REIT returns: between the Pacific and the Atlantic

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Abstract

Purpose – The purpose of this paper is twofold in examining the international transmission of REIT returns volatility. The first purpose is to add to the literature on whether the real estate securities market and the broader equity market are integrated. The second objective of the study is to determine whether geographic risk factors can be transmitted beyond their region of influence.

Design/methodology/approach – The study uses the GARCH(1, 1), EGARCH, and GARCH-M models.

Findings – The results show that there are significant international spillovers of REIT returns volatility within the Pacific region. The results also show that there are significant volatility transmissions between the Pacific and the Atlantic regions.

Practical implications – The results are consistent with the implication that the real estate sector and the general equity market are integrated such that geographic risk can be transmitted across national borders. The result will have major implications for international investment strategies.

Originality/value – To date, there has been no published study on the international transmission of REIT returns volatility. This study therefore examines whether the conditional variance of REIT returns of a country is affected by volatility transmission across markets in the same region using four Pacific markets.

Keywords Portfolio investments, Unit trusts, Economic cycles

Paper type Research paper

Introduction

The finance literature has ample evidence that the volatility of stock returns can be transmitted across national borders (e.g. King and Wadhwanis, 1990; Hamao *et al.*, 1990; Lin *et al.*, 1994; Karolyi, 1995; Bekeart and Harvey, 1997). The evidence on real estate securities, however, is relatively scant and ambiguous. On one hand, the line of research that finds the real estate market and the general equity market integrated would lend support to the hypothesis that volatility of real estate stock returns can also be transmitted internationally (e.g. Liu *et al.*, 1990; Mei and Lee, 1994; Li and Wang, 1995; Ling and Naranjo, 1999). On the other hand, the literature on portfolio diversification benefits of international real estate investments would argue that there is not much international volatility transmission of real estate returns across national borders (e.g. Worzala and Sirmans, 2003).

Empirical evidence on the volatility transmission of real estate returns has been surprisingly few. The only published study by Stevenson (2002) documents the spillover of returns volatility from equity real estate investment trusts (REITs) to other classes of REITs within the USA. To date, there is no published investigation on the international volatility transmission of real estate stock returns. This study therefore examines the international transmission of REIT returns volatility using REITs of four Pacific countries (Australia, Hong Kong, Japan, and Singapore) and two Atlantic

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countries (UK and USA)[1]. REITs are closed-end companies that invest primarily in real estate-related assets and distribute most of their profits as dividends to shareholders. The significant growth of REIT markets around the globe in recent years makes it an important and urgent matter to understand better the generating process underlying REIT returns.

The purpose of examining the international transmission of REIT returns volatility is twofold. The first purpose is to add to the literature on whether the real estate securities market and the broader equity market are integrated. Empirical results on the topic have been inconclusive. If our study shows that REIT returns volatility can be transmitted internationally, then it would lend support to the argument that the real estate and stock markets are integrated even internationally. The second objective of the study is to determine whether geographic risk factors can be transmitted beyond their region of influence. *A priori*, we expect the geographic risk factors in the Pacific region to have an influence on countries within the region. However, the influence of geographic risk factors from the Atlantic region cannot be predetermined. Real estate stock returns volatility transmission between the Pacifica and the Atlantic will prove that geographic risk is transportable across national boundaries and will have major implications for international investment strategies.

Data and methodology

Daily returns of the six Pacific and Atlantic REIT indices between 1 January 1999 and 31 December 2003 are obtained from the National Association of Real Estate Investment Trusts (NAREITs) of the USA. To be included in an index, the firm must be a closed-end company listed on an official stock exchange. In addition, the firm must meet specific geographic and financial standards. These standards in general request that the majority of earnings or bulk of total assets is the result of relevant real estate activity. Relevant real estate activities include the ownership, trading, and development of income producing real estate. The majority of the earnings must also be derived from domestic operations. The company must also meet a minimum requirement regarding market capitalization[2].

The US REIT industry has a relatively long history that goes back to 1960. However, it was the Tax Reform Act of 1986 that triggered the dramatic growth of the industry by permitting REIT to own and to operate most types of income-producing commercial properties. The number of REITs in USA grew from 40 in 1970 to 140 in 2001. Over the same period, the total equity market capitalization increased from US$1.5 billion to US$ 155 billion. On the other hand, with the exception of the long and successful history of Listed Property Trusts in Australia, the REIT markets in Asia have started to flourish only in the recent years. Both the Japanese and Singaporean REITs have fared relatively well with a market capitalization of about US$19.9 billion and US$5.2 billion in 2005. The Hong Kong REIT industry suffered a temporary setback in 2004 when a major REIT initial public offering had to be withdrawn due to legal issues. According to Ooi *et al.* (2006), the driving forces for the REITs in Asia came largely from companies that own significant real estate holdings and banks saddled with non-performing real estate-related loans. In Japan, REIT was seen as a vehicle for banks to recapitalize in a market burdened with high non-performing loans. Demand by investors to diversify their investment risk in the volatile Asian equity markets also contributed to the growth of REITs in the region. An investigation of the volatility transmission of REIT returns between the Pacific and the Atlantic regions would shed light on how well the REIT markets integrate internationally.

The methodology for detecting REIT returns volatility transmission among the REIT indices is a technique suitable for handling high frequency financial data that specifically allows for a time-varying conditional variance. Specifically, we use three different forms of the multivariate Generalized Autoregressive Conditional Heteroscedasticity (GARCH) model in this study. They include the basic GARCH(1, 1), the Exponential GARCH (EGARCH), and the GARCH-M specifications[3]. The GARCH model was developed by Bollerslev (1986) from the basic Autoregressive Conditional Heteroscedasticity (ARCH) procedures of Engle (1982). Both procedures have been found to perform remarkably well in modeling financial time series. These models allow for a time-varying conditional variance and that the conditional variance is modeled as a function of its past values as well as independent and/or exogenous variables. Specifically, the following GARCH(1, 1) specification is used to determine if the conditional variance of REIT returns is affected by volatility transmission within the Pacific region. Then the model is expanded to include the Atlantic region.

For the Pacific region alone:

$$R_{i,t} = \beta_{i,0} + \beta_{i,1} R_{i,t-1} + \varepsilon_{i,t} \tag{1}$$

$$\sigma^2_{i,t} = \alpha_{i,0} + \sum_{j=1}^{4} \alpha_{i,j} \varepsilon^2_{j,t-1} + \gamma_i \sigma^2_{i,t-1} \text{ for } i,j = 1,\ 2,\ 3, 4 \tag{2}$$

For the Pacific and Atlantic regions together:

$$R_{i,t} = \beta_{i,0} + \beta_{i,1} R_{i,t-1} + \varepsilon_{i,t} \tag{3}$$

$$\sigma^2_{i,t} = \alpha_{i,0} + \sum_{j=1}^{6} \alpha_{i,j} \varepsilon^2_{j,t-1} + \gamma_i \sigma^2_{i,t-1} \text{ for } i,j = 1,\ 2,\ 3, \ldots, 6 \tag{4}$$

where $R_{i,t}$ is the daily REIT return series of country i, $i = 1, 2, 3, \ldots, 6$ (i.e. $1 =$ Australia, $2 =$ Singapore, $3 =$ Hong Kong, $4 =$ Japan, $5 =$ USA, and $6 =$ UK). In the conditional variance equations (2) and (4), the variance of REIT returns depends on its own lagged value as well as the lagged squared residuals (innovations) of all the other countries. The lagged squared residuals in the equation are used for detecting volatility transmission across international boundaries. That is, volatility spillovers across markets are measured by $\alpha_{i,j}$ for $i, j = 1, 2, 3, 4$ and $i \neq j$ (the Pacific region alone), and for $i, j = 1, 2, 3, \ldots, 6$ (the Pacific and Atlantic regions together).

We also use the EGARCH specification for detecting the volatility transmission. Nelson (1991) developed the EGARCH specification. An advantage of EGARCH is that it is ideally suited to test the possibility of asymmetries in the volatility transmission mechanism because it allows own market and cross-market innovations to exert an asymmetric impact on the volatility in a given market. In other words, news generated in one market is evaluated in terms of both size (i.e. the quantity) and sign (i.e. the quality) by other markets. Nelson (1991) finds that, for the USA stock market, negative innovations increase volatility more than positive ones. Cheung and Ng (1992), Koutmos (1992), and Poon and Taylor (1992) all report evidence of the asymmetric impact of news shocks on volatility. The following EGARCH specification is used.

For the Pacific region alone:

$$R_{i,t} = \beta_{i,0} + \beta_{i,1}R_{i,t-1} + \varepsilon_{i,t} \tag{5}$$

$$\sigma^2_{i,t} = \exp\left\{\alpha_{i,0} + \sum_{j=1}^{4}\alpha_{i,j}f_j(z_{j,t-1}) + \gamma_i \ln(\sigma^2_{i,t-1})\right\} \quad \text{for } i,j = 1,2,3,4 \tag{6}$$

$$f_j(z_{j,t-1}) = \{|z_{j,t-1}| - E(|z_{j,t-1}| + \delta_j z_{j,t-1}\} \quad \text{for } j = 1,\ 2,\ 3, 4 \tag{7}$$

$$\sigma_{i,j,t} = \rho_{i,j}\sigma_{i,t}\sigma_{j,t} \quad \text{for } i,j = 1,\ 2,\ 3,\ 4 \text{ and } i \neq j \tag{8}$$

For both the Pacific and Atlantic regions together:

$$R_{i,t} = \beta_{i,0} + \beta_{i,1}R_{i,t-1} + \varepsilon_{i,t} \tag{9}$$

$$\sigma^2_{i,t} = \exp\left\{\alpha_{i,0} + \sum_{j=1}^{6}\alpha_{i,j}f_j(z_{j,t-1}) + \gamma_i \ln(\sigma^2_{i,t-1})\right\} \quad \text{for } i,j = 1,\ 2,\ 3, \ldots, 6 \tag{10}$$

$$f_j(z_{j,t-1}) = \{|z_{j,t-1}| - E(|z_{j,t-1}| + \delta_j z_{j,t-1}\} \quad \text{for } j = 1,\ 2,\ 3, \ldots, 6 \tag{11}$$

$$\sigma_{i,j,t} = \rho_{i,j}\sigma_{i,t}\sigma_{j,t} \quad \text{for } i,j = 1,\ 2,\ 3, \ldots, 6 \text{ and } i \neq j \tag{12}$$

Equations (6) and (10) stipulate that the conditional variance of a country's REIT returns can be affected by volatility spillovers from other countries. Volatility spillovers across markets are measured by α_{ij} for i, j = 1, 2, 3,..., 6 and $i \neq j$. A significant α_{ij} coupled with a negative δ_j implies that negative innovations in market j have a higher impact on the volatility of market i than positive innovations, i.e. the volatility spillover mechanism is asymmetric. The γ_i in equations (6) and (10) measure the persistence of volatility.

Finally, we also use the GARCH-M specification to determine if the conditional volatility of REIT returns of a country is affected by volatility spillovers from other countries. The GARCH-M specification is often used in financial applications where the expected return on an asset is related to the expected asset risk. The coefficient on the expected risk is a measure of the risk-return tradeoff. The following GARCH-M specification is used.

For the Pacific region alone:

$$R_{i,t} = \beta_{i,0} + \beta_{i,1}R_{i,t-1} + \beta_{i,2}\sigma^2_{i,t} + \varepsilon_{i,t} \tag{13}$$

$$\sigma^2_{i,t} = \alpha_{i,0} + \sum_{j=1}^{4}\alpha_{i,j}\varepsilon^2_{j,t-1} + \gamma_i\sigma^2_{i,t-1} \quad \text{for } i,j = 1,\ 2,\ 3,\ 4 \tag{14}$$

For the Pacific and Atlantic regions together:

$$R_{i,t} = \beta_{i,0} + \beta_{i,1}R_{i,t-1} + \beta_{i,2}\sigma^2_{i,t} + \varepsilon_{i,t} \tag{15}$$

$$\sigma^2_{i,t} = \alpha_{i,0} + \sum_{j=1}^{6}\alpha_{i,j}\varepsilon^2_{j,t-1} + \gamma_i\sigma^2_{i,t-1} \text{ for } i,j = 1,\ 2,\ 3, \ldots, 6 \tag{16}$$

Two variants of the GARCH-M specification use the conditional standard deviation or the log of the conditional variance in place of the variance. In this paper, we report results using the log of the conditional variance.

Results

We report results for the Pacific region first. From the descriptive statistics reported in Table I, we find the REIT raw returns of Singapore and Japan positively skewed while those of Australia and Hong Kong negatively skewed. The kurtosis values of all the REIT returns series are much larger than three. This indicates that all the REIT raw returns series are leptokurtic and have fat tails relative to the normal distribution. For all the four REIT returns series, the Jarque-Bera statistics reject the null hypothesis of normal distribution at the 1 per cent significance level. In addition, the augmented Dickey-Fuller (ADF) test was conducted to check for unit root (stationarity) in order to determine whether the REIT returns need to be transformed before model estimation. The ADF statistics strongly indicated that all the REIT returns are stationary. We reject the null hypothesis of unit root at the 1 per cent level. The Ljung-Box Q test statistics indicate that the squared raw REIT returns have substantially higher

Statistics	JP	HK	Sing	Aus
Mean (μ)	0.0192	−0.0077	−0.04457	0.0473
Median	0.0005	0.0000	−0.1000	0.0770
SD (σ)	2.1606	1.8108	2.0496	0.9523
Skewness	0.3248	−0.3860	0.3268	−0.2302
Kurtosis	4.0884	5.1174	5.1251	4.2930
Minimum	−6.1082	−9.9480	−9.1900	−4.2012
Maximum	9.7282	7.4490	10.7900	4.0741
Jarque-Bera	69.62	194.54	214.20	81.64
Probability	0.0000*	0.0000*	0.0000*	0.0000*
ADF test at level I(0)[a]	−14.66*	−14.59*	−14.02*	−14.86*
Ljung-Box Q test results				
Q-statistics				
A: Ljung-Box Q test for autocorrelation of raw returns				
Lag (4)	10.695**	12.611**	5.424	1.811
Lag (8)	11.392	18.520**	10.804	4.869
Lag (12)	14.413	19.874***	13.851	9.685
Lag (16)	20.988	21.871	16.544	10.956
Lag (20)	23.895	23.804	16.946	14.058
Lag (24)	27.062	35.546***	23.523	19.236
B: Ljung-Box Q test for autocorrelation of squared raw returns				
Lag (4)	1.411	28.230*	38.069*	29.555*
Lag (8)	12.574	34.730*	53.281*	42.424*
Lag (12)	26.366**	38.534*	64.214*	64.799*
Lag (16)	33.265**	43.531*	69.292*	99.004*
Lag (20)	36.926**	45.628*	75.960*	121.66*
Lag (24)	44.226**	60.222*	77.018*	137.26*

Notes: [a]The ADF test is augmented Dickey-Fuller unit root test. The ADF test is a test of stationarity. *Significant at 10 per cent; **significant at 5 per cent; ***significant at 10 per cent

Table I.
Summary statistics of REIT index raw returns

autocorrelations than the raw returns. This indicates the presence of strong conditional heteroscedasticity in REIT returns. In short, statistical properties of the data strongly support the usage of the various GARCH model in this study.

In Table II, we report results of the GARCH(1, 1) model to determine if the conditional variance of REIT returns of a country is affected by volatility spillover across markets in the Pacific region. Results in Table II show that there are significant volatility spillovers from Singapore to Japan (α_{42} equals -0.0336 and is significant at 1 per cent) and Hong Kong (α_{32} equals 0.0528 and is significant at 5 per cent), and from Japan to Singapore (α_{24} equals 0.0215 and is significant at 5 per cent). Hong Kong and Australia have no impact on other countries other than their own past volatilities. The findings imply that geographic risk factors of a country can affect volatility of REIT returns of other countries within the Pacific region. Given that the REITs included in the NAREIT international indices are required to derive most of their earnings from domestic operations, it is therefore unlikely that the international transmission of REIT returns volatility is caused by correlated cash flows among the REITs. Therefore, it appears that the reason for the volatility transmission is due to the integration of international REIT markets that makes possible the international transportation of geographic risk factors after they are securitized. Such an observation has major implications for investors who seek portfolio risk diversification by investing in

From Aus ($\alpha_{4,1}$), Sing ($\alpha_{4,2}$), HK ($\alpha_{4,3}$) to JP		From Aus ($\alpha_{3,1}$) Sing ($\alpha_{3,2}$), JP ($\alpha_{3,4}$) to HK		From Aus ($\alpha_{2,1}$) HK ($\alpha_{2,3}$), JP ($\alpha_{2,4}$) to Sing		From Sing ($\alpha_{1,2}$), HK ($\alpha_{1,3}$), JP ($\alpha_{1,4}$) to Aus	
$\beta_{4,0}$	0.0004	$\beta_{3,0}$	0.0015	$\beta_{2,0}$	−0.0245	$\beta_{1,0}$	0.0685
	(0.0664)		(0.0531)		(0.0600)		(0.0280)*
$\beta_{4,1}$	0.0569	$\beta_{3,1}$	0.1145	$\beta_{2,1}$	0.0454	$\beta_{1,1}$	0.0056
	(0.0315)*		(0.0331)**		(0.0351)		(0.0324)
$\alpha_{4,0}$	3.2600	$\alpha_{3,0}$	0.5666	$\alpha_{2,0}$	0.0742	$\alpha_{1,0}$	0.0295
	(2.3952)		(0.2273)*		(0.0838)		(0.0164)***
$\alpha_{4,1}$	0.0014	$\alpha_{3,1}$	0.0885	$\alpha_{2,1}$	0.07786	$\alpha_{1,1}$	0.05814
	(0.1093)		(0.1272)		(0.0530)		(0.0169)**
$\alpha_{4,2}$	−0.0336	$\alpha_{3,2}$	0.0528	$\alpha_{2,2}$	0.0466	$\alpha_{1,2}$	0.0008
	(0.0083)**		(0.0287)*		(0.0232)*		(0.0022)
$\alpha_{4,3}$	0.0164	$\alpha_{3,3}$	0.0457	$\alpha_{2,3}$	0.0189	$\alpha_{1,3}$	0.0016
	(0.0331)		(0.0253)*		(0.0194)		(0.0031)
$\alpha_{4,4}$	0.0163	$\alpha_{3,4}$	0.0203	$\alpha_{2,4}$	0.0215	$\alpha_{1,4}$	−0.0009
	(0.0320)		(0.0161)		(0.0121)*		(0.0013)
γ_4	0.3004	γ_3	0.6546	γ_2	0.8793	γ_1	0.9042
	(0.5166)		(0.1041)**		(0.0397)**		(0.0277)**

Notes:

$$R_{i,t} = \beta_{i,0} + \beta_{i,1}R_{i,t-1} + \varepsilon_{i,t}$$

$$\sigma^2_{i,t} = \alpha_{i,0} + \sum_{j=1}^{4} \alpha_{i,j}\varepsilon^2_{j,t-1} + \gamma_i\sigma^2_{i,t-1} \text{ for } i,j = 1, 2, 3, 4$$

Australia is 1, Singapore is 2, Hong Kong is 3, Japan is 4. ***Significant at 1 per cent; **significant at 5 per cent; *significant at 10 per cent

Table II. Multivariate GARCH (1, 1) model: volatility spillovers in the Pacific region international real estate securities. It implies that investors would get better diversification benefits by investing in countries that have a lower degree of integration between the general equity and real estate securities markets. Gordon and Canter (1999) provide empirical support that some countries have a low correlation between the property securities and the broader equity market.

The persistence of volatility is measured by γ. They are all significantly less than one, a result that is necessary for the unconditional variance to be finite. Persistence is strongest in Australia and weakest in Japan. This can be interpreted by using half-life concept, which measures the time it takes a shock to reduce its impact by one-half. For Australia the half-life is 6.88 days, for Singapore the half-life is 5.39 days, for Hong Kong the half-life is 1.64 days, and for Japan the half-life is 0.58 day. (half-life for market i equals $\ln(0.5)/\ln \gamma$).

In Table III, we provide results of several diagnostic tests of the standardized residuals obtained from the multivariate GARCH(1, 1) model. The standardized residuals of Singapore, Hong Kong, and Japan are positively skewed, but the standardized residuals

	JP	HK	Sing	Aus
Panel A: diagnostic tests				
Skewness	0.289	0.057	0.291	−0.077
Kurtosis	3.981	4.921	4.293	3.773
Jarque-Bera	56.064	160.306	86.949	26.933
Probability	0.0000*	0.0000*	0.0000*	0.0000*
Lag				
Panel B: autocorrelation functions of standardized residuals				
4	0.029	0.002	0.040	−0.023
8	0.004	0.021	0.046	−0.003
12	0.038	−0.026	−0.007	0.005
16	0.033	−0.008	0.002	−0.024
20	0.050	0.005	0.000	0.020
24	−0.024	0.058	−0.003	−0.046
Lag				
Panel C: autocorrelation Q-statistics for standardized residuals				
4	7.846	2.635	2.807	0.964
8	8.618	6.845	7.988	3.249
12	12.040	8.067	12.053	9.169
16	18.279	10.607	15.437	12.332
20	21.107	12.308	15.587	15.472
24	25.159	24.751	23.090	20.001
Lag				
Panel D: autocorrelation Q-statistics for standardized residuals squared				
4	1.625	9.605	4.172	7.028
8	11.613	11.235	4.219	12.307
12	26.842*	14.670	5.424	14.287
16	33.994**	19.401	10.812	17.127
20	38.069**	22.293	11.998	26.750
24	45.696*	44.427**	14.499	30.903

Notes: ***Significant at 1 per cent; **significant at 5 per cent; *significant at 10 per cent

Table III. Descriptive statistics for the standardized residuals for the GARCH (1, 1) spillover model (Pacific region only) of Australia are negatively skewed. The kurtosis values are still significantly larger than three for all the four countries. Despite the Jarque-Bera normality test rejects the null hypothesis of normally distributed standardized residuals for all the returns series, all the coefficients for skewness and kurtosis are smaller than those of the raw returns. Moreover, the autocorrelation functions of the standardized residuals reported in Panel B show that the GARCH(1, 1) model has absorbed the dependence in the autocorrelations of the residuals. Panels C and D display the Ljung-Box Q statistics for the standardized residuals and squared standardized residuals at the 4th, 8th, 12th, 16th, 20th, 24th day lags. For Hong Kong, Singapore, and Australia, nearly all the Q-statistics are insignificant. Also there is no autocorrelation in the standardized residuals and squared standardized residuals of these four countries. However, for Japan, some of the squared standardized residuals are significant. The GARCH(1, 1) model therefore appears to provide a good parameterization of the REIT returns series except in the case of Japan.

Given that we find the conditional variance of REIT returns in the Pacific region affected by volatility transmission within the region, the next question is whether there is an asymmetry in the volatility transmission mechanism between positive and negative news shocks. In Table IV, we report results of the multivariate EGARCH specification. Similar to the results of the GARCH(1, 1) model, we find strong evidence of international transmission of volatility of REIT returns within the Pacific region. Specifically, there are significant volatility spillovers from Hong Kong to Australia (α_{13} equals 0.0075 and is significant at 5 per cent), from Japan to Singapore (α_{24} equals 0.0060 and is significant at 5 per cent), and from Singapore to Hong Kong (α_{32} equals 0.0078 and is significant at 5 per cent). The spillovers from Hong Kong to Australia are asymmetric since the coefficient measuring asymmetry for the Hong Kong market is significant. That is, negative news shocks from Hong Kong have larger impacts than positive news shocks. On the other hand, the spillovers from Japan to Singapore and

From Aus ($\alpha_{4,1}$), Sing ($\alpha_{4,2}$), HK ($\alpha_{4,3}$) to JP		From Aus ($\alpha_{3,1}$), Sing ($\alpha_{3,2}$), JP ($\alpha_{3,4}$) to HK		From Aus ($\alpha_{2,1}$), HK ($\alpha_{2,3}$), JP ($\alpha_{2,4}$) to Sing		From Sing ($\alpha_{1,2}$), HK ($\alpha_{1,3}$), JP ($\alpha_{1,4}$) to Aus	
$\beta_{4,0}$	0.0088	$\beta_{3,0}$	−0.0262	$\beta_{2,0}$	−0.0494	$\beta_{1,0}$	0.0539
	(0.0668)		(0.0531)		(0.0580)		(0.0283)*
$\beta_{4,1}$	0.0527	$\beta_{3,1}$	0.1148	$\beta_{2,1}$	0.0447	$\beta_{1,1}$	0.0142
	(0.0310)**		(0.0322)***		(0.0351)		(0.0322)
$\alpha_{4,0}$	1.5261	$\alpha_{3,0}$	0.0541	$\alpha_{2,0}$	−0.0434	$\alpha_{1,0}$	−0.1332
	(0.7521)*		(0.0696)		(0.0391)		(0.0357)***
$\alpha_{4,1}$	0.0234	$\alpha_{3,1}$	0.0106	$\alpha_{2,1}$	0.0197	$\alpha_{1,1}$	0.1345
	(0.0240)		(0.0278)		(0.0130)		(0.0377)***
$\alpha_{4,2}$	−0.0079	$\alpha_{3,2}$	0.0078	$\alpha_{2,2}$	0.1215	$\alpha_{1,2}$	−0.0001
	(0.0058)		(0.0035)*		(0.0533)*		(0.0023)
$\alpha_{4,3}$	0.0050	$\alpha_{3,3}$	0.1301	$\alpha_{2,3}$	0.0033	$\alpha_{1,3}$	0.0075
	(0.0071)		(0.0449)***		(0.0043)		(0.0031)*
$\alpha_{4,4}$	−0.0054	$\alpha_{3,4}$	0.0031	$\alpha_{2,4}$	0.0060	$\alpha_{1,4}$	−0.0017
	(0.0886)		(0.0035)		(0.0032)*		(0.0024)
δ_4	0.0820	δ_3	−0.0678	δ_2	0.0048	δ_1	−0.0608
	(0.0504)		(0.0387)*		(0.0289)		(0.0241)***
γ_4	0.0040	γ_3	0.8138	γ_2	0.9218	γ_1	0.9176
	(0.482)		(0.0776)***		(0.0321)***		(0.0276)***

Notes: ***Significant at 1 per cent; **significant at 5 per cent; *significant at 10 per cent

Table IV.
Multivariate EGARCH model: volatility spillovers in the Pacific region

from Singapore to Hong Kong are symmetric in nature. Negative and positive news shocks have the same effects in terms of volatility transmission. The persistence of volatility, as measured by γ, is strongest for Singapore and weakest for Japan.

Table V provides several diagnostic tests results of the standardized residuals obtained from the multivariate EGARCH model. Compared with the multivariate GARCH(1, 1) model estimation, the results are consistent and similar. All the coefficients for skewness and kurtosis are smaller than those of the raw returns. Autocorrelations of the standardized residuals have also been absorbed by the EGARCH model, according to diagnostic results in Panels B, C, and D. The EGARCH specification performs better for Australia, Hong Kong, and Singapore than for Japan.

In Table VI, we report results of the multivariate GARCH-M model in determining if conditional variance of REIT returns is affected by volatility transmission across markets in the Pacific region. Consistent with the results of the GARCH(1, 1) and the EGARCH specifications, results of the GARCH-M specification also show significant volatility transmission across markets in the region. Results in Table VI show that

	JP	HK	Sing	Aus
Panel A: diagnostic tests				
Skewness	0.265	0.160	0.320	−0.0852
Kurtosis	3.935	4.633	4.133	3.863
Jarque-Bera	49.894	119.736	73.235	33.451
Probability	0.0000*	0.0000*	0.0000*	0.0000*
Lag				
Panel B: autocorrelation functions for standardized residuals				
4	0.002	0.003	0.039	−0.025
8	0.006	0.016	0.048	−0.003
12	0.037	−0.029	−0.004	0.049
16	0.034	−0.007	0.003	−0.015
20	0.050	0.005	−0.001	0.018
24	−0.024	0.058	−0.033	−0.047
Lag				
Panel C: autocorrelation Q-statistics for standardized residuals				
4	8.098	3.076	2.348	1.259
8	9.109	7.392	7.676	3.924
12	12.417	9.102	11.133	9.354
16	18.899	11.195	14.187	13.062
20	21.665	13.283	14.415	15.793
24	25.794	25.503	22.705	19.686
Lag				
Panel D: autocorrelation Q-statistics for standardized residuals squared				
4	1.496	7.444	5.839	7.730
8	13.514	9.196	6.844	16.929
12	27.613*	11.949	8.183	18.418
16	34.908*	16.810	12.734	21.502
20	39.264*	18.373	15.176	31.242
24	46.971*	41.152**	17.494	35.504

Notes: ***Significant at 1 per cent; **significant at 5 per cent; *significant at 10 per cent

Table V. Descriptive statistics for the standardized residuals for the multivariate EGARCH model (the Pacific region only)

Table VI. Multivariate GARCH-M model: volatility spillovers in the Pacific region

From Aus ($\alpha_{4,1}$), Sing ($\alpha_{4,2}$), HK ($\alpha_{4,3}$) to JP		From Aus ($\alpha_{3,1}$), Sing ($\alpha_{3,2}$), JP ($\alpha_{3,4}$) to HK		From Aus ($\alpha_{2,1}$), HK ($\alpha_{2,3}$), JP ($\alpha_{2,4}$) to Sing		From Sing ($\alpha_{1,2}$), HK ($\alpha_{1,3}$), JP ($\alpha_{1,4}$) to Aus	
$\beta_{4,0}$	−1.0061 (0.5872)*	$\beta_{3,0}$	−0.1013 (0.2264)	$\beta_{2,0}$	0.1165 (0.2456)	$\beta_{1,0}$	0.0385 (0.0358)
$\beta_{4,1}$	0.0537 (0.0314)*	$\beta_{3,1}$	0.1187 (0.0333)**	$\beta_{2,1}$	0.0458 (0.0352)	$\beta_{1,1}$	0.0020 (0.0323)
$\beta_{4,2}$	0.6826 (0.3935)*	$\beta_{3,2}$	0.0931 (0.2102)	$\beta_{2,2}$	−0.1133 (0.1889)	$\beta_{1,2}$	−0.1176 (0.0872)
$\alpha_{4,0}$	0.3015 (0.1496)*	$\alpha_{3,0}$	0.4576 (0.2200)***	$\alpha_{2,0}$	0.0699 (0.0824)	$\alpha_{1,0}$	0.0256 (0.0146)*
$\alpha_{4,1}$	−0.0609 (0.0405)	$\alpha_{3,1}$	0.0935 (0.1278)	$\alpha_{2,1}$	0.0852 (0.0530)	$\alpha_{1,1}$	0.0568 (0.0161)**
$\alpha_{4,2}$	−0.0076 (0.0091)	$\alpha_{3,2}$	0.0519 (0.0298)***	$\alpha_{2,2}$	0.0450 (0.0227)***	$\alpha_{1,2}$	0.0009 (0.0021)
$\alpha_{4,3}$	0.0205 (0.0186)	$\alpha_{3,3}$	0.0511 (0.0243)***	$\alpha_{2,3}$	0.0186 (0.0187)	$\alpha_{1,3}$	0.0003 (0.0028)
$\alpha_{4,4}$	0.0328 (0.0136)***	$\alpha_{3,4}$	0.0151 (0.0143)	$\alpha_{2,4}$	0.0222 (0.0118)***	$\alpha_{1,4}$	−0.0005 (0.0012)
γ_4	0.9062 (0.0378)**	γ_3	0.6935 (0.1108)**	γ_2	0.8799 (0.0384)**	γ_1	0.9123 (0.0247)**

Notes:

$$R_{i,t} = \beta_{i,0} + \beta_{i,1} R_{i,t-1} + \beta_{i,2} \log(\sigma^2_{i,t}) + \varepsilon_{i,t}$$

$$\sigma^2_{i,t} = \alpha_{i,0} + \sum_{j=1}^{4} \alpha_{i,j} \varepsilon^2_{j,t-1} + \gamma_i \sigma^2_{i,t-1} \text{ for } i,\ j = 1,\ 2,\ 3, 4$$

Australia is 1, Singapore is 2, Hong Kong is 3, Japan is 4. ***Significant at 1 per cent; **significant at 5 per cent; *significant at 10 per cent

there are significant volatility spillovers from Singapore to Hong Kong (α_{32} equals 0.0519 and is significant at 5 per cent), and from Japan to Singapore (α_{24} equals 0.0222 and is significant at 5 per cent). Hong Kong and Australia have no impact on other countries other than their own past volatilities.

Diagnostic tests results in Table VII show that the GARCH-M model perform better than the GARCH(1, 1) and the EGARCH specifications. All the coefficients for skewness and kurtosis of residuals are relatively smaller, and even the autocorrelations for the squared residuals of the Japan REIT series are all insignificant.

Next we report the estimation results for volatility transmission between the Pacific and the Atlantic regions. We want to determine if geographic risk factors can exert an influence outside their region. Given that the Atlantic and the Pacific stock markets open and close sequentially, the estimations are performed with the difference in trading hours taken into consideration. In Table VIII, from the GARCH model, there are significant volatility spillovers between the Atlantic and the Pacific regions. The volatility spillovers basically come from USA rather than UK. Specifically, we observed spillovers from USA to Australia (α_{15} equals −0.0126 and is significant at 5 per cent), Singapore (α_{25} equals 0.3374 and is significant at 5 per cent), Hong Kong (α_{35} equals 0.5921 and is significant at 1 per cent), and Japan (α_{45} equals −0.2236 and is significant

	JP	HK	Sing	Aus
Panel A: diagnostic tests				
Skewness	0.289	0.142	0.311	−0.096
Kurtosis	3.818	4.678	4.165	3.801
Jarque-Bera	42.724	125.25	77.628	29.359
Probability	0.0000*	0.0000*	0.0000*	0.0000*
Lag				
Panel B: autocorrelation functions for standardized residuals				
4	0.027	0.002	0.042	−0.025
8	0.005	0.012	0.046	−0.006
12	0.032	−0.024	−0.007	0.045
16	0.034	−0.009	0.002	−0.027
20	0.045	0.004	0.000	0.019
24	−0.026	0.050	−0.031	−0.048
Lag				
Panel C: autocorrelation Q-statistics for standardized residuals				
4	5.455	2.480	2.612	0.864
8	6.598	7.317	8.134	3.735
12	10.605	8.331	11.552	8.975
16	17.646	10.846	14.183	12.182
20	19.833	12.520	14.373	15.014
24	24.028	24.662	23.036	19.212
Lag				
Panel D: autocorrelation Q-statistics for standardized residuals squared				
4	3.601	8.976	5.313	6.415
8	6.115	10.951	6.714	11.581
12	13.895	13.844	8.041	13.465
16	18.009	18.390	13.161	16.338
20	20.083	19.816	14.795	24.918
24	28.058	39.764**	16.703	28.912

Notes: ***Significant at 1 per cent; **significant at 5 per cent; *significant at 10 per cent

Table VII. Descriptive statistics for the standardized residuals for the GARCH-M model (the Pacific region only)

at 1 per cent). However, there is no spillover from UK to the Pacific region. On the other hand, the spillovers from the Pacific region appear to land in UK rather than in USA. That is, USA appears to be an emitter of volatility whereas UK a recipient of volatility in the exchange between the Atlantic and the Pacific. Results of the EGARCH model are similar. In Table IX, we find strong evidence of international transmission of volatility of REIT returns between the Atlantic and the Pacific. Specifically, there are significant volatility spillovers from USA to Singapore (α_{25} equals 0.0603 and is significant at 1 per cent) and Hong Kong (α_{35} equals 0.0548 and is significant at 1 per cent); from Japan to Singapore (α_{24} equals 0.0139 and is significant at 5 per cent) and UK (α_{64} equals 0.0076 and is significant at 10 per cent); from Singapore to Hong Kong (α_{32} equals 0.0009 and is significant at 5 per cent) and UK (α_{62} equals 0.0106 and is significant at 1 per cent); from Australia to USA (α_{51} equals 0.0598 and is significant at 1 per cent) and UK (α_{61} equals 0.0697 and is significant at 1 per cent), and from Hong Kong to Australia (α_{13} equals 0.0067 and is significant at 10 per cent). The spillover

Table VIII. Multivariate GARCH (1, 1) model: volatility spillovers between the Atlantic and the Pacific regions

From Aus ($\alpha_{4,1}$), Sing ($\alpha_{4,2}$), HK ($\alpha_{4,3}$), USA ($\alpha_{4,5}$), UK ($\alpha_{4,6}$) to JP		From Aus ($\alpha_{3,1}$), Sing ($\alpha_{3,2}$), JP ($\alpha_{3,4}$), USA ($\alpha_{3,5}$), UK ($\alpha_{3,6}$) to HK		From Aus ($\alpha_{2,1}$), HK ($\alpha_{2,3}$), JP ($\alpha_{2,4}$), USA ($\alpha_{2,5}$), UK ($\alpha_{2,6}$) to Sing		From Sing ($\alpha_{1,2}$), HK ($\alpha_{1,3}$), JP ($\alpha_{1,4}$), USA ($\alpha_{1,5}$), UK ($\alpha_{1,6}$) to Aus		From Aus ($\alpha_{5,1}$), Sing ($\alpha_{5,2}$), HK ($\alpha_{5,3}$), JP ($\alpha_{5,4}$), UK ($\alpha_{5,6}$) to US		From Aus ($\alpha_{6,1}$), Sing ($\alpha_{6,2}$), HK ($\alpha_{6,3}$), JP ($\alpha_{6,4}$), USA ($\alpha_{6,5}$) to UK	
$\beta_{4,0}$	0.0383	$\beta_{3,0}$	−0.0204	$\beta_{2,0}$	−0.0158	$\beta_{1,0}$	0.0814	$\beta_{5,0}$	0.0665	$\beta_{6,0}$	0.0623
	(0.1645)		(0.0535)		(0.0607)		(0.0287)*		(0.0396		(0.0257)*
$\beta_{4,1}$	0.0608	$\beta_{3,1}$	0.1077	$\beta_{2,1}$	0.0468	$\beta_{1,1}$	0.0007	$\beta_{5,1}$	0.1349	$\beta_{6,1}$	0.09136
	(0.0395)**		(0.0327)***		(0.0362)		(0.0339)		(0.0738)*		(0.0353)***
$\alpha_{4,0}$	4.3229	$\alpha_{3,0}$	0.8700	$\alpha_{2,0}$	0.7631	$\alpha_{1,0}$	0.0374	$\alpha_{5,0}$	0.4769	$\alpha_{6,0}$	0.1089
	(1.6677)		(0.3090)*		(0.3035)*		(0.0172)*		(0.02422)*		(0.0438)*
$\alpha_{4,1}$	−0.2259	$\alpha_{3,1}$	−0.0410	$\alpha_{2,1}$	−0.0219	$\alpha_{1,1}$	0.0549	$\alpha_{5,1}$	−0.0029	$\alpha_{6,1}$	0.0893
	(0.0751)***		(0.0774)		(0.0835)		(0.0176)***		(0.1150)		(0.0324)***
$\alpha_{4,2}$	−0.0312	$\alpha_{3,2}$	0.0634	$\alpha_{2,2}$	0.1084	$\alpha_{1,2}$	0.0008	$\alpha_{5,2}$	−0.0048	$\alpha_{6,2}$	0.0139
	(0.0264)		(0.0297)*		(0.0474)***		(0.0021)		(0.0082)		(0.0059)*
$\alpha_{4,3}$	−0.0525	$\alpha_{3,3}$	0.0119	$\alpha_{2,3}$	0.0005	$\alpha_{1,3}$	0.0140	$\alpha_{5,3}$	−0.0026	$\alpha_{6,3}$	−0.0078
	(0.0372)		(0.0302)*		(0.0322)		(0.0098)		(0.0152)		(0.0043)*
$\alpha_{4,4}$	0.0834	$\alpha_{3,4}$	0.0471	$\alpha_{2,4}$	0.0698	$\alpha_{1,4}$	−0.0018	$\alpha_{5,4}$	−0.0086	$\alpha_{6,4}$	0.0051
	(0.0371)*		(0.0228)*		(0.0379)*		(0.0013)		(0.0072)		(0.0040)
$\alpha_{4,5}$	−0.2236	$\alpha_{3,5}$	0.5921	$\alpha_{2,5}$	0.3374	$\alpha_{1,5}$	−0.0126	$\alpha_{5,5}$	0.1112	$\alpha_{6,5}$	0.0163
	(0.0902)***		(0.2492)***		(0.1785)*		(0.0069)*		(0.0598)*		(0.0216)
$\alpha_{4,6}$	−0.0894	$\alpha_{3,6}$	0.0245	$\alpha_{2,6}$	0.0585	$\alpha_{1,6}$	0.0140	$\alpha_{5,6}$	−0.0268	$\alpha_{6,6}$	0.1896
	(0.1551)		(0.0634)		(0.0903)		(0.0098)		(0.0187)		(0.0557)***
γ_4	0.5690	γ_3	0.4677	γ_2	0.5812	γ_1	0.8991	γ_5	0.5314	γ_6	0.5116
	(0.1848)***		(0.1395)***		(0.1095)***		(0.0294)***		(0.2050)***		(0.1015)***

Notes:

$$R_{i,t} = \beta_{i,0} + \beta_{i,1} R_{i,t-1} + \varepsilon_{i,t}$$

$$\sigma^2_{i,t} = \alpha_{i,0} + \sum_{j=1}^{6} \alpha_{i,j} \varepsilon^2_{j,t-1} + \gamma_i \sigma^2_{i,t-1} \quad \text{for } i,j = 1,\ 2,\ 3,\ 4,\ 5,\ 6$$

Australia is 1, Singapore is 2, Hong Kong is 3, Japan is 4, USA is 5, UK is 6. ***Significant at 1 per cent; **significant at 5 per cent; *significant at 10 per cent

Table IX. Multivariate EGARCH model with volatility spillovers between the Atlantic and the Pacific regions

From Aus ($\alpha_{4,1}$), Sing ($\alpha_{4,2}$), HK ($\alpha_{4,3}$), USA ($\alpha_{4,5}$), UK ($\alpha_{4,6}$) to JP		From Aus ($\alpha_{3,1}$), Sing ($\alpha_{3,2}$), JP ($\alpha_{3,4}$), USA ($\alpha_{3,5}$), UK ($\alpha_{3,6}$) to HK		From Aus ($\alpha_{2,1}$), HK ($\alpha_{2,3}$), JP ($\alpha_{2,4}$), USA ($\alpha_{2,5}$), UK ($\alpha_{2,6}$) to Sing		From Sing ($\alpha_{1,2}$), HK ($\alpha_{1,3}$), JP ($\alpha_{1,4}$), USA ($\alpha_{1,5}$), UK ($\alpha_{1,6}$) to Aus		From Aus ($\alpha_{5,1}$), Sing ($\alpha_{5,2}$), HK ($\alpha_{5,3}$), JP ($\alpha_{5,4}$), UK ($\alpha_{5,6}$) to USA		From Aus ($\alpha_{6,1}$), Sing ($\alpha_{6,2}$), HK ($\alpha_{6,3}$), JP ($\alpha_{6,4}$), USA ($\alpha_{6,5}$) to UK	
$\beta_{4,0}$	0.0343 (0.0680)	$\beta_{3,0}$	−0.0339 (0.0527)	$\beta_{2,0}$	−0.0163 (0.05978)	$\beta_{1,0}$	0.0677 (0.0291)*	$\beta_{5,0}$	0.0693 (0.0202)***	$\beta_{6,0}$	0.0655 (0.0258)*
$\beta_{4,1}$	0.0499 (0.0316)**	$\beta_{3,1}$	0.1117 (0.0324)***	$\beta_{2,1}$	0.0502 (0.0364)	$\beta_{1,1}$	0.0048 (0.0343)	$\beta_{5,1}$	0.0841 (0.0365)*	$\beta_{6,1}$	0.0929 (0.0357)***
$\alpha_{4,0}$	1.2653 (0.5565)*	$\alpha_{3,0}$	0.0806 (0.0760)	$\alpha_{2,0}$	0.1791 (0.1346)	$\alpha_{1,0}$	−0.1373 (0.0426)***	$\alpha_{5,0}$	−0.4391 (0.0807)***	$\alpha_{6,0}$	−0.4347 (0.092)***
$\alpha_{4,1}$	0.0158 (0.0243)	$\alpha_{3,1}$	−0.0101 (0.0244)	$\alpha_{2,1}$	−0.0047 (0.0217)	$\alpha_{1,1}$	0.1346 (0.0462)***	$\alpha_{5,1}$	0.0598 (0.0214)***	$\alpha_{6,1}$	0.0697 (0.0245)***
$\alpha_{4,2}$	−0.0067 (0.0052)	$\alpha_{3,2}$	0.0009 (0.0004)*	$\alpha_{2,2}$	0.2409 (0.0874)***	$\alpha_{1,2}$	−0.0002 (0.0023)	$\alpha_{5,2}$	0.0005 (0.0034)	$\alpha_{6,2}$	0.0106 (0.0042)***
$\alpha_{4,3}$	0.0006 (0.0087)	$\alpha_{3,3}$	0.1325 (0.0539)*	$\alpha_{2,3}$	−0.0022 (0.0069)	$\alpha_{1,3}$	0.0067 (0.0040)**	$\alpha_{5,3}$	0.0004 (0.0063)	$\alpha_{6,3}$	−0.0085 (0.0078)
$\alpha_{4,4}$	−0.0171 (0.0900)	$\alpha_{3,4}$	0.0046 (0.0037)	$\alpha_{2,4}$	0.0139 (0.0067)*	$\alpha_{1,4}$	−0.0021 (0.0026)	$\alpha_{5,4}$	0.0026 (0.0042)	$\alpha_{6,4}$	0.0076 (0.0048)**
$\alpha_{4,5}$	−0.0283 (0.0367)	$\alpha_{3,5}$	0.0548 (0.0217)***	$\alpha_{2,5}$	0.0603 (0.0254)***	$\alpha_{1,5}$	−0.0102 (0.0127)	$\alpha_{5,5}$	0.3098 (0.0633)***	$\alpha_{6,5}$	0.0217 (0.0207)
$\alpha_{4,6}$	0.0122 (0.0423)	$\alpha_{3,6}$	0.0013 (0.0142)	$\alpha_{2,6}$	0.0342 (0.0233)	$\alpha_{1,6}$	0.0173 (0.0114)	$\alpha_{5,6}$	0.0157 (0.0117)	$\alpha_{6,6}$	0.3038 (0.0763)***
δ_4	0.0811 (0.0612)	δ_3	−0.0526 (0.0384)	δ_2	0.0761 (0.0441)	δ_1	−0.0636 (0.0275)*	δ_5	−0.0453 (0.0418)	δ_6	−0.0180 (0.0547)
γ_4	0.1944 (0.3562)	γ_3	0.7624 (0.0922)***	γ_2	0.6495 (0.1013)***	γ_1	0.9065 (0.0343)***	γ_5	0.8541 (0.0369)***	γ_6	0.7467 (0.0718)***

Notes: ***Significant at 1 per cent; **significant at 5 per cent; *significant at 10 per cent

Table X. Multivariate GARCH-M model: volatility spillovers between the Atlantic and the Pacific regions

From Aus ($\alpha_{4,1}$), Sing ($\alpha_{4,2}$), HK ($\alpha_{4,3}$), USA ($\alpha_{4,5}$), UK ($\alpha_{4,6}$) to JP		From Aus ($\alpha_{3,1}$), Sing ($\alpha_{3,2}$), JP ($\alpha_{3,4}$), USA ($\alpha_{3,5}$), UK ($\alpha_{3,6}$) to HK		From Aus ($\alpha_{2,1}$), HK ($\alpha_{2,3}$), JP ($\alpha_{2,4}$), USA ($\alpha_{2,5}$), UK ($\alpha_{2,6}$) to Sing		From Sing ($\alpha_{1,2}$), HK ($\alpha_{1,3}$), JP ($\alpha_{1,4}$), USA ($\alpha_{1,5}$), UK ($\alpha_{1,6}$) to Aus		From Aus ($\alpha_{5,1}$), Sing ($\alpha_{5,2}$), HK ($\alpha_{5,3}$), JP($\alpha_{5,4}$), UK ($\alpha_{5,6}$) to USA		From Aus ($\alpha_{6,1}$), Sing ($\alpha_{6,2}$), HK ($\alpha_{6,3}$), JP ($\alpha_{6,4}$), USA ($\alpha_{6,5}$) to UK	
$\beta_{4,0}$	−1.1963	$\beta_{3,0}$	−0.4626	$\beta_{2,0}$	−0.0221	$\beta_{1,0}$	0.0556	$\beta_{5,0}$	0.0609	$\beta_{6,0}$	0.0432
	(0.5879)*		(0.1948)*		(0.2772)		(0.0360)		(0.0522)		(0.0369)
$\beta_{4,1}$	0.0566	$\beta_{3,1}$	0.1085	$\beta_{2,1}$	0.0499	$\beta_{1,1}$	−0.0021	$\beta_{5,1}$	0.0985	$\beta_{6,1}$	0.0904
	(0.0317)**		(0.0332)***		(0.0365)		(0.0338)		(0.0342)***		(0.0355)***
$\beta_{4,2}$	0.8255	$\beta_{3,2}$	0.4276	$\beta_{2,2}$	0.0042	$\beta_{1,2}$	−0.0960	$\beta_{5,2}$	−0.0189	$\beta_{6,2}$	−0.0378
	(0.3941)*		(0.1857)*		(0.2098)		(0.0839)		(0.0545)		(0.0558)
$\alpha_{4,0}$	0.2545	$\alpha_{3,0}$	0.9166	$\alpha_{2,0}$	0.7055	$\alpha_{1,0}$	0.0348	$\alpha_{5,0}$	0.0401	$\alpha_{6,0}$	0.1089
	(0.1268)		(0.2986)*		(0.2940)*		(0.0155)*		(0.0267)		(0.0431)*
$\alpha_{4,1}$	−0.0602	$\alpha_{3,1}$	−0.0424	$\alpha_{2,1}$	−0.0032	$\alpha_{1,1}$	0.0537	$\alpha_{5,1}$	0.0307	$\alpha_{6,1}$	0.0882
	(0.0349)*		(0.0614)		(0.0868)		(0.0168)***		(0.0141)*		(0.0322)***
$\alpha_{4,2}$	−0.0062	$\alpha_{3,2}$	0.0728	$\alpha_{2,2}$	0.1049	$\alpha_{1,2}$	0.0011	$\alpha_{5,2}$	0.0004	$\alpha_{6,2}$	0.01456
	(0.0064)		(0.0308)***		(0.0469)*		(0.0021)		(0.0020)		(0.0059)*
$\alpha_{4,3}$	0.0177	$\alpha_{3,3}$	0.0403	$\alpha_{2,3}$	−0.0017	$\alpha_{1,3}$	0.0006	$\alpha_{5,3}$	0.0022	$\alpha_{6,3}$	−0.0084
	(0.0182)		(0.0373)*		(0.0313)		(0.0025)		(0.0034)		(0.0042)*
$\alpha_{4,4}$	0.0299	$\alpha_{3,4}$	0.0412	$\alpha_{2,4}$	0.0672	$\alpha_{1,4}$	−0.0016	$\alpha_{5,4}$	0.0005	$\alpha_{6,4}$	0.0047
	(0.0126)*		(0.0220)*		(0.0372)*		(0.0011)		(0.0019)		(0.0039)
$\alpha_{4,5}$	−0.0318	$\alpha_{3,5}$	0.7145	$\alpha_{2,5}$	0.3225	$\alpha_{1,5}$	−0.0125	$\alpha_{5,5}$	0.1665	$\alpha_{6,5}$	0.0149
	(0.0317)		(0.2498)***		(0.1722)*		(0.0066)*		(0.0437)*		(0.0208)
$\alpha_{4,6}$	0.0327	$\alpha_{3,6}$	−0.0025	$\alpha_{2,6}$	0.0585	$\alpha_{1,6}$	0.0119	$\alpha_{5,6}$	0.0109	$\alpha_{6,6}$	0.1892
	(0.0426)		(0.0534)		(0.0889)		(0.0090)		(0.0086)		(0.0549)***
γ_4	0.9179	γ_3	0.4161	γ_2	0.6010	γ_1	0.9061	γ_5	0.6647	γ_6	0.5152
	(0.0314)***		(0.1277)***		(0.1089)***		(0.0265)***		(0.0572)***		(0.0995)***

Notes:

$$R_{i,t} = \beta_{i,0} + \beta_{i,1}R_{i,t-1} + \beta_{i,2}\log\left(\sigma^2_{i,t}\right) + \varepsilon_{i,t}$$

$$\sigma^2_{i,t} = \alpha_{i,0} + \sum_{j=1}^{6}\alpha_{i,j}\varepsilon^2_{j,t-1} + \gamma_i\sigma^2_{i,t-1} \quad \text{for } i,j = 1, 2, 3, \ldots, 6$$

***Significant at 1 per cent; **significant at 5 per cent; *significant at 10 per cent effect is asymmetric for Australia. It implies that negative innovations in the Australian market have a higher impact on the volatilities of USA and UK than positive innovations. On the other hand, no asymmetry is found for Japan, Singapore, Hon Kong, USA and UK. In Table X, we report results of the multivariate GARCH-M model. Consistent with the GARCH(1, 1) and the EGARCH estimation results, it is found that the conditional variance of REIT returns is affected by volatility spillovers between the Atlantic and the Pacific regions. In addition to the volatility transmissions within the Pacific region, the results show significant volatility spillovers from USA to the Pacific markets. Specifically, there are spillovers from USA to Hong Kong (α_{35} equals 0.7145 and is significant at 1 per cent), Singapore (α_{25} equals 0.3225 and is significant at 5 per cent), and Australia (α_{15} equals -0.0125 and is significant at 5 per cent). The results do not show any spillover from UK to the Pacific region. Similar to the GARCH(1, 1) and the EGARCH results, the spillovers from the Pacific region affect mostly UK rather than USA. That is, USA appears to be an emitter of volatility whereas UK a recipient of volatility in the exchange between the Atlantic and the Pacific[4]. Existing literature on international transmission of stock price volatility has yet to come up with a successful explanation regarding the cause of the transmission. At the moment, one can only conjecture that USA is an emitter of volatility because of its more significant influence due to its relatively large market size.

Conclusion

To date, there is no published study on the international transmission of REIT returns volatility. This study therefore examines if the conditional variance of REIT returns of a country is affected by volatility transmission across markets in the same region using four Pacific markets. In addition, the study also examines if the volatility of REIT returns can be transmitted between the Pacific (Australia, Hong Kong, Japan, and Singapore) and the Atlantic (USA and UK) regions. After evaluating the statistical properties of the time series data of the REIT returns, we use the GARCH(1, 1), EGARCH, and GARCH-M models in the study. The results show that there are significant international spillovers of REIT returns volatility within the Pacific region. In some cases, the volatility transmissions are asymmetric. The results also show that there are significant volatility transmissions between the Pacific and the Atlantic regions. In the transmission process, USA play the role of an emitter of volatility whereas UK is primarily a recipient of volatility. The results are consistent with the implication that the real estate sector and the general equity market are integrated such that geographic risk can be transmitted across national borders.

Notes

1. The included companies are required to have the majority of their incomes generated from domestic real estate-related assets. Such a requirement ensures no significant cross-correlations of the cash flows of the REIT of different countries.
2. According to the National Association of Real Estate Investment Trusts, the NAREITs series are designed to track the performance of listed real estate companies and REITs worldwide. The composition of each series may differ slightly. For example, firms involved in the construction of residential homes for sale are excluded from the USA series but permitted for the Asia series. As such, the USA series is basically composed

of REITs whereas the Asia series may have non-REIT constituents. (Please refer to the NAREIT website for details.)

3. The various models are estimated using EViews, a software specifically used for econometric applications.
4. Unreported diagnostic tests show the GARCH(1, 1), EGARCH, and GARCH-M models reported in Tables VIII-X are adequately specified. They are available upon request.

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Further reading

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