209
Canada	1	−2.589*	7.219*	−.400	4.594*	3.223
U.K.	2	−2.789*	3.991*	−3.166*	3.900	5.737*
			Industrial			
U.S.	1	−2.686*	4.031*	.243	4.169*	5.773*
Canada	1	−2.645*	4.054*	.224	3.132	4.135
U.K.	1	−2.739*	3.875*	−2.201	3.025	4.413
			Asymptotic Critical Values			
10% level*		−2.57	3.78	−3.13	4.03	5.34

t-values (single hypothesis) and *F*-values (multiple hypotheses) are used to test the various hypotheses concerning equation (1) (no trend) and equation (2) (with trend). $\alpha1=0$ is the unit root test; $\alpha0=0$ tests for drift; $\alpha2=0$ tests for a linear trend. Asymptotic critical values are from Davidson and MacKinnon (1993).

Exhibit 2
Phillips-Perron (PP) Tests for Commercial Real Estate Indices of U.S., Canada and the U.K.: Nominal Values

		No Trend		With Trend		
Series	Nlags	$\alpha1=0$	$\alpha0=\alpha1=0$	$\alpha1=0$	$\alpha0=\alpha1=\alpha2=0$	$\alpha1=\alpha2=0$
			Total			
U.S.	1	−1.981	2.584	.416	5.247*	6.760*
Canada	1	−2.454	10.411*	.592	.964	4.960
U.K.	2	−2.444	5.474*	−.827	4.517*	3.832
			Office			
U.S.	1	.479	.672	.139	3.423	4.184
Canada	1	−2.193	7.318*	.493	6.625*	3.850
U.K.	3	−2.053	2.759	−.546	3.848	4.624
			Retail			
U.S.	1	−3.018*	12.573*	.977	16.301*	10.692*
Canada	1	−2.513	20.176*	−.129	13.759*	3.319
U.K.	2	−2.387	6.305*	−1.410	4.108*	2.814
			Industrial			
U.S.	1	−3.361*	12.263*	.761	17.260*	13.889*
Canada	1	−2.816*	16.633*	.830	15.546*	6.684*
U.K.	1	−2.334	10.025*	−.507	6.770*	2.821
			Asymptotic Critical Values			
10% level*		−2.57	3.78	−3.13	4.03	5.34

t-values (single hypothesis) and *F*-values (multiple hypotheses) are used to test the various hypotheses concerning equation (1) (no trend) and equation (2) (with trend). $\alpha1=0$ is the unit root test; $\alpha0=0$ tests for drift; $\alpha2=0$ tests for a linear trend. Asymptotic critical values are from Davidson and MacKinnon (1993).

properties, the null hypothesis of a unit root ($\alpha_1=0$) for the U.S. cannot be rejected and therefore all the series are nonstationary. The null hypothesis to determine the presence of a unit root for Canada cannot be rejected for the aggregate, office and retail property, whereas industrial properties are found to be stationary. Curiously, U.K. indices suggest stationarity for aggregate, retail and industrial property and nonstationarity for offices.

For the U.S. nominal indices, the PP test indicates nonstationarity for aggregate, office and retail property and stationarity for industrial properties. Correspondingly, the Canadian real estate indices indicate nonstationarity for aggregate, office and retail property and stationarity for industrial properties. The U.K. series demonstrate nonstationarity for all commercial real estate wealth indices. However, when trend and drift are included the evidence for the presence of a unit root for all U.K. properties is overwhelming, except for retail property. The results are stronger when the PP test is

Exhibit 3
Augmented Dickey-Fuller (ADF) Tests for Commercial Real Estate Indices of the U.S., Canada and the U.K.: Real Values

		No Trend		With Trend		
Series	Nlags	$\alpha1=0$	$\alpha0=\alpha1=0$	$\alpha1=0$	$\alpha0=\alpha1=\alpha2=0$	$\alpha1=\alpha2=0$
			Total			
U.S.	0	1.848	3.878*	−.189	5.967*	6.066*
Canada	1	−2.447	3.501	−.585	2.727	3.578
U.K.	1	−3.234*	5.229*	−3.190*	4.218*	6.327*
			Office			
U.S.	0	1.839	10.782*	−.466	7.957*	2.559
Canada	0	−2.154	3.720	.052	3.669	3.971
U.K.	2	−2.311	2.765	−2.433	2.608	3.811
			Retail			
U.S.	1	−2.172	2.437	.062	4.892*	7.229*
Canada	0	−2.643*	9.113*	−.829	5.845*	3.398
U.K.	1	−3.197*	5.118*	−3.858*	5.305*	7.951*
			Industrial			
U.S.	1	−1.566	1.241	−.893	3.853	5.756*
Canada	1	−2.759*	4.129*	−.894	2.840	3.945
U.K.	1	−2.839*	4.150*	−2.235	2.645	3.854
			Asymptotic Critical Values			
10% level*		−2.57	3.78	−3.13	4.03	5.34

t-values (single hypothesis) and *F*-values (multiple hypotheses) are used to test the various hypotheses concerning equation (1) (no trend) and equation (2) (with trend). $\alpha1=0$ is the unit root test; $\alpha0=0$ tests for drift; $\alpha2=0$ tests for a linear trend. Asymptotic critical values are from Davidson and MacKinnon (1993).

performed and almost all (U.S., U.K., Canada) time series exhibit nonstationarity.

If the series has a unit root and the hypothesis $\alpha_1=\alpha_2=0$ is rejected, this suggests the absence of a trend component ($\alpha_2=0$) and indicates that, without trend, the model is conceivably more appropriate for the series under investigation. The ADF test indicates when (whenever a time series has a unit root) the presence of a trend component cannot be rejected. Hence, for most of the time series under investigation, both drift and trend in the series should be included in the model. However, the PP test indicates the absence of a trend for U.S. aggregate, retail and industrial property. A similar conclusion can be drawn for the Canadian industrial index.

Exhibits 3 and 4 contain the results of the ADF and PP tests using inflation-adjusted wealth indices (real). It is also useful to express these indices in real terms, since nominal indices among countries can also be expressed as the sum of expected inflation and real series (see, for example, Kasman and Pigott, 1988; McDonald and Murphy, 1989). A test

Exhibit 4
Phillips-Perron (PP) Tests for Commercial Real Estate Indices of the U.S., Canada and the U.K.: Real Values

		No Trend		With Trend		
Series	Nlags	$\alpha1=0$	$\alpha0=\alpha1=0$	$\alpha1=0$	$\alpha0=\alpha1=\alpha2=0$	$\alpha1=\alpha2=0$
				Total		
U.S.	1	1.523	2.913	−.185	6.003*	6.101*
Canada	1	−2.311	4.458*	−.077	4.570*	4.552
U.K.	2	−1.729	1.700	−1.317	3.709	5.268*
				Office		
U.S.	1	2.085	13.058*	−.337	9.326*	2.938
Canada	1	−2.033	3.155	−.058	3.249	3.518
U.K.	2	−1.412	1.043	−.997	3.859	5.737*
				Retail		
U.S.	1	−2.263	3.176	.0461	10.721*	14.432*
Canada	1	−2.584*	8.594*	−.849	5.649*	3.303
U.K.	1	−1.475	1.186	−1.790	2.519	3.669
				Industrial		
U.S.	1	−1.498	1.169	−.329	7.526*	11.214*
Canada	1	−2.685*	7.085*	−.155	6.267*	5.210*
U.K.	1	−2.459	5.026*	−.955	3.939	3.724
				Asymptotic Critical Values		
10% level*		−2.57	3.78	−3.13	4.03	5.34

t-values (single hypothesis) and *F*-values (multiple hypotheses) are used to test the various hypotheses concerning equation (1) (no trend) and equation (2) (with trend). $\alpha1=0$ is the unit root test; $\alpha0=0$ tests for drift; $\alpha2=0$ tests for a linear trend. Asymptotic critical values are from Davidson and MacKinnon (1993).

for the real series would enable identification of whether it is the inflationary expectation that provides the common bond between the real estate indices across national boundaries. The results for the ADF tests are not significantly different when testing the real versus the nominal series. The PP tests provide much stronger evidence of nonstationarity and the presence of a drift and trend component for most of the time series using real values.

Exhibits 5 and 6 contain the results of using exchange rate-adjusted values. One possible explanation for integration of international real estate markets could be the globalization of foreign financial markets (see, for example, Radecki and Reinhart, 1988; Kasman and Pigott, 1988; McKinnon, 1991; Eichengreen, 1992). Hence, existence of different national currencies and greater integration of foreign currencies may be the underlying cause creating a linkage between these markets. In order to explore this issue further, the indices for the three countries are denominated in a common currency (U.S.

Exhibit 5
Augmented Dickey-Fuller (ADF) Tests for Commercial Real Estate Indices of the U.S., Canada and the U.K.: Exchange Rate-Adjusted Values

		No Trend		With Trend		
Series	Nlags	$\alpha1=0$	$\alpha0=\alpha1=0$	$\alpha1=0$	$\alpha0=\alpha1=\alpha2=0$	$\alpha1=\alpha2=0$
			Total			
U.S.	1	−2.151	2.525	−.004	3.173	4.518
Canada	0	−2.462	6.708*	1.619	8.822*	8.229*
U.K.	0	−2.258	3.839*	−1.787	2.697	2.784
			Office			
U.S.	1	−.222	.336	.026	3.347	4.568
Canada	0	−2.295	5.503*	1.529	7.372*	7.252*
U.K.	0	−2.358	3.621	−1.051	2.448	2.859
			Retail			
U.S.	1	−2.511	3.841*	.295	3.285	4.209
Canada	0	−2.619*	10.280*	1.069	9.218*	5.948*
U.K.	0	−2.175	3.517	−2.626	3.517	4.017
			Industrial			
U.S.	1	−2.686*	4.031*	.243	4.169*	5.773*
Canada	0	−2.615*	8.349*	1.738	10.334*	8.784*
U.K.	0	−1.771	4.204*	−1.788	3.455	2.459
			Asymptotic Critical Values			
10% level*		−2.57	3.78	−3.13	4.03	5.34

t-values (single hypothesis) and *F*-values (multiple hypotheses) are used to test the various hypotheses concerning equation (1) (no trend) and equation (2) (with trend). $\alpha1=0$ is the unit root test; $\alpha0=0$ tests for drift; $\alpha2=0$ tests for a linear trend. Asymptotic critical values are from Davidson and MacKinnon (1993).

dollars). In this case, even the ADF test detects stronger evidence of nonstationarity than the nominal and real series. On the other hand, the PP test provides the strongest evidence of nonstationarity and the presence of a drift and trend component in most of the exchange rate-adjusted time series.

Co-Integration

Exhibits 7 and 8 contain the tests for co-integration. In most cases, both the ADF and PP tests do not show significant evidence of co-integration in nominal or real terms for any of the systems (except office when using the PP test). In contrast, both the ADF ad PP tests indicate the presence of co-integration for the systems comprising total and office property indices when adjusted for exchange rates. The results for the Johansen tests are in sharp contrast to those for the ADF and PP tests. The Johansen tests reject the

Exhibit 6
Phillips-Perron (PP) Tests for Commercial Real Estate Indices of the U.S., Canada and the U.K.: Exchange Rate-Adjusted Values

		No Trend		With Trend		
Series	Nlags	$\alpha1=0$	$\alpha0=\alpha1=0$	$\alpha1=0$	$\alpha0=\alpha1=\alpha2=0$	$\alpha1=\alpha2=0$
			Total			
U.S.	1	−1.981	2.584	.416	5.247*	6.760*
Canada	1	−2.278	5.508*	1.737	9.527*	8.928*
U.K.	1	−2.314	4.176*	−1.714	2.774	2.762
			Office			
U.S.	1	.479	.672	.139	3.423	4.184
Canada	1	−2.129	4.520*	1.590	7.679*	7.572*
U.K.	1	−2.375	3.693	−.982	2.613	3.020
			Retail			
U.S.	1	−3.018*	12.573*	.977	16.301*	10.692*
Canada	1	−2.497	9.143*	1.251	10.481*	6.848*
U.K.	1	−2.189	3.710*	−2.595	3.524	3.950
			Industrial			
U.S.	1	−3.361*	12.263*	.761	17.260*	13.889*
Canada	1	−2.450	7.111*	1.954	11.798*	10.124*
U.K.	1	−1.835	4.887*	−1.705	3.554	2.367
			Asymptotic Critical Values			
10% level*		−2.57	3.78	−3.13	4.03	5.34

t-values (single hypothesis) and *F*-values (multiple hypotheses) are used to test the various hypotheses concerning equation (1) (no trend) and equation (2) (with trend). $\alpha1=0$ is the unit root test; $\alpha0=0$ tests for drift; $\alpha2=0$ tests for a linear trend. Asymptotic critical values are from Davidson and MacKinnon (1993).

hypothesis of no co-integration ($r=0$) for total, office and retail for the nominal, real and exchange rate-adjusted time series. However, the Johansen test does not provide evidence of co-integration for nominal terms when the industrial property indices are tested. However, tests for both the real and exchange rate-adjusted systems detect the presence of co-integration.

In contrast, when the system comprising the property indices of each of the three countries is considered on an individual basis, evidence of co-integration is the strongest for U.S. indices, irrespective of whether the time series is in nominal, real, or exchange rate-adjusted form, whereas none of the Canadian indices indicate any evidence of co-integration. However, the U.K. indices indicate co-integration for both the nominal and exchange rate-adjusted forms, but not the real form.

Evidently, the nonstationarity in the time series for aggregate, office, retail, and

Exhibit 7
Co-Integration Tests for Commercial Real Estate Indices of the U.S., Canada and the U.K.

			Johansen		
System	ADF[1]	PP[2]	r=0	r<=1	r<=2
		Nominal			
Total	−3.499	−3.508	53.657**	18.396	.017
Office	−3.523	−4.304*	57.129**	19.215	.043
Retail		−2.830	65.853***	20.719	.133
Industrial	−3.803	−3.358	46.259	12.878	1.054
		Real			
Total	−3.156	−3.220	51.057*	17.408	6.047
Office	−1.710	−4.171*	56.895**	21.668	6.428
Retail	−2.255	−2.453	68.440***	24.455	8.065
Industrial	−2.849	−2.993	50.227*	9.378	.296
		Exchange Rate-Adjusted			
Total	−3.895*	−3.902*	64.421***	24.183	8.246
Office	−4.426*	−4.423*	79.641***	31.933	5.435
Retail	−3.443	−3.520	55.469**	26.104	8.505
Industrial	−3.574	−3.603	60.641***	24.846	7.239
		Asymptotic Critical Values			
10% level	−3.84	−3.84	49.93	32.09	17.96
5% level			53.35	35.07	20.17
1% level			60.05	40.20	24.99

[1]ADF is the augmented Dickey-Fuller test. [2]PP is the Phillips-Perron test. t-values are used to test for co-integration (ADF and PP) and the Johansen test. r refers to the number of co-integrating vectors in the model. Asymptotic critical values for the ADF and PP tests are from Davidson and MacKinnon (1993) and for the Johansen test, from Johansen and Juselius (1990). *, **, *** indicates significance at the 1%, 5% and 10% levels, respectively.

industrial is dominant when both drift and trend are included in the model. This could be logically expected, since many of the properties that are used to construct all of the real estate series have a third-party (not owner or manager) appraisal on an annual basis. Hence, in the context of this study the Johansen test is considered more powerful because it is formulated such that the presence of seasonality is embedded in the model. In addition, the Johansen test does not rely on an arbitrary choice of dependent variables. The ADF and PP tests, on the other hand, do not allow for seasonality.

Conclusions

All the commercial real estate time series under investigation (U.S., Canadian, U.K.) indicate clear evidence of nonstationarity. Furthermore, the presence of both a drift and trend component is indicated. Hence, in the context of this study, the co-integration tests,

Exhibit 8
Co-Integration Tests for Systems Comprising Three Property Types (Office, Retail, Industrial) for the U.S., Canada and the U.K.

			Johansen		
System	ADF[1]	PP[2]	*r*=0	*r*<=1	*r*<=2
		Nominal			
U.S.	−2.460	−4.890*	68.952***	12.509	.867
Canada	−3.280	−3.290	45.404	11.316	1.675
U.K.	−3.989*	−2.450	69.306***	25.734	.001
		Real			
U.S.	−2.618	−2.714	55.279**	10.405	.245
Canada	−3.492	−3.504	14.397	4.257	.384
U.K.	−2.187	−2.420	43.222	19.155	2.924
		Exchange Rate-Adjusted			
U.S.	−2.460	−4.890*	68.952***	12.509	.867
Canada	−3.394	−3.413	42.059	15.741	3.127
U.K.	−3.229	−3.257	66.737***	16.177	2.014
		Asymptotic Critical Values			
10% level	−3.84	−3.84	49.93	32.09	17.96
5% level			53.35	35.07	20.17
1% level			60.05	40.20	24.99

[1]ADF is the augmented Dickey-Fuller test. [2]PP is the Phillips-Perron test. *t*-values are used to test for co-integration (ADF and PP) and the Johansen test. *r* refers to the number of co-integrating vectors in the model. Asymptotic critical values for the ADF and PP tests are from Davidson and MacKinnon (1993) and, for the Johansen test, from Johansen and Juselius (1990). *, **, *** indicates significance at the 1%, 5% and 10% levels, respectively.

which are robust for nonstationarity, were performed. The implication is that the long-run forecasts of U.S., Canadian and U.K. real estate indices (except industrial properties in nominal terms) do not diverge significantly in the long run.[3] Hence, a common factor that creates a linkage between the indices of the three countries examined is indicated. Since, both the exchange rate-adjusted and real series form provide stronger evidence of co-integration, it is conceivable that the common bond linking these time series is provided by inflationary expectations. Although no study has examined this issue as yet, knowledge of these linkages possibly can be used to develop portfolio models that use real estate property indices from different countries.

Notes

[1]See for example, Fuller (1976), Dickey and Fuller (1979, 1981), Granger (1981, 1986), Granger and Weiss (1983), Engle and Granger (1987), Phillips and Perron (1988), Johansen (1988), and Johansen and Juselius (1990).

[2]For a similar, but more detailed, presentation of the Johansen model, see Muscatelli and Hurm (1992).
[3]One of the important implications of a co-integrated system is that the long-run forecasts of co-integrated systems will be tied together even if the individual forecasts diverge to infinity (see Engle and Yoo, 1987).

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