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ORIGINAL PAPER

A multivariate analysis of United States and global real estate investment trusts

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Abstract Using daily data for the period February 2006 to July 2013 we examine the return and volatility linkages between the two main United States REIT sub-sectors and global linkages between the Americas, Europe and the Asia Pacific regions using the BEKK-GARCH and the DCC-GARCH models. We find that there is no evidence of any volatility spillovers between the US sub-sectors. By contrast, we find evidence of volatility spillovers between the Asia Pacific and the Americas, the Asia Pacific and Europe but no spillovers between the United States and Europe. Our results suggest that the REIT market is becoming increasingly globalized and that investors need to consider time varying volatility and correlations across different regions of the world when forming their optimal portfolio-allocations.

Keywords Real estate investment trusts · Volatility spillover · GARCH · BEKK · DCC

JEL classifications G14 · G32

1 Introduction

Volatility and correlations of asset returns are significant inputs in the calculation of risk in modern portfolio theories and in the analysis of risk management, strategic financial planning and asset allocation. This paper is one of the first to look at the issue of the globalization of the real estate investment trusts (REITs) market by comparing the volatility interactions in the form of co-movements and spillovers between USA subsectors with that between the Americas, Europe and Asia Pacific regions using

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daily returns. The increasing globalization of finance and the greater correlation of financial markets as shown in studies such as Morana and Beltratti (2008), Rua and Nunes (2009), and Soares da Fonseca (2013) raises the question as to whether a similar globalization process is taking place with respect to the global property market. As such, our examination of the performance of REITS in three key regions of the world has potentially important lessons for investors making investment decision and policy makers concerned about the importance of globalization forces in determining property price fluctuations and returns.

While a number of papers such as Devaney (2001), Stevenson (2002), Asteriou and Begiazi (2013) and Chang and Chen (2014) have examined REITs volatility linkages they have utilized univariate models. This paper extends the analysis of volatility by using a multivariate GARCH (M-GARCH) framework. M-GARCH models are ideal for modeling volatility transmission and understanding the comovements of financial returns. For example Mondal (2013) used a bivariate GARCH model to test volatility spillover among RBI'S intervention and exchange rate. The most obvious application of M-GARCH models is the study of the relations between the volatilities of several markets. It is now widely accepted that financial volatilities move together over time across assets and markets. On the other hand, univariate models are unable to show volatility and correlation transmission, so multivariate modelling leads to more relevant empirical models and facilitates better decisions.

M-GARCH models were initially developed in the late 1980s and the first half of the 1990s, and after a period of tranquility in the second half of the 1990s, this approach is experiencing a revival. In recent research, Bauwens et al. (2006) mention that the crucial point in M-GARCH modelling is to provide a realistic but parsimonious specification of the variance matrix ensuring its positivity.

The two most widely used models of conditional covariances and correlations are the BEKK and the Dynamic Conditional Correlation (DCC) models, developed by Engle and Kroner (1995) and Engle (2002), respectively. The BEKK model can be used for conditional covariances and the DCC for conditional correlations. The purpose of this study is to apply these two popular M-GARCH models to daily REITs return series covering both the crisis and recovery periods. Firstly, we consider volatility spillover modeling by using the bivariate BEKK-GARCH specification. The BEKK specification enables us to study the possible transmission of volatility from one market to another, as well as any increased persistence in market volatility Engle et al. (1990). The next step is to apply the DCC specification to the same time series pairs so as to analyze the conditional correlations.

2 Literature review

The early literature on REITS examined the return and volatility of REITS and correlations with domestic stock indices and interest rates. Devaney (2001) examines the relationship between REIT volatility and interest rates using monthly REIT data. The study concludes that the trade-off between excess returns and the conditional variance is positive for both equity and mortgage REITs but it was significant only for the latter. The study also found that changes in interest rates and their conditional variance were negatively related to REITs excess returns. In terms of returns, He (1998) and Lee and Chiang (2004), find evidence to support the existence of commonality between US equity and mortgage REITs. These results are disputed by Cotter and Stevenson (2006) using monthly returns and the multivariate VAR-GARCH technique on REIT sub-sectors who find that the influence of various US equity series and the correlations are weak.[1] There is a growing literature examining the relationship between REITs sector and broader equity market indices such as Subrahmanyam (2007) who finds that stock market returns are negatively related to REIT order flows and that the real estate market is a substitute for investments in the stock market.

When it comes to global REITs there has been a limited but growing literature focusing on correlations in returns but next to nothing on correlations between volatilities of returns. Bond et al. (2003) examine the risk and return characteristics of publicly traded real estate companies for 14 countries for the period 1990–2001 using monthly data and find substantial variation in mean returns and standard deviations. They also detect evidence of a strong global market risk component using the MSCI world index. Yunus and Swanson (2007) examine the short run and long run relationships between the Asia Pacific region (Australia, Hong Kong, Japan and Singapore) and the US for the period January 2000 to March 2006. Their short run causality tests show no evidence of significant lead-lag relationships suggesting the potential for significant benefits from international portfolio diversification. They find that from a long run perspective Hong Kong and Japan provide the best diversification benefits.

Liow et al. (2009) examine correlation and volatility dynamics of publicly traded real estate securities using monthly data for the period 1986–2006. They find that correlations between real estate security returns are lower than those between stock markets. They also detect significant positive connections between real estate securities market correlations and their conditional volatilities and that the international correlation structure of real estate securities and stock markets are linked to each other. In a recent paper Chang and Chen (2014) look for evidence of contagion using daily REITs for 16 countries covering the period 2006–2010. To do this they look to see if correlation coefficients increase significantly during the crisis period 2007–2010. Their results show significant evidence of contagion in global REITs during the crisis. However their evidence looks at transmission from the US market to the other countries and not vice-versa.

To effectively diversify their portfolios investors are interested in spreading their investments across international markets. As such, the interdependence between domestic and global financial markets is very important for them. Volatility spillover is present when a market shows significant signs of co-movement with other global markets and this is important for policy makers because it affects the financial system and the economic performance. Consider for example, Mishkin (2005) and Singh et al. (2010) who find that interdependence is accompanied by speedy transmission of volatility shocks linking the domestic and global stockmarkets. To date research that examines volatility spillovers and return co-movements between the national REIT

[1] Portfolio theory makes it clear that low correlations between security reruns increases the potential for risk reduction and improves the risk-return trade-off.

markets in different regions of the globe has been very limited.[2] This is the gap that the current research is trying to address.

3 Data and methodology

The empirical tests conducted in this paper utilize the FTSE EPRA/NAREIT daily indices. The dataset used comprises of daily data for the period February 2006 to July 2013. The first dataset consists of the two main US REIT sub-sectors, the FTSE NAREIT All Equity REITs Index (FNRE) and the FTSE NAREIT Mortgage REITs Index (FNMR).[3] To examine the linkages between the global markets we use the FTSE EPRA/NAREIT Americas (US), FTSE EPRA/NAREIT Europe (EU) and FTSE EPRA/NAREIT Asia Pacific (APAC) that incorporate REITs and Real Estate Holding & Development companies in each geographic region. The formation of the global indices is represented below according to FTSE EPRA/NAREIT Global Real Estate Index Series Factsheets. Table 1 presents details about these indices.

Figure 1 shows the price movement of the three global REIT indices under examination. We observe that from 2006 to 2009 Europe outperforms Asia Pacific and Americas index on average but from 2009 to 2013 became third having the lowest prices while Americas index comes second and Asia Pacific first. Prices have reached their lowest point in March 2009. This is consistent with the general stock market decline in March 2009, measured by the S&P 500 index. US equity and Mortgage REIT prices follow the same pattern. The only difference is that Mortgage REITs reached their lowest point earlier in November 2008.

Some descriptive statistics of the respective series are outlined in Table 2 detailing the first four moments of each series, and the correlation matrix between the series. The values of the coefficients of skewness, kurtosis together with the large Jarque-Bera statistics lead to the rejection of the null hypothesis of a normal distribution. From the correlation matrix we can see that the correlation among our variables are positive and high (>0.7). Therefore, some degree of multicollinearity is unavoidably present. Heteroskedasticity is also present as indicated by the high value of the LM-statistic. It is clear that all series exhibit cases of volatility clustering requiring that the estimation should include ARCH-type processes.

The empirical analysis is undertaken using an MGARCH framework. To examine the relationship between the Equity and Mortgage US REITs we use a bivariate (restricted and unrestricted) GARCH model and a trivariate (restricted) GARCH model for the Global indices.

First we have to determine the suitability of the BEKK model. This requires the existence of heteroskedastic effects in the return series. Using the Engle (1982) LM test for ARCH (p) effects, we find strong evidence of ARCH effects for all cases. The following mean equations were estimated for each index.

$$r_t = c + \theta r_{t-1} + \varepsilon_t \tag{1}$$

[2] The FTSE Global Real Estate Indices cover companies whose relevant activities are defined as the ownership, disposal and development of income producing real estate. The index series covers Global, Developed and Emerging indices.

[3] Those two REIT indices were first launched in February 2006 so our analysis starts from this date onwards.

Table 1 Country Breakdown per Index

Country	No. of Constituents	Net Market Cap ($ millions)	Weight
Asia Pacific (APAC)			
Australia	13	69,373	16.20
China	34	44,634	10.42
Hong Kong	18	93,107	21.74
India	6	1,785	0.42
Indonesia	14	7,277	1.70
Japan	33	147,493	34.43
Malaysia	13	6,480	1.51
New Zealand	1	883	0.21
Philippines	6	8,194	1.91
Singapore	18	43,142	10.07
Taiwan	1	202	0.05
Thailand	15	5,774	1.35
Asia Pacific Totals	172	428,345	100
Europe (EU)			
Austria	2	1,200	1.09
Belgium & Lux	7	3,440	3.1
Czech Rep	1	235	0.21
Finland	3	1,742	1.59
France	8	9,562	8.70
Germany	12	10,319	9.39
Greece	1	172	0.16
Italy	2	492	0.45
Netherlands	6	21,035	19.15
Norway	1	520	0.47
Poland	2	1,154	1.05
Russia	2	3,308	3.01
Sweden	8	6,984	6.36
Switzerland	4	7,605	6.92
Turkey	5	841	0.77
UK	30	41,253	37.55
Europe Totals	94	109,871	100
Americas (US)			
Brazil	21	15,906	3.02
Canada	23	42,784	8.12
Mexico	4	494	0.09
USA	33113	467,739	88.77
Americas Totals	161	526,923	100

where r_t is an 2×1 vector of daily returns at time t for each index, and $\varepsilon_t|\varepsilon_{t-1} \sim N(0, H_t)$ is an 2×1 vector of random errors for each index at time t. This model helps us in the

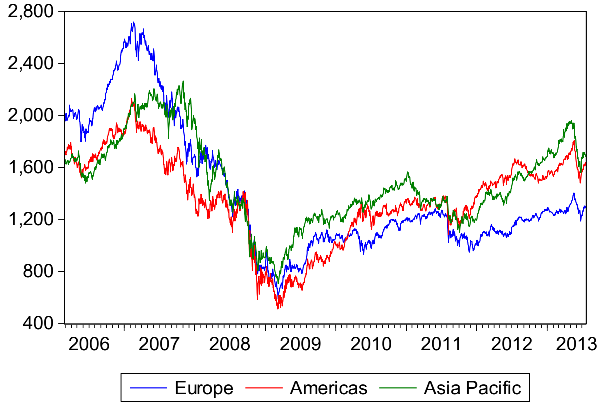

Fig. 1 Time plot of the Global REIT indices

examination of any volatility transmission. The main advantage of the BEKK model is that it has few parameters and ensures positive definiteness of the conditional covariance matrix to ensure non-negative estimated variances. The bivariate version of the BEKK GARCH specification (Engle and Kroner 1995) is defined as:

$$\begin{aligned} H_t &= CC' + A\varepsilon_{t-1}\varepsilon'_{t-1}A' + BH_{t-1}B' \\ y_t &= \mu_t + \varepsilon_t \\ \varepsilon_t &\sim N(0, H) \end{aligned} \tag{2}$$

where y_t is a 2×1 vector of random variables incorporating the returns and ε_t is a normally distributed error term. H_t, denotes the conditional variance-covariance matrix at t and matrices B and A as well as the diagonal elements of C have to be positive. The elements of the covariance matrix H_t, depends only on past values of itself and past values of ε_t $/\varepsilon_t$, which is innovation. Each matrix C, A and B dimension is 2×2 and C is restricted to be upper triangular. The elements of

Table 2 Descriptive statistics of daily returns series

REITs	Equity US	Mortgage US		Americas	Europe	Asia Pacific
Panel A: Moments						
Mean	0.0001	−0.0006		−0.00003	−0.0002	0.000005
Std. Dev.	0.0250	0.0219		0.0241	0.0150	0.0150
Skewness	−0.1251	0.0054		−0.2892	−0.2916	−0.3286
Kurtosis	13.3395	19.7583		13.0790	6.3223	7.1946
Panel B: Correlation matrix						
	Equity US	Mortgage US		Americas	Europe	Asia Pacific
Equity	1.0000		Americas	1.0000		
Mortgage	0.7618	1.0000	Europe	0.3328	1.0000	
			Asia Pacific	0.0567	0.3709	1.0000

matrix A measure the effects of shocks or "news" on the conditional variances (ARCH effects). The 2 × 2 square matrix B shows how past conditional variances affect the current levels of conditional variances, in other words, the degree of volatility persistence in conditional volatility among the markets (GARCH effects). The diagonal parameters in matrices A and B measure the effects of own past shocks and volatility on its conditional variance. The volatility spillover measures the cross-market effects of shocks and volatility using the off-diagonal parameters in matrices A and B. This model is suitable for cross dynamics of conditional covariances because A and B do not need to be diagonal.

We assume that $a_{11}>0$ and $b_{11}>0$ due to the uniqueness of the BEKK representation. Then, if $K=1$ there exists no other C, B, A in the model that will give an equivalent representation. The purpose of the restrictions is to eliminate all other observationally equivalent structures. The amount of parameters to be estimated is $N(5N+1)/2$, thus in a bivariate model ($N=2$, with $p=q=1$) *11* parameters should be estimated. We can differentiate between two alternative specifications presented analytically below:

a) Bivariate Unrestricted Specification
GARCH (1,1) - BEKK, $N=2$:

$$H_t = CC' + \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \begin{bmatrix} \varepsilon^2_{1t-1} & \varepsilon_{1t-1}\varepsilon_{2t-1} \\ \varepsilon_{2t-1}\varepsilon_{1t-1} & \varepsilon^2_{2t-1} \end{bmatrix} \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix}' + \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix} \begin{bmatrix} h_{11t-1} & h_{12t-1} \\ h_{21t-1} & h_{22t-1} \end{bmatrix} \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix}' \quad (3)$$

The matrix multiplication is presented as:

$$h_{11,t} = c^2_{11} + a^2_{11}\varepsilon^2_{1,t-1} + 2a_{11}a_{21}\varepsilon_{1,t-1}\varepsilon_{2,t-1} + a^2_{21}\varepsilon^2_{2,t-1} + b^2_{11}h_{11,t-1} + 2\ b_{11}b_{21}h_{21,t-1} + \ b^2_{21}\ h_{22,t-1} \quad (4)$$

$$h_{22,t} = c^2_{21}c^2_{22} + a^2_{12}\varepsilon^2_{1,t-1} + 2a_{12}a_{22}\varepsilon_{1,t-1}\varepsilon_{2,t-1} + a^2_{22}\varepsilon^2_{2,t-1} + b^2_{12}h_{11,t-1} + 2\ b_{12}b_{22}h_{21,t-1} + \ b^2_{22}\ h_{22,t-1} \quad (5)$$

$$h_{12,t} = c_{11}c_{22} + a_{11}a_{12}\varepsilon^2_{1,t-1} + (a_{21}a_{12} + a_{11}a_{22})\varepsilon_{1,t-1}\varepsilon_{2,t-1} + a_{21}a_{22}\varepsilon^2_{2,t-1} + \ b_{11}b_{12}h_{11,t-1} + \ (b_{21}b_{12} + b_{11}b_{22})\ h_{12,t-1} + \ b_{21}b_{22}h_{22,t-1} \quad (6)$$

b) Trivariate Restricted Specification
Consider the BEKK GARCH (1,1) with $N=3$. In the restricted trivariate model the matrices A and B are diagonal and the amount of parameters to be estimated is 24. The matrix multiplication is presented below.

$$h_{22,t} = c_{22}^2 + c_{21}^2 + a_{22}^2 \varepsilon_{1t-1}^2 + b_{22}^2 h_{11t-1} \tag{7}$$

$$h_{33,t} = c_{33}^2 + c_{31}^2 + c_{32}^2 + a_{33}^2 \varepsilon_{1t-1}^2 + b_{33}^2 h_{11t-1} \tag{8}$$

$$h_{12,t} = c_{11}c_{22} + a_{22}a_{11}\varepsilon_{1t-1}\varepsilon_{2t-1} + b_{22}b_{11}h_{12t-1} \tag{9}$$

$$h_{13,t} = c_{11}c_{33} + a_{33}a_{11}\varepsilon_{1t-1}\varepsilon_{2t-1} + b_{33}b_{11}h_{12t-1} \tag{10}$$

$$h_{23,t} = c_{22}c_{33} + c_{21}c_{31} + a_{33}a_{22}\varepsilon_{1t-1}\varepsilon_{2t-1} + b_{33}b_{22}h_{12t-1} \tag{11}$$

The last restricted specification of the BEKK model restrict the off diagonal elements in A and B, that measure the volatility spillover, to zero. Consequently, each conditional variance depends only on past values of itself and the lagged cross-product of residuals.

For our volatility analysis, we use the DCC-GARCH model proposed by Engle (2002). This is a generalized Bollerslev's (1990) constant conditional correlation model by making the conditional correlation matrix time-dependent. This method takes as input the standardized residuals, which are simply the data series residuals divided by the GARCH conditional standard deviation to estimate DCC conditional correlations.[4] The model for two assets is defined as:

$$\rho_{12,t} = \frac{q_{12,t}}{\sqrt{q_{11,t}q_{22,t}}} \tag{12}$$

$$q_{12,t} = \overline{R}_{12}(1-\alpha-\beta) + \alpha s_{1,t-1}s_{2,t-1} + \beta q_{12,t-1} \tag{13}$$

$$q_{11,t} = \overline{R}_{11}(1-\alpha-\beta) + \alpha\left(s_{1,t-1}\right)^2 + \beta q_{11,t-1} \tag{14}$$

$$q_{22,t} = \overline{R}_{22}(1-\alpha-\beta) + \alpha\left(s_{2,t-1}\right)^2 + \beta q_{22,t-1} \tag{15}$$

$$\omega = \overline{R}_{12}(1-\alpha-\beta) \tag{16}$$

$$\overline{R}_{12} = \frac{1}{2}\sum_{t-1}^{n} s_{1,t}s_{2,t} \tag{17}$$

[4] Engle (2009) refers to this process as "DE-GARCHING" the data.

In this model $\rho_{12,t}$ is the DCC-model conditional correlation, $\overline{R}_{12}$ is the average realized correlation, $s_{1,t-1}$ and $s_{2,t-1}$ are the lagged GARCH standardized residuals and the “quasi-correlations” are represented by q values. The first term $\overline{R}_{12}(1-\alpha-\beta)\equiv\omega$ is restricted to be constant. This is known as correlation targeting and reduces the number of unknown parameters to only α and β. To estimate α and β parameters, we use maximum likelihood estimation. As noted by Engle (2009), the log-likelihood function in this case applies to a pair of assets, which is given by:

$$L_{12} = -\frac{1}{2}\sum_{t=1}^{n}\left(\log\left[1-\rho_{12,t}^2\right] + \frac{s_{1,t}^2 + s_{2,t}^2 - 2\rho_{12,t}s_{1,t}s_{2,t}}{\left[1-\rho_{12,t}^2\right]}\right) \tag{18}$$

4 Empirical results

4.1 BEKK-GARCH

4.1.1 US equity and US mortgage REITs

Table 3 reports the results from the conditional variance equation findings for the bivariate BEKK model examining the interrelationships between US mortgage and US equity returns. The impact of an asset’s own market effects are represented by

Table 3 Unrestricted bivariate Coefficients

BEKK GARCH (1,1)		
Variance-Covariance equation		
US Equity- US Mortgage		
Variable	Coefficient	z-Statistic
c_{11}	0.00 *	4.16
b_{11}	0.96*	138.93
b_{21}	−0.01	−0.83
α_{11}	0.31*	11.32
α_{21}	0.03	1.21
c_{21}	0.00*	8.70
c_{22}	0.00*	2.51
b_{12}	−0.01	−1.15
b_{22}	0.95*	119.49
α_{12}	0.05*	2.44
α_{22}	0.29*	12.60
Log likelihood	11546.44	
Avg. log likelihood	5.991925	
Schwarz criterion	−11.9132	

* indicates significance at the 5% level or higher

subscripts 11 for asset 1, and 22 for asset 2. Similarly, cross-market effects are given by subscripts 21 and 12 for asset 1 and asset 2 respectively. All the past shocks and past volatility are significant. The result that $|\alpha_{ii}| < |b_{ii}|$, suggests that the behavior of current variance and covariance is not so much affected by the magnitude of past innovations as by the magnitude of lagged variances and covariances. In the conditional variance equation the α_{ii} coefficients represent ARCH effects, while the b_{ii} coefficients represent GARCH effects. As would be expected in the volatility equation, current returns and volatility are affected from their own past series returns. The coefficients are significant revealing that autocorrelation and volatility clustering is present in the returns with an autocorrelated relationship in the second moment of the distribution. Autoregressive and time dependent volatility effects incur for each series as shown by the α_{11}, α_{22}, b_{11}, b_{22} parameters.

The off-diagonal elements of matrices *A* and *B* capture the cross-market effects such as shock and volatility spillover. In documenting the shock transmission between the main US REIT subsectors, we find evidence of unidirectional linkage between Equity and Mortgage REITs running from equity to mortgage (i.e., only the off-diagonal parameter α_{12} is statistically significant). In other words, equity shocks affected mortgage mean returns. Second, we did not identify any volatility spillover between them (the off-diagonal parameters of matrix *B* are statistically insignificant). The use of different data frequency can lead to very contrasting empirical findings as outlined in Cotter and Stevenson (2006). It is possible that the use of the higher frequency data masks more of the fundamental relationships, with general market sentiment coming more to the force.

Figure 2 shows the variance series for the US Equity and US Mortgage REIT indices together with their covariance. It shows how the Mortgage index variation shoots through the roof during the period of the financial crisis from 2007 to 2009; after that through 2009–2010 Equity had a greater variation and from 2010 to 2013 they are moving together.

4.1.2 Global REITs

Table 4 reports the results of the unrestricted bivariate BEKK GARCH (1,1) estimations that examine the global linkage of REIT markets. First, we estimate three pairwise models using a bivariate GARCH framework and adopting a BEKK

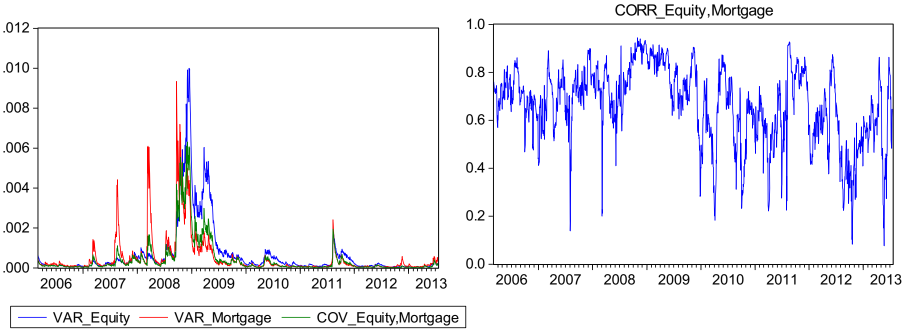

Fig. 2 Variance and Correlation of the Mortgage and Equity REIT indices

Table 4 BEKK GARCH coefficients

BEKK GARCH (1,1)						
Variance-Covariance equation						
Variable	US Equity- US Mortgage		Americas-Asia Pacific		Europe-Asia Pacific	
	Coefficient	z-Statistic	Coefficient	z-Statistic	Coefficient	z-Statistic
c_{11}	0.00*	4.82	0.00*	4.87	0.00*	4.53
b_{11}	0.97*	188.05	0.97*	193.54	0.95*	134.64
b_{21}	−0.02	−1.76	−0.05*	−4.73	−0.04*	−5.05
α_{11}	0.25*	12.73	0.24*	12.54	0.28*	13.52
α_{21}	0.03	1.12	0.12*	4.72	0.10*	4.60
c_{21}	0.00*	6.16	0.00	−0.00	0.00*	3.24
c_{22}	0.00	1.74	0.00*	4.14	0.00	1.95
b_{12}	−0.00	−0.08	0.02*	5.73	0.02*	3.29
b_{22}	0.95*	136.18	0.96*	136.14	0.97*	187.59
α_{12}	0.02	1.33	−0.07*	−5.55	−0.02	−1.09
α_{22}	0.30*	13.10	0.22*	11.35	0.19*	10.63
Loglikelihood	11313.62		11217.89		11719.39	
Avg. log likelihood	5.874152		5.824448		6.084835	
Schwarz criterion	−11.678		−11.611		−12.099	

* indicates significance at the 5% level or higher

representation. The modeled pairs are: America-Europe, Americas-Asia Pacific, Europe-Asia Pacific. The parameters α_{11}, α_{22}, b_{11}, b_{22} show that autoregressive and time dependent volatility effects are present. The off-diagonal elements of matrices A and B capture the cross-market effects such as shock and volatility spillover. In documenting the shock transmission globally, we find a bidirectional correlation between America and Asia Pacific since the off-diagonal elements α_{12} and α_{21} are statistically significant. This indicates a strong connection between them. Further, we find evidence of unidirectional linkage between Europe and Asia Pacific running from Asia Pacific to Europe since only the α_{21} coefficient is statistically significant. In other words, Asia Pacific shocks affected Europe mean returns. No mean effects were found between Americas and Europe. Second, we identify bidirectional volatility linkages between Americas-Asia Pacific and Europe-Asia Pacific; the pairs of off-diagonal parameters, b_{12} and b_{21}, are both statically significant. These results provide strong evidence of the global REIT market's integration.

Next, we proceed by estimating a restricted trivariate BEKK GARCH (1,1) model. Table 5 presents the estimated coefficients of the variance-covariance matrix of a trivariate M-GARCH BEKK model employed for analyzing volatility relationship between global REITs. The results show that all the conditional variance coefficients are significantly positive. As seen above, all the past shocks and past volatility are significant. Since we observe that $|\alpha_{ii}|<|b_{ii}|$, we conclude that the behavior of current variance and covariance is not so much affected by the magnitude of past innovations as by the magnitude of lagged variances and covariances. Moreover, the statistical significance of the GARCH b_{ii} parameters reveals the large extent of volatility clustering.

Table 5 Restricted Trivariate Coefficients

BEKK GARCH (1,1)		
Variance-Covariance equation		
Americas-Europe-Asia Pacific		
Variable	Coefficient	z-Statistic
c_{11}	0.00*	9.30
b_{11}	0.96*	352.72
α_{11}	0.27*	28.22
c_{22}	0.00*	3.33
c_{21}	0.00*	9.87
b_{22}	0.94*	249.80
α_{22}	0.32*	27.25
c_{33}	0.00*	3.11
c_{31}	0.00*	3.47
c_{32}	0.00*	6.36
b_{33}	0.98*	384.46
α_{33}	0.21*	20.02
Loglikelihood	16961.85	
Avg. log likelihood	8.793077	
Schwarz criterion	−17.5273	

* indicates significance at the 5% level or higher

Finally, from the dynamic correlations series presented in Fig. 3, we observe that the correlation stays within 0.87 and −0.15 (mean: 0.35) for Americas and Europe, 0.61 and

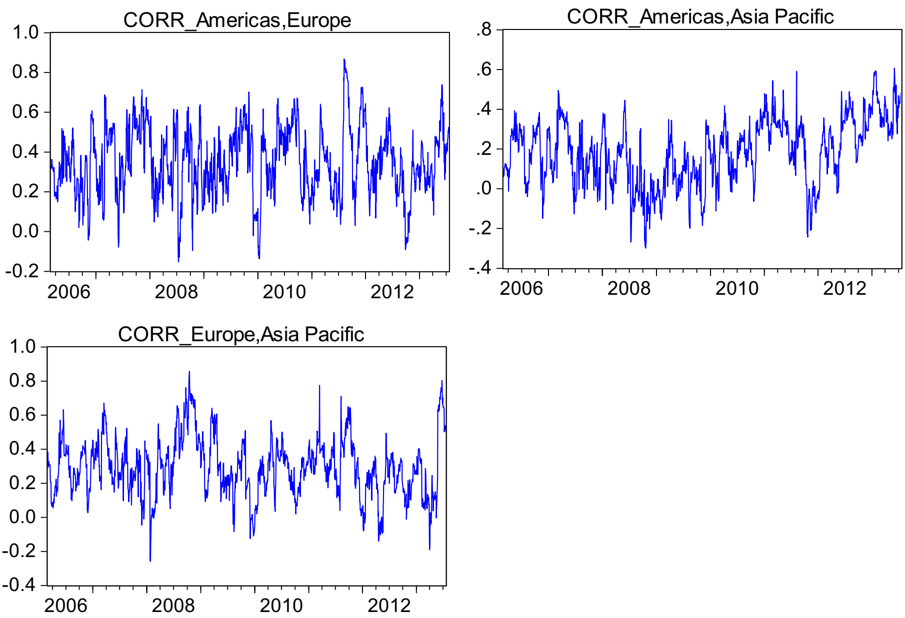

Fig. 3 Correlations from Restricted Trivariate BEKK GARCH (1,1) model

−0.30 (mean: 0.18) for Americas and Asia Pacific and 0.86 and −0.26 (mean: 0.30) for Europe and Asia Pacific. It's worth mentioning that from 2012 to 2013 the correlation between Americas and Asia Pacific has steadily been increasing (mean: 0.32).

4.2 DCC-GARCH specification

The final test involves estimating the DCC-GARCH model. The results of this analysis are presented in Table 6. We obtain the model parameters (α, β) for any given pair of assets. The coefficients α and β refer to the DCC (1,1) estimates. The estimated GARCH-DCC model appears to provide a good representation of the conditional variance of the data. The persistence of the conditional correlations, measured by α and β, is close to unity that is between 0.92 and 0.99. The β coefficient is always significant and above 0.90 and α is below 0.04 revealing slight response to innovations and major persistency. Only the Americas and Europe report an insignificant parameter α. All the other parameters α and β are positive and statistically significant suggesting evidence of a strong interaction between the returns of the indices. It is worth noting that all significant coefficients highlight the time varying nature of conditional variances and covariances.

Figure 4 presents the graphs of the conditional correlation coefficients, as estimated using the GARCH-DCC (1,1) procedure, for each pairing of the REIT time-series. A number of issues are of interest; however, there is no evident consistency across the different pairs. When the majority of the correlations are relatively low, this implies diversification potential across REIT sectors and when they display a relatively high level of spread across the correlations, this confirms the findings for the unconditional coefficients (0.0-0.2: very weak, 0.2-0.4 weak, 0.4-0.7 moderate, 0.7-0.9 strong, 1 perfect correlation).

As expected, the strongest correlations are reported in the two main US subsectors. US Equity and US Mortgage REITs report high conditional correlations in general, ranging from 0.5 to 0.8 (moderate) and the lowest conditional correlation (0.27) is reported around the end of 2012. In Americas-Asia Pacific the conditional correlations follow a downward trend from 2006 to 2009 (very weak) and a strong upward trend from 2009 to 2013 (weak) that clearly indicate that the sector has undergone a distinct shift over the last few years. On the other hand Europe-Asia Pacific and Americas-Europe (weak) correlations tend to be far more tightly banded. Indeed, only positive conditional correlations are reported in all the tested pairs.

Table 6 DCC-GARCH

	US Equity-Mortgage		Americas-Europe		Americas-Asia Pacific		Europe-Asia Pacific	
	Coefficient	z-Statistic	Coefficient	z-Statistic	Coefficient	z-Statistic	Coefficient	z-Statistic
α	0.0360	7.344	0.0168	1.588	0.0066	1.994	0.0247	2.987
β	0.9541	143.08	0.9001	10.540	0.9924	188.34	0.9370	35.683
Logl	−4803.2		−5332.41		−5441.2		−5370.2	
Avg. Logl	−2.4900		−2.764		−2.8207		−2.783	
Schwarz	4.9878		5.536		5.6494		5.575	

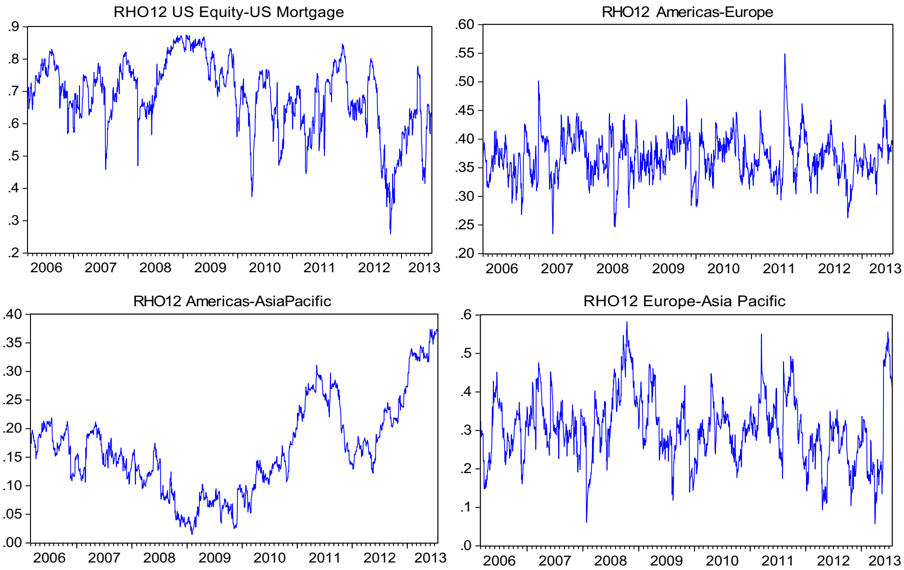

Fig. 4 Conditional correlation coefficients from the GARCH-DCC (1,1)

5 Conclusions

This paper examined the linkage of REITs. The starting point we examine the linkage between the two main US REIT subsectors (Equity and Mortgage) and then we extended our analysis globally for Americas, Europe and Asia Pacific REITs. We employ GARCH-BEKK and DCC models based on daily return indices from 2006 to 2013.

As would be expected both ARCH and GARCH effects are present. In the volatility equation, past own series returns affect current returns and volatility. The appropriate coefficients are significant, supporting the findings of autocorrelation in the returns. Regarding the two main US subsectors we find no evidence of any volatility spillover between them. This result leads to the assumption that investors can benefit from risk diversification. Another factor which may play an important role in this interdependence is the fact that fewer than 10 % of REITs are mortgage sector in the United States. Therefore the equity sector is clearly larger than the mortgage and this may also explain why equity shocks affect mortgage mean returns. Depending on their variance analysis the Mortgage index variation shoots through the rough during 2007–2009, after that through 2009–2010 the Equity index had a greater variation and from 2010 to 2013 they are moving together.

As far as the global linkage of REIT market and the shock transmissions are concerned, we find a bidirectional correlation of Americas and Asia Pacific that indicates a strong connection between them. Further, we find that Asia Pacific shocks affected Europe mean returns; while there are no mean effects between Americas and Europe. Second, we identify bidirectional volatility linkages between Americas-Asia Pacific and Europe-Asia Pacific. These results provide convincing evidence of the global REITs markets integration. The global REIT market is a financial market with particular characteristics and each REIT system has its own legislation. The Asia Pacific REIT index that consists of most constituents according to Table 1 seems to be the more influential for both the Americas and Europe. The absence of any cross market effects between Americas and Europe implies that investors can significantly benefit from a reduction of diversifiable risk.

The most immediate implication of the DCC model is that there is a strong interaction between the returns of the indices that highlights the time varying nature of conditional variances and covariances. DCC coefficients also reveal a slight response to innovations and a major persistency. Conditional correlations show the way that the returns of one REIT index correlate with the returns of another REIT index over time. While Americas-Europe and Europe-Asia Pacific weak correlations follows a more stable trend, Americas-Asia Pacific correlations have undergone a distinct upward shift over the last few years. This is an indication that Americas and Asia Pacific have become more integrated post 2009 and that they have lost some of their diversification properties. On a local base in the US REIT market strangely we discover that the diversification potential within the two main sectors has slightly risen in the last years with the subsectors behaving not as homogeneous as in the period 2006–2012. .

It is commonly argued that REITs should adopt a focused investment strategy in order that investors can make their own diversification decisions. However, this is based on an underlying assumption that performance does differ and that the share prices of REITs reflect the fundamentals of the underlying property sectors. Recent research by Philippas et al. (2013) and Chong et al. (2012) have concluded that REITs are behaving in a more homogenous manner than the past and this calls into question the investment based argument for REITs to be focused.

The results of this study will help investors in their portfolio selection to incorporate time varying volatility and correlations and can be extended in several directions. Empirical research on the matter can possibly apply other multivariate techniques such as constant correlation (CC) or time-varying correlation (VC). Also, it would be interesting to apply the current methodology in more secondary US REIT subsectors and in a more analytical global based analysis; however, these issues are left for further research.

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