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Article

Exploring a Three-Factor Dependence Structure of Conditional Volatilities: Some Quantile Regression Evidence from Real Estate Investment Trusts

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Abstract: We propose a simple three-factor pricing model, consisting of a local stock market index, a global REIT market index, and a global stock market index, to examine the dependence structure of conditional volatilities in the real estate investment trust (REIT) market from 11 countries over the sample period from 1 June 2008 to 30 April 2021. The main quantile regression results reveal that a simultaneous dependence structure exists between each REIT market and local stock, global REIT market, and global stock market. There is a positive and significant dependence between REITs and three factors for every part of the quantiles. Across each quantile, Asia-Pacific REIT markets have a consistently higher average degree of dependence with their local stock markets than with the global stock and global REIT markets, whereas European REIT markets are generally more globally integrated. Furthermore, the lower and upper quantile estimates for over half of the REIT-quantiles for the three market factors are statistically different. Additionally, some REIT markets display asymmetric co-movement with at least one of the three factors as the degree of dependence increases when these markets are booming, but the dependence level declines when the markets are bearish. This evidence of dependence across the three influential factors and REIT markets provides meaningful insights into REIT market growth, international asset pricing, risk management, and dynamic linkages in the global economy.

Keywords: real estate investment trusts; dependence structure; quantile regression; local stocks; global REITs; global stocks



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1. Introduction

This paper examines the degree and structure of conditional volatility interdependence between 11 national real estate investment trust (REIT) markets and their corresponding local stocks, global REIT, and global stock market benchmark over June 2008 to April 2021, using the quantile regression (QR) approach originally developed by [Koenker and Bassett \(1978\)](#), and which was advocated by [Baur \(2013\)](#), to reveal asymmetric and nonlinear effects of conditional variables on the dependent variable. The main element of novelty is thus represented by using this methodology which allows capturing a non-linear response in this relatively new asset class globally.

In the reality of progressing globalization, research on the interdependency between the quickly developing financial and real estate markets is particularly relevant for supporting market growth, but also for its effective supervision, which aims at sustainable development. Thus, extending the knowledge of REITs lies within the interest of various stakeholders as it broadens previous studies on financial market integration. This consideration greatly motivates our paper.

Unlike the ordinary least squares (OLS), QR allows the coefficient estimates to vary throughout the distribution of the dependable variables, and it provides a complete picture of the relationship between the explanatory variables and the dependent variable. In our case, the QR approach is appropriate to provide direct and specific insights on the

market interdependence effects of three influential market factors under three usual market conditions: bearish (lower quantile), normal (intermediate quantile), and bullish (upper quantile). The choice of the three factors relies on their great relevance for REIT market growth, financial integration, and contagion. This issue has been very important because many established REIT regimes were initially developed locally, and thus, connected to their local stock markets. Over time, they needed to invest in international property projects to grow. Consequently, the mechanism by which REIT markets are linked internationally requires to be clearly understood by market players, financial institutions, and policy makers in order to attract global capital (via global REIT and global stock) from real estate asset securitization.

A review of the literature (see Section 2 below) indicates that much more work needs to be done to enhance a better understanding of dependence structure across national REIT markets, as well as between REITs and global markets for their investment and policy implications. This study seeks to expand the financial integration literature. In the context of economic globalization and financial market integration, [Parker \(2018\)](#) has noted that an ongoing and unresolved issue is the appropriate level of integration or interdependence between REIT markets at both the regional and global levels; on one hand, excessive integration could inadvertently facilitate contagion, whereas inadequate integration does not contribute to REIT market growth. Although this study does not intend to directly address this question, it considers the globalization of REITs by examining their time-varying conditional volatility relationship with three influential market factors from 11 national REIT markets over the period from 1 June 2008 to 30 April 2021, with the beginning date dictated by the availability of first-day index data for all markets. Accordingly, the contributions and added values are compared with the existing literature in three different ways. First, we study REITs (not public real estate which covers both REITs and traditional real estate stocks). REIT can be viewed as a bridge between the direct property asset class and stock asset class. As the size of the REIT sector grows, and as it pursues greater sector/international specialization in a relatively short time span, the cross-REITs and cross REIT-stock interdependences are expected to display different profiles and change differently from those of cross-stock markets; therefore, separate studies on REITs are warranted in order to provide an insightful understanding of the cross-country REIT-stock differences in terms of relations and cross-sectional heterogeneity with regard to market interdependence and financial contagion. This is because of differences in risk and return, diversification, liquidity, and leverage over time (see [Giacomini et al. \(2015\)](#)). Second, in contrast to the individual treatments that appear in the literature, this study simultaneously assesses three important types of REIT market interdependence to underscore the complexity of REIT-stock market relationships at three different hierarchical levels (local and global). Third, I use contemporary methodologies, including a standard GARCH specification and QR, to analyze the structure and degree of volatility interdependence. With the QR methodology, the study empirically evaluates the estimated coefficients across seven quantiles $q = \{0.01, 0.10, 0.25, 0.50, 0.75, 0.90, 0.99\}$ to address the following questions: (a) Does dependence exist between each REIT and the two influential stock market factors under consideration? (b) Is there any symmetric or asymmetric dependence of the REIT markets on each of the factors? (c) Has the dependence structure been affected by the 2008–2012 financial crisis? The findings from this research will have important implications for market regulators and financial institutions who are interested in exploiting both REIT market growth and diversification benefits over time, which should vary following changes to the economic and financial global factors.

The remainder of this study is structured as follows. Section 2 provides a review of prior studies that support this research. Section 3 explains the data and a three-factor QR model used. This is followed by Section 4 which comprehensively discusses the QR results. Section 5 then concludes the study and suggests some avenues for future research.

2. Brief Literature Review

[Bardhan et al. \(2008\)](#) found that a country's real estate security (stock of publicly traded real estate companies including REITs) excess returns are negatively related to its openness. Other significant determinants of individual firms' returns include other international factors, such as a country's index returns over its risk rates, and its supply and demand fundamentals. Although their results (not confined to REITs) are robust across different model specifications and sample partitions, they did not use the QR regression method. [Liow \(2012\)](#) finds that conditional public real estate stock correlations at the local and global levels are time-varying and asymmetric in some cases, using different approaches (but did not include the QR method) for his sample of eight Asian real estate markets during 1995–2009. Moreover, they find that public real estate global stock correlations co-move significantly and positively with real estate local stock correlations. [Liow and Schindler \(2014\)](#) assess whether their sample of nine international public real estate markets and stock markets are linked at the local, regional, and global levels, and examine the evolution of their dynamic relationship and global integration during the last two decades. Although their study includes the use of various econometrics, such as dynamic conditional correlations, time-varying integration scores, principal component structure, and linear causality, they did not use the QR method in their analysis. Within the context of market integration, [Liow and Song \(2022\)](#) explore the frequency connectedness of volatilities across 14 international REIT markets over the last ten years. They evaluate whether the REIT volatility connectedness results from the short-, medium-, or long-term impact of shocks, which can reveal the underlying frequency sources of volatility connectedness. They also identify the systematic risk source—that the US REIT market played an influential role in volatility connectedness across global REITs.

As far as this study is concerned, [Baur \(2013\)](#) first proposes the QR method (originally developed by [Koenker and Bassett 1978](#)) to decompose dependence, including asymmetric and non-linear relationships. Consequently, changes in the degree of the structure of dependence can be modelled and tested for each quantile of distribution. Empirically, he applies the QR framework to three different financial time-series in 54 global equity markets, and demonstrates that substantial differences in dependence patterns can be detected among the asset classes over time, thereby providing useful criteria to adequately assess the benefits of diversification in normal and crisis times.

The literature on quantile regression in financial markets is growing. This is important as these studies not only indicate evidence of quantile regression between different (sets of) domestic and international (/global) stock markets, but between financial markets and macroeconomic factors. [Mensi et al. \(2014\)](#) examine the dependence structure of the emerging stock markets between BRICS countries and influential global factors using the quantile regression method. They examine the BRICS markets' dependence alongside the global stock and commodity markets (S&P index, oil and gold), as well as changes in the US stock market regarding uncertainty (CBOE Volatility Index). This dependence structure is often asymmetric and is affected by the onset of the recent global financial crisis. [Albulescu et al. \(2020\)](#) investigate the casual relationship between banking and real estate sectors in the US using a daily quantile causality framework from 31 August 2006 to 9 September 2016. Their non-linearity tests indicate the suitability of the quantile causality approach to uncover causal effects at tail quantiles that are much different from those at middle quantiles and at the mean. The findings reveal bi-directional causality that is derived from only lower and upper levels of quantiles, suggesting that the returns in each of the markets under examination can be used to predict the returns of the other markets in bullish and bearish conditions, and not under normal conditions. Accordingly, investors should be cautious in hedging the risk across these markets when they are extremely unstable. Another study by [Abuzayed et al. \(2020\)](#) consider co-movement and portfolio management by analyzing the time-varying correlation, hedging ratios, and portfolio weights. Using daily data from 6 January 2003 to 11 April 2018, they show a significant shift in the correlation coefficients between the two assets under financial and economic stress.

Consequently, potential diversification benefits appear limited when investing across REITs and stock markets. During crisis periods, investors are subject to a high cost for rebalancing their positions in REITs to mitigate stock portfolio risk. Further analyses confirm the inability of REITs to play hedge and safe-haven roles against the stock market. [Balcilar et al. \(2020\)](#) find that the relationship between daily housing returns with mortgage default risks is in fact nonlinear, and hence, a linear predictive model is mis-specified. They use a k-th order nonparametric causality in-quantiles test, which in turn, tests for predictability over the entire conditional distribution of housing returns and volatility, by controlling for misspecification due to nonlinearity. Consequently, their results show that mortgage default risks do indeed predict housing returns and volatility, barring at the extreme upper end of the respective conditional distributions. [Lesame et al. \(2021\)](#) investigate the time-varying interconnectedness of international REIT markets using daily REIT prices in twelve major REIT countries since the GFC. They construct the dynamic total, net total, and net pairwise return and volatility connectedness measures to better understand systemic risk and the transmission of shocks across REIT markets. Their findings show that that REIT market interdependence is dynamic and increases significantly during times of heightened uncertainty, including the COVID-19 pandemic. The US REIT market, along with major European REITs, are generally sources of shocks to Asian-Pacific REIT markets. Finally, other recent QR stock market integration studies include: [Ilyas \(2016\)](#); [Al Nasser and Hajilee \(2016\)](#); [Rejeb \(2017\)](#); [Nusair and Al-Khasawneh \(2018\)](#); [Aslanidis et al. \(2021\)](#); [Yang et al. \(2018\)](#); [Naifar \(2016\)](#); [You et al. \(2017\)](#); [Tiwari et al. \(2019\)](#); [Dohaiman \(2017\)](#); and [Das and Kannadhasan \(2020\)](#).

3. Research Design

Mainly based on the availability of data criterion, the research sample includes 11 equity REIT markets from two continental groups from the data stream: European REITs (France (FR), the UK, Germany (GE), Italy (IT), Netherlands (NE), Belgium (BE)) and Asia-Pacific REITs (Japan (JP), Australia (AU), New Zealand (NZ), Hong Kong (HK), and Singapore (SG)), with JP and IT as the largest and smallest REIT markets, respectively. The REIT markets of the countries included are of differentiated history, size, market conditions, financial leverage, and have different levels of linkage with the American economy. Table 1 provides some summary statistics.

Table 1. Summary of the REIT daily sample: 1 June 2008–30 April 2021.

REITs	Size ('million)	Date First Listed	Mean (%)	Median (%)	std. dev (%)
US (global REIT proxy)	1,070,235	June-65	0.026%	0.060%	2.129%
AU	100,677	April-71	0.014%	0.028%	1.800%
JP	147,962	September-01	0.025%	0.024%	1.487%
SG	54,112	July-02	0.025%	0.038%	1.311%
HK	24,022	November-05	0.051%	0.006%	1.173%
NZ	6141	December-93	0.031%	0.045%	1.207%
FR	33,476	June-03	0.001%	0.033%	1.880%
UK	82,755	January-07	0.002%	0.034%	1.853%
GE	3965	January-07	0.019%	0.037%	2.286%
IT	267	April-08	−0.013%	0.000%	2.377%
BE	18,638	November-95	0.025%	0.056%	1.317%
NE	2904	December-72	−0.012%	0.031%	1.721%

The 11 equity REIT markets are AU (Australia), JP (Japan), SG (Singapore), HK (Hong Kong), NZ (New Zealand), FR (France), UK, GE (Germany), IT (Italy), BE (Belgium), and NE (Netherlands). The US REIT market is used as a global REIT market proxy

We use daily frequency data expressed in USD, from the earliest 1 June 2008 to 30 April 2021 (the starting date was dictated by availability of data for Italy REITs), to extract the Standard and Poors (S&P) market returns, the S&P local stocks, a global REIT index

(proxied by the US REIT due to its sheer size of USD 1.07 trillion market capitalization), and a S&P global stock index. All the time series have no missing intermittent observations.

A three-factor return index model R_{jt} of the j th REIT market is:

$$R_{j,t} = a_j + b_{j,ls}U_{ls,t} + c_{j,gr}U_{gr,t} + d_{j,gs}R_{gs,t} + \varepsilon_j \tag{1}$$

where:

R_{gs} —global stock market return,

U_{rs} and U_{ls} are obtained as residuals (adjusted factors) from the following regressions by which the effects from local stock, global REIT, and global stock markets are orthogonalized:

$$R_{gr,t} = e + fR_{gs,t} + U_{gr,t}; R_{ls,t} = g + hR_{gr,t} + iR_{gs,t} + U_{ls,t}$$

R_{gr} = global REIT return; R_{ls} —local stock return

After estimating the conditional volatility (CV) series from the AR (1)-GARCH (1,1),¹ we employ the QR model to estimate (1) in volatility form:

$$Y = c + X'\beta + \varepsilon \quad \text{with } Q_y \left(\frac{\tau}{X} \right) = c + X'\beta(\tau)$$

where Y is the dependent variable, X is a vector of exogeneous variables, and $Q(\tau/X)$ denotes the τ th conditional quantile of Y which is linearly dependent on X . The values of $\beta(\tau)$ for $\tau \in [0, 1]$ determine the complete dependence structure of Y . The dependence of Y based on X could be constant, monotonically increasing (decreasing) or symmetric (asymmetric).

The coefficients of quantiles are estimated by minimizing the weighted sum of absolute errors using the linear programming algorithm:

$$\beta(\tau) = \operatorname{argmin} \sum_{t=1}^T (\tau - 1_{(y_t < x'_t \beta(\tau))}) \operatorname{abs}(Y_t - X'_t \beta(\tau))$$

Additionally, the QR approach is appropriate for capturing any marginal effects originating from different global factors, such as the two recent financial crises and the 2020 global pandemic on market interdependence. An extended QR model is developed for this purpose:

$$Q \left(\frac{\tau}{X} \right) = c(\tau) + \sum_k \beta_k(\tau) X_k + D[\pi(\tau) + \sum_k \varphi_k(\tau) X_k]$$

where D is the financial crisis (/Covid19) variable that takes the value of 1 if the dependent variable is in the financial crisis (/Covid19) subperiod, and zero otherwise. The parameters $\pi(\tau)$ and $\varphi_k(\tau)$ capture the additional marginal effects of the different conditional variables in the financial crisis subperiod for each quantile τ in comparison with the effects measured by the parameters $c(\tau)$ and $\beta_k(\tau)$ in the non-crisis period.

4. Results and Discussion

Equation (1) includes two time-dummy variables. D_{crisis} was used to capture the marginal effects in market interdependence due to two recent consecutive financial crises (GFC and European sovereign debt crisis, GFC, and EDC), which takes the value 1 over 1 June 2008–9 May 2012, and zero otherwise. $D_{covid-19}$ was employed to capture the effects of the global pandemic on the countries, which takes the value 1 over 1 January 2020–30 April 2021, and zero otherwise.

We observe that there is a positive and significant dependence between REITs' conditional volatilities and three factors for every part of the quantiles. In Table 2, which, for brevity, we only report the results of OLS and three major quantiles (0.01-lower quantile, 0.50-medium and 0.99-upper quantile). These three quantiles examine extreme REIT mar-

ket movements (bearish/normal/bullish). The average relationship revealed by the OLS results are mostly positive and appear satisfactory. Moving up the conditional distribution, the volatility interdependence effects with the local stock, the global REIT, and the global stock markets, are positive and significant across all conditional volatility distributions in all quantiles with some minor exceptions. We also note that the interdependence effects with the global REIT market are not significant at the three major quantiles in HK, whereas the global REIT volatility effect is significantly negative at the two extreme quantiles of JP REITs. In FR and IT, the local stock volatility effects are significantly negative at Q (0.01). In SG and BE in the bearish market, there is weak volatility dependence with the global stock market. Finally, there is a significant and negative global stock volatility effect on the GE REIT market in the bearish quantiles. Overall, considering the three major quantiles, and bearing in mind some cross-sectional heterogeneity on the cross-market differences, there are significant and positive effects (85 number, 85.9%) of REITs' quantiles with the three major factors. Thus, consistent with the existing literature discussed above, we have at least identified a strong volatility interdependence relationship between national REITs markets and three major market factors. Intuitively, the results may also imply a degree of market inefficiency in the sense that nonlinear volatility information from one or more of the three major market factors can be used to forecast volatility changes in some REIT markets. Following the efficient market hypothesis (EMH), there should not be any nonlinear volatility relationship between a specific national REIT market and the three influential factors; therefore, the quantile regression results imply that the REIT markets and the three major market factors are relatively inefficient in their conditional second moment measures.

Table 2 also reveals the marginal volatility effect is significantly positive in Dcovid-19 (18 number, 54.5%) and Dcrisis (23 number, 69.7%). Moreover, the two time-dummies have a stronger effect on the dependence structure at a lower quantile, in that the coefficient estimates are significantly positive in seven and nine cases of Dcovid-19 and Dcrisis, implying that during extreme bearish market periods, some REIT markets are more responsive to integration than in bullish/normal markets. Again, these results are intuitively pleasing.

Further analysis of upper and lower quantiles reveals that the interdependence levels increase during bullish markets with local stocks in JP/HK/NZ/FR/UK/BE REIT markets, with global REIT in SG/UK/GE/IT markets, and with global stock for REITs markets in AU/JP/HK/NZ/BE, whereas they decrease for some other REIT markets during bearish markets, especially with local and global stocks. Accordingly, the interdependence structure is asymmetric for some cases. Thus, REIT markets have become more globally integrated, implying more opportunities for international property investments and real estate asset securitization. This finding is especially empirically pleasing for smaller REIT markets which were initially developed locally, and will later need to invest in global activities (overseas markets).

The findings are supported by Table 3 (quantile slope equality test), which indicates the estimated coefficients are not constant across various quantiles and statistically significant for local stock (61, 69.3%), global REIT (51, 58%), and global stock (64, 72.7%) of slope parameters. Thus, we may conclude that the conditional quantiles tend not to be identical.

Table 2. Estimated results of the three-factor OLS and quantile regression models (with two crisis dummies).

	REITs	AU	JP	SG	HK	NZ	FR	UK	GE	IT	BE	NE
Local stock	OLS	2.233 ***	0.886 ***	1.293 ***	0.273 ***	2.073 ***	1.852 ***	5.895 ***	6.351 ***	0.821 ***	0.195 ***	1.705 ***
	Q(0.01)	0.325 ***	0.143 ***	0.306 ***	0.058 ***	0.291 ***	−0.299	−0.054	0.215 ***	−0.341	0.091 ***	0.081
	Q(0.50)	1.391 ***	0.894 ***	1.286 ***	0.239 ***	1.176 ***	1.171 ***	1.561 ***	0.833 ***	1.314 ***	0.156 ***	1.436 ***
	Q(0.99)	1.331 ***	3.941 ***	1.947 ***	1.724 ***	1.998 ***	4.570 **	12.858 ***	1.534 ***	1.879 ***	0.455 ***	4.471 **
Global REIT	OLS	0.029 ***	−0.065	0.322 ***	0.025 ***	−0.056	−0.054	0.220 ***	1.432 ***	0.484 ***	−0.019	−0.011
	Q(0.01)	0.117 ***	0.061 ***	0.142 ***	−0.003	0.059 ***	0.073 ***	0.162 ***	0.433 ***	0.244 ***	0.055 ***	0.080 ***
	Q(0.50)	0.156 ***	0.070 ***	0.179 ***	−0.003	0.021 ***	0.074 ***	0.489 ***	1.239 ***	0.438 ***	−0.003	0.038 ***
	Q(0.99)	0.781 ***	−0.222 **	1.954 ***	−0.174	−0.071	0.231 ***	0.656 ***	4.213 ***	1.059 ***	0.068 ***	−0.028
Gobal stock	OLS	1.269 ***	1.591 ***	0.358 ***	0.147 ***	1.121 ***	1.126 ***	0.016	−0.439	1.324 ***	0.904 ***	0.998 ***
	Q(0.01)	0.341 ***	0.056 ***	−0.011	0.016 ***	0.069 ***	0.571 ***	0.390 ***	−0.226	0.866 ***	0.055	0.481 ***
	Q(0.50)	0.975 ***	0.594 ***	0.391 ***	0.087 ***	0.138 ***	1.068 ***	0.564 ***	0.595 ***	1.094 ***	0.918 ***	1.008 ***
	Q(0.99)	2.315 ***	3.147 ***	0.409 ***	1.232 ***	0.613 ***	1.070 ***	0.791 ***	0.461 **	1.673 ***	1.302 ***	1.437 ***
D-Covid 19	OLS	$4.7 \times 10^{-0.5}$ ***	$2.60 \times 10^{-0.5}$	$5.6 \times 10^{-0.5}$ ***	$-3.50 \times 10^{-0.6}$	$1.2 \times 10^{-0.5}$ *	0.00061 ***	−0.0002	$-8.1 \times 10^{-0.5}$ ***	0.00012 ***	0.00002 ***	0.00028 ***
	Q(0.01)	$1.9 \times 10^{-0.5}$ ***	$9.3 \times 10^{-0.6}$ ***	$1.3 \times 10^{-0.5}$ ***	$-2.3 \times 10^{-0.6}$ ***	$1.50 \times 10^{-0.6}$	$-5.60 \times 10^{-0.6}$	$1.5 \times 10^{-0.5}$ **	$2.6 \times 10^{-0.5}$ ***	0.000008	0.00001 ***	0.00002 **
	Q(0.50)	$2.4 \times 10^{-0.5}$ ***	$6.00 \times 10^{-0.7}$	$-7.50 \times 10^{-0.7}$	$-5.1 \times 10^{-0.6}$ ***	$7.2 \times 10^{-0.6}$ ***	0.00041 ***	$-5.10 \times 10^{-0.6}$	$8.60 \times 10^{-0.6}$	0.00005 ***	0.00001 ***	0.00018 ***
	Q(0.99)	$3.5 \times 10^{-0.5}$ ***	$-9.10 \times 10^{-0.95}$	$-8.9 \times 10^{-0.5}$ ***	0.00011	$7.8 \times 10^{-0.5}$ ***	0.00016 ***	−0.00018 ***	−0.00014 ***	0.0018 ***	−0.00004 **	0.00085 ***
DCRISIS	OLS	$1.50 \times 10^{-0.5}$	$7.2 \times 10^{-0.5}$ ***	$-1.10 \times 10^{-0.5}$	$-2.6 \times 10^{-0.5}$ ***	$2.9 \times 10^{-0.5}$ ***	$8.9 \times 10^{-0.5}$ ***	0.00017 ***	0.00030 ***	0.00021 ***	0.00003 ***	0.00009 ***
	Q(0.01)	$3.4 \times 10^{-0.5}$ ***	$7.3 \times 10^{-0.5}$ ***	$2.7 \times 10^{-0.5}$ ***	$-5.3 \times 10^{-0.6}$ *	$1.9 \times 10^{-0.5}$ ***	$2.6 \times 10^{-0.5}$ ***	$3.5 \times 10^{-0.5}$ **	$9.3 \times 10^{-0.5}$ ***	$9.70 \times 10^{-0.6}$	0.00003 ***	0.00003 **
	Q(0.50)	$1.9 \times 10^{-0.5}$ ***	$-3.70 \times 10^{-0.6}$	$-7.70 \times 10^{-0.7}$	$-1.4 \times 10^{-0.5}$ ***	$3.6 \times 10^{-0.5}$ ***	$7.7 \times 10^{-0.5}$ ***	$7.1 \times 10^{-0.5}$ ***	0.00024 ***	$9.2 \times 10^{-0.5}$ ***	0.00003 ***	0.00004 ***
	Q(0.99)	0.00012	$-4.80 \times 10^{-0.5}$	$-6.5 \times 10^{-0.5}$ ***	$-9.7 \times 10^{-0.5}$ ***	$5.9 \times 10^{-0.5}$ ***	$8.6 \times 10^{-0.5}$ ***	$1.80 \times 10^{-0.5}$	0.00074 ***	0.00077 ***	0.00003 ***	0.00013 ***

The three selected influential factors of REITs' GARCH volatilities are the GARCH volatilities of the respective local stock markets, the global REIT market (using the US REITs as the proxy), and a global stock market benchmark. The two crisis dummies are: (a) D-COVID 19 is used to capture the effect of the global pandemic, which takes the value 1 for the period 1 January 2020 to 30 April 2021, and 0 otherwise; (b) Dcrisis is used to capture the effect on market interdependence of the two consecutive global financial crises (global financial crisis and European sovereign bond crisis), which takes the value 1 for the period 2 June 2008 to 9 May 2012, and 0 otherwise (based on official timelines). Although we implemented seven quantiles (0.01, 0.10, 0.25, 0.50, 0.75, 0.90, 0.99), for brevity, here, we just report on the results of the three major quantiles: 0.01 (lower quantile–bearish market), 0.50 (median quantile–normal market) and 0.99 (upper quantile–bullish market). Finally, ***, **, and * indicates statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 3. Results of the quantile slope equality tests.

REITS	AU	JP	SG	HK	NZ	FR	UK	GE	IT	BE	NE
Panel A; local stock											
0.01	S(**)	S(**)	S(**)	S(*)	S(**)	S(**)	S(**)	NS	S(**)	NS	S(**)
0.10	S(**)	S(**)	S(**)	S(**)	S(**)	S(**)	S(**)	NS	S(**)	NS	NS
0.10	S(**)	S(**)	S(**)	S(**)	S(**)	S(**)	S(**)	NS	S(**)	NS	NS
0.25	S(**)	S(**)	S(**)	S(**)	S(**)	S(**)	S(**)	S(**)	S(**)	NS	S(**)
0.25	S(**)	S(**)	S(**)	S(**)	S(**)	S(**)	S(**)	S(**)	S(**)	NS	S(**)
0.50	NS	S(**)	NS	S(**)	S(**)	S(**)	S(**)	S(**)	NS	NS	S(**)
0.50	NS	S(**)	NS	S(**)	S(**)	S(**)	S(**)	S(**)	NS	NS	S(**)
0.75	S(*)	NS	S(**)	NS	S(**)	S(**)	S(**)	NS	NS	NS	NS
0.75	S(*)	NS	S(**)	NS	S(**)	S(**)	S(**)	NS	NS	NS	NS
0.90	S(*)	S(**)	NS	S(**)	NS	NS	NS	NS	NS	S(**)	NS
0.90	S(*)	S(**)	NS	S(**)	NS	NS	NS	NS	NS	S(**)	NS
0.99	S(**)	S(**)	S(**)	S(**)	S(**)	S(**)	S(**)	S(**)	S(**)	NS	S(**)
0.99	S(**)	S(**)	S(**)	S(**)	S(**)	S(**)	S(**)	S(**)	S(**)	NS	S(**)
0.99	NS	S(**)	S(**)	S(**)	S(**)	S(**)	S(**)	NS	S(**)	NS	S(**)
total no of sig qunatiles slope test: 61(69.3%)											
Panel B: global REIT											
0.01	NS	NS	NS	NS	NS	NS	S(**)	S(**)	S(**)	S(**)	NS
0.10	NS	NS	NS	NS	NS	NS	S(**)	S(**)	S(**)	S(**)	NS
0.10	NS	NS	NS	NS	S(**)	S(*)	NS	S(**)	S(**)	S(**)	NS
0.25	NS	NS	NS	NS	S(**)	S(*)	NS	S(**)	S(**)	S(**)	NS
0.25	NS	NS	S(**)	NS	S(**)	NS	S(**)	S(**)	NS	S(**)	S(*)
0.50	NS	NS	S(**)	NS	S(**)	NS	S(**)	S(**)	S(**)	S(**)	NS
0.50	NS	NS	S(**)	NS	S(**)	NS	S(**)	S(**)	S(**)	S(**)	NS
0.75	S(**)	S(**)	S(**)	NS	S(**)	S(**)	NS	S(**)	S(**)	S(**)	S(*)
0.75	S(**)	S(**)	S(**)	NS	S(**)	S(**)	NS	S(**)	S(**)	S(**)	S(*)
0.90	S(**)	S(**)	S(**)	NS	NS	S(**)	NS	S(**)	NS	NS	NS
0.90	S(**)	S(**)	S(**)	NS	NS	S(**)	NS	S(**)	NS	NS	NS
0.99	S(**)	S(**)	S(**)	NS	NS	S(**)	NS	S(**)	NS	NS	NS
0.99	S(**)	S(**)	S(**)	NS	NS	S(**)	NS	S(**)	NS	NS	NS
0.99	NS	NS	NS	NS	S(**)	NS	S(**)	S(**)	S(**)	S(**)	S(**)
0.99	S(**)	S(**)	S(**)	NS	S(**)	S(**)	S(**)	S(**)	S(**)	S(**)	S(**)
0.99	S(**)	S(**)	S(**)	NS	S(**)	S(**)	S(**)	S(**)	S(**)	S(**)	S(**)
total no of sig qunatiles slope test: 51 (58%)											
Panel C: global stock											
0.01	S(**)	S(**)	S(**)	S(**)	S(*)	NS	S(**)	S(**)	NS	S(**)	S(*)
0.10	S(**)	S(**)	S(**)	S(**)	S(*)	NS	S(**)	S(**)	NS	S(**)	S(*)
0.10	S(**)	S(**)	S(**)	S(**)	NS	NS	S(*)	NS	S(**)	S(**)	S(**)
0.25	S(**)	S(**)	S(**)	S(**)	NS	NS	S(*)	NS	S(**)	S(**)	S(**)
0.25	S(**)	S(**)	S(**)	S(**)	NS	NS	S(**)	NS	S(**)	S(**)	S(**)
0.50	S(**)	S(**)	S(**)	S(**)	NS	NS	S(**)	NS	S(**)	S(**)	S(**)
0.50	S(**)	S(**)	S(**)	S(**)	NS	NS	S(**)	NS	S(**)	S(**)	S(**)
0.75	S(**)	S(**)	S(**)	S(**)	S(**)	S(**)	S(*)	S(*)	NS	S(**)	S(**)
0.75	S(**)	S(**)	S(**)	S(**)	S(**)	S(**)	S(*)	S(*)	NS	S(**)	S(**)
0.90	NS	S(**)	NS	S(**)	S(**)	S(**)	S(**)	NS	NS	S(**)	S(**)
0.90	NS	S(**)	NS	S(**)	S(**)	S(**)	S(**)	NS	NS	S(**)	S(**)
0.99	S(*)	NS	NS	S(**)	NS	NS	S(**)	NS	NS	S(**)	S(**)
0.99	S(*)	NS	NS	S(**)	NS	NS	S(**)	NS	NS	S(**)	S(**)
0.99	S(**)	S(**)	S(**)	S(**)	S(**)	S(**)	S(*)	S(**)	S(*)	S(**)	S(**)
0.99	S(**)	S(**)	S(**)	S(**)	S(**)	S(**)	S(*)	S(**)	S(*)	S(**)	S(**)
0.99	S(**)	S(**)	S(**)	S(**)	S(**)	S(**)	S(*)	S(**)	S(*)	S(**)	S(**)
0.99	S(**)	S(**)	S(**)	S(**)	S(**)	S(**)	S(*)	S(**)	S(*)	S(**)	S(**)
total no of sig qunatiles slope test: 64 (72.7%)											

*, ** and ***, indicates statistical significance at the 10, 5 and 1% levels.

This tests the null hypothesis that the slope parameters are equal across the various quantiles (S: significant; NS: not significant). Rejection of the null hypothesis implies that the slopes are significantly different at the 1% (***) , 5% (**), and 10% (*) levels, respectively. The results are provided for every two quantiles (for example, Q (0.0) = Q (0.10)), lowest quantile against the median (Q (0.01) = Q(0.50)), and for the highest quantile against the median (Q(0.50) = Q(0.99)). The 11 equity REIT markets are AU (Australia), JP (Japan), SG (Singapore), HK (Hong Kong), NZ (New Zealand), FR (France), UK, GE (Germany), IT (Italy), BE (Belgium), and NE (The Netherlands). The US REIT market is used as a global REIT market proxy. Finally, Table 4 provides some evidence of asymmetrical dependence with local stock (14, 42.4%), global REIT (20, 60.6%), and global stock (20, 60.6%), implying that over 60 percent of the REIT quantiles display asymmetric co-movements with the global REIT and global stock markets as the degree of dependence increases when these markets are booming, but the dependence level declines when the markets are bearish.

Table 4. Summary results for symmetric quantiles test.

Symmetry Test'-FINAL									
Quantiles	Local Stock			Global REIT			Global Stock		
	0.01 0.09	0.1 0.9	0.25 0.75	0.01 0.09	0.1 0.9	0.25 0.75	0.01 0.09	0.1 0.9	0.25 0.75
AU	ASY ***	SY	SY	ASY ***	ASY *	SY	ASY ***	ASY ***	ASY ***
JP	ASY ***	ASY ***	SY	ASY ***	ASY **	SY	ASY ***	ASY ***	ASY ***
SG	SY	SY	SY	ASY ***	ASY **	SY	ASY ***	ASY *	SY
HK	ASY ***	SY	SY	SY	SY	SY	ASY ***	SY	SY
NZ	SY	SY	SY	ASY ***	ASY ***	ASY **	ASY ***	ASY ***	ASY **
FR	AYS **	ASY	SY	AYS ***	SY	SY	ASY *	SY	SY
UK	ASY ***	ASY ***	ASY ***	SY	AYS **	AYS ***	SY	ASY *	ASY ***
GE	SY	SY	SY	AYS ***	AYS ***	SY	ASY *	SY	SY
IT	ASY ***	ASY **	ASY **	AYS ***	AYS ***	AYS **	SY	SY	SY
BE	SY	SY	SY	ASY ***	ASY ***	ASY ***	ASY ***	ASY ***	ASY ***
NE	ASY ***	ASY ***	ASY ***	SY	SY	SY	SY	ASY ***	ASY ***
No of ASY	14 (42.4%)			20 (60.6%)			20 (60.6%)		

If the null is rejected at the conventional levels, then this test of conditional symmetry (SY) will reveal some/more evidence of conditional asymmetry (ASY). ***, ** and * indicates statistical significance of the ASY at the 1, 5, and 10% levels, respectively. The 11 equity REIT markets are AU (Australia), JP (Japan), SG (Singapore), HK (Hong Kong), NZ (New Zealand), FR (France), UK, GE (Germany), IT (Italy), BE (Belgium), and NE (The Netherlands). The US REIT market is used as a global REIT market proxy.

Regarding the relative magnitudes of market integration with the three major factors across the two regional groups, Table 5 reports that the respective interdependence levels are increasing, and it assumes the highest at the upper quantile, implying that the effects of the three influential market factors are stronger during bullish markets.

Table 5. Overall and regional (Asia-Pacific and European) REIT market interdependence levels with local stocks, global REITs, and global stocks.

Panel A: Asia-Pacific REIT markets (AU/NZ/JP/SG/HK)			
Quantile	local stock	Global REIT	Global stock
0.01	0.225	0.075	0.094
0.1	0.467	0.078	0.191
0.25	0.728	0.077	0.291
0.5	0.997	0.085	0.437
0.75	1.221	0.095	0.773
0.9	1.519	0.163	1.149
0.99	2.188	0.454	1.543
Panel B: European REIT markets (FR/GE/UK/IT/BE/NE)			
Quantile	local stock	Global REIT	Global stock
0.01	−0.051	0.174	0.356
0.1	0.211	0.248	0.551
0.25	0.555	0.284	0.649
0.5	1.079	0.379	0.874
0.75	1.971	0.507	1.017
0.9	3.431	0.679	0.964
0.99	4.295	1.033	1.122
Panel C: All-REIT markets			
Quantile	local stock	Global REIT	Global stock
0.01	0.087	0.125	0.225
0.1	0.338	0.163	0.371
0.25	0.641	0.181	0.469
0.5	1.038	0.232	0.656
0.75	1.595	0.301	0.895
0.9	2.475	0.421	1.056
0.99	3.241	0.743	1.333

For the Asia-Pacific REIT group, its average volatility interdependence level with the local stock market is consistently the highest. A stronger linkage between these REIT markets and local stock markets—for small locally oriented stock markets in particular—could be driven by the fact that these REIT companies initially only invest domestically, and thus, are much more vulnerable to domestic economic shocks; however, given the increasing economic integration, the domestic economy and REIT markets are increasingly connected to international stock markets, which might cause direct spillovers to the property markets.

A different situation emerges for European REIT markets in that the average effects of the global stock market are stronger than the local stock market at the first three quantiles for some markets, such as FR/UK/GE. From the medium quantile onward, the local stock market effects assume a higher predominance compared with the global stock market. One possible explanation for this detected regional difference is that some European stock markets such as FR/UK/GE/IT have higher correlations with the global stock market because of the impact of geographical proximity on market integration; although, developed Europe accounted for only around 13.75% of the global market as of February 2017 (Moss 2018). This trend of absolute growth (from USD 50 billion to USD 200 million) and relative decline in the global market share, reflects the improving direct property market values; for example, GFC and some equity issuance, which has been somewhat overshadowed by growth in the US market. These Europe REIT markets are more ready to attract regional and international investors to their real estate equity and debt investment instruments, in an era of increasing globalization and real estate asset securitization; however, they still need more time to grow domestically due to their respective younger ages of establishment (such as Italy and Germany).² Overall, we expect that the average REIT's volatility interdependence effect with the global stock market, will fluctuate intermittently in the short run, but we are cautiously optimistic that the long-run effect will be consistently higher than the local stock market in years to come (with global REIT market bridges between global stock and local

stock) for the European economies, as several national REIT markets (such as UK/FR/GE) will become more mature and globally integrated. Thus, our work broadly agrees with Liow (2012), who finds that conditional real estate stock correlations at the local and global levels are time-varying and asymmetric in some cases using different approaches, as was the case with his sample of eight Asian public real estate markets over 1995–2009. Moreover, real estate global stock correlations co-move significantly and positively with real estate local stock correlations.

5. Conclusions

The research paper expands the existing literature by analysing the dependence structure between 11 national REIT markets and local stock, global REITs, and global stocks, using the advantageous QR methodology on a simultaneous three-factor model. Modelling dependence between established REIT markets and the three major market factors is of great importance for the market participants (investors and policy makers) as the obtained results can be used to make important portfolio allocation decisions, especially for those established REITs which need to go “international” at some points to support continuing corporate growth and dividend payments to unitholders. Historically, almost all REIT markets were initially established and developed locally (horizontal development), and therefore, they were closely connected to local economic conditions (horizontal integration). Then, they need to acquire and invest in international property holdings (via vertical development and integration) to continue to grow. An interesting question emerging from this process is the mechanism by which REIT market volatilities are connected globally, perhaps through some important connections/spillovers in the REITs’ cash flow, market growth, or discount rate as the markets are more integrated. This paper contributes to understanding how global market (both global REITs and the global stocks) integration is related to this important market connectedness question.

Overall, the existence of significant dependence between national REIT markets and local stock/global REIT/global stock is critical in contributing towards healthy market growth in this new asset class. Several key findings emerge from this study, thereby presenting a particular importance for regulators to make policy decisions. They are summarized as follows:

- (a) A simultaneous dependence structure exists between each REIT market and local stock, global REIT market, and global stock market. Overall, there is positive and significant dependence between the REIT and the three factors for every one of the quantiles. Across each quantile, Asia-Pacific REIT markets have a consistently higher average degree of dependence with their local stock market than with the global stock and global REIT markets, whereas European REIT markets are generally more globally integrated.
- (b) The estimates for the lower and upper quantiles for over half of the REIT-quantiles for the three market factors are generally statistically different. Additionally, some REIT markets display an asymmetric co-movement with at least one of the three factors as the degree of dependence increases when these markets are booming, but the dependence level declines when the markets are bearish.
- (c) The dependence structure and the co-movement between some REITs’ market volatility and the three factors were affected by the 2008–2012 financial crises and the COVID-19 pandemic in 2020, in that during these extreme bearish market periods, these markets can be significantly more responsive to integration than in bullish/normal markets.

This evidence of dependence across the three influential factors and REIT markets provides meaningful insights into REIT market growth, international asset pricing, risk management, and dynamic linkages in the global economy. This research is particularly helpful for portfolio risk management, policy makers, financial institutions, and international investors who should be cautious about making investments in simultaneous REIT and common stock markets that display pure contagion. Cognizance of the dependencies

of the REIT markets is crucial for policy makers to discern the directions of REIT common stock co-movement, and to safeguard the REIT markets from contagion during future crises or major events, while at the same time, being able to strike a balance with market growth.

In this regard, some important future work could involve the modelling of portfolio benefits of diversification and extreme risk management across the individual REIT markets in the context of asset pricing/market integration. One last possible research avenue involves exploring the appropriate structure and optimal level of overall interdependence between REIT markets at both the regional and global levels due to increasing REIT market maturity over time. This is because excessive integration could inadvertently facilitate contagion, whereas inadequate integration does not contribute to REIT market growth (Parker 2018). Pending the expanded development and maturity of this younger asset class in several countries, with a larger REIT sample, it would be interesting to extend the present “three-factor” research to a “four/ five-factor” study, using a time-varying dependence structure governed by the following specification: REITs (dependence structure) = f (local stock, global REIT, global stock market, global EPU (global economic policy uncertainty), global interest rate). We shall leave this integration/contagion issue for future work.³

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Notes

- ¹ The diagnostic of standardised residuals suggests that the residuals and squared residuals are not serially correlated. As such, the AR (1)—GARCH (1,1) model appears to be adequate. The detailed results are straightforward, and thus, not reported for brevity.
- ² Remember that the US REIT market took much more time to grow horizontally, as well as vertically, in order to maintain and improve its competitive advantage over other regional and national REIT markets.
- ³ We sincerely thank the reviewer for proposing this constructive suggestion to conclude the paper.

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