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## Article

# On the global integration of REITs market returns: A multiresolution analysis

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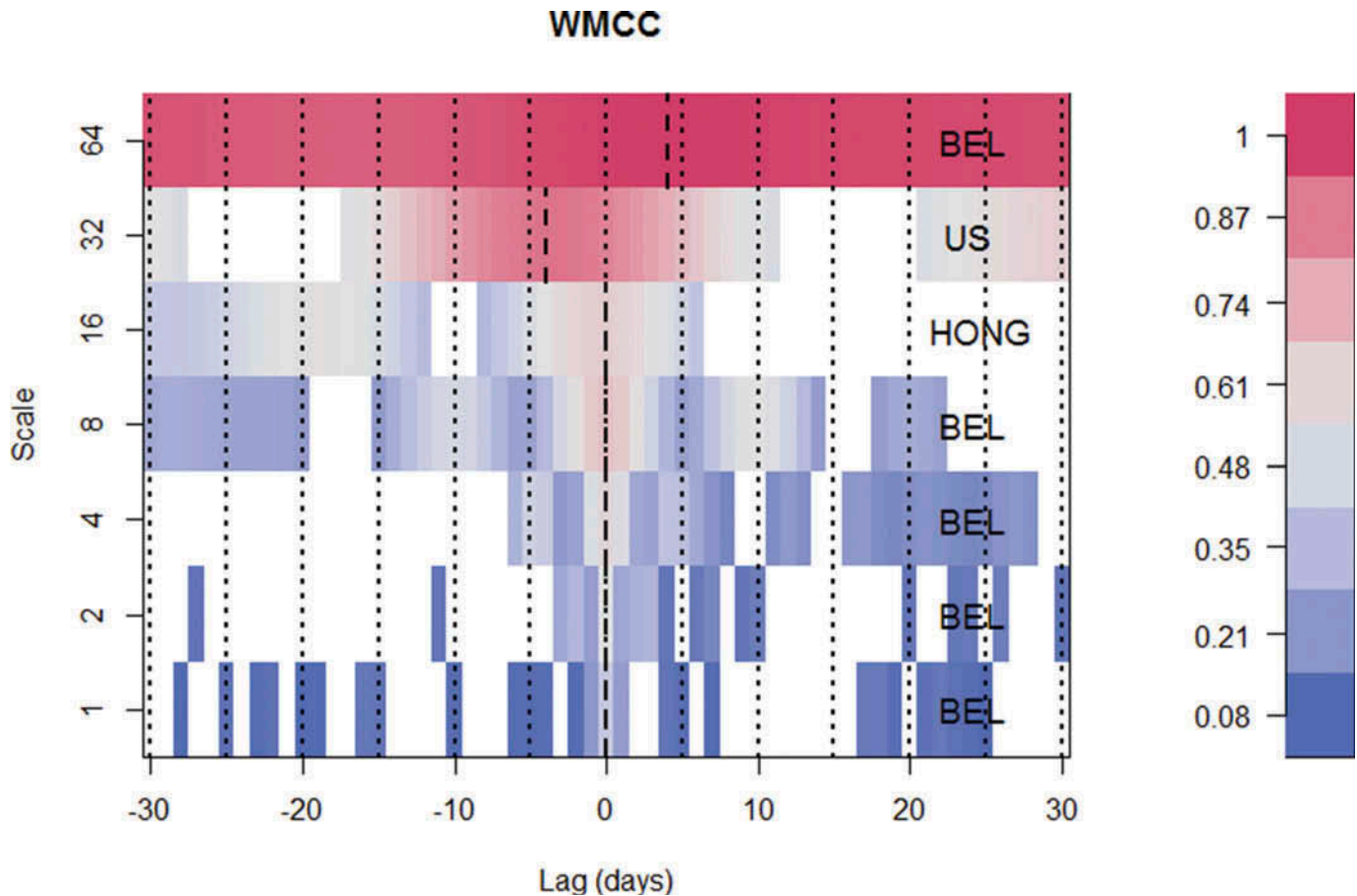
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## GENERAL & APPLIED ECONOMICS | RESEARCH ARTICLE

# On the global integration of REITs market returns: A multiresolution analysis

Kola Ijasan<sup>1\*</sup>, George Tweneboah<sup>2</sup>, Maurice Omane-Adjepong<sup>2</sup> and Peterson Owusu Junior<sup>2</sup>

**Abstract:** This paper explores dynamic correlation and interdependence of five global REIT markets using multivariate wavelet methods. United States, Hong Kong, Belgium, South Africa and Australia's daily REITs returns are used as proxies for North America, Asia, Europe, Africa and the Oceania continents, respectively. Highlights from our results indicate the following: First, almost a perfect market integration at long-run periods for the REIT markets is observed. However, such strong market correlations dissipate significantly to moderate and weaker linkages at the medium, and short-run periods, thereby showing possible diversification opportunities at the latter scales. The finding also signifies that global REITs linkages increases with investment horizons. Second, an interdependent global market is found, where well-developed REITs tend to lead/lag relatively smaller or less developed market (especially Africa's REIT) across scales. Third, there are prospects of gaining higher expected daily returns per unit of risk from Europe and Asia's REITs than all other markets. Though not totally integrated, there exist conspicuous evidence against a segmented global REIT market. Our findings are useful for improving portfolio selection and minimising trading risk.

## ABOUT THE AUTHORS

Kola Ijasan is a research scholar with special interests in Real Estate Corporate Finance and Valuation. He is a South Africa National Research Foundation Rated researcher with more than 15 years experience in real estate market analysis, investment and housing studies.

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## PUBLIC INTEREST STATEMENT

There are many ways of investing in real estate, REITs are one of such ways. Investors and fund managers alike are continuously seeking ways of maximizing returns while minimizing risk. One of the ways of achieving this is through portfolio diversification. Research is needed to know where to invest (which market to invest). Investors would not want to invest in integrated markets because in such cases, anything that affect market 1 would also affect market 2. What this research does is to compare five global REITs to see if they are integrated. This research uses an advanced multiresolution analysis statistical method called wavelets to compare returns among the five global REITs.

This paper offers greater diversification possibility for international investors in the short-to-medium runs; and an abundant diminished investment advantage in the long-run. Portfolio risk of international investors may also be minimised by incorporating the trading scale dynamics when designing global portfolios using the REIT markets.

**Subjects:** Multivariate Statistics; Statistics & Computing; Statistics for Business, Finance & Economics; Economics; Finance

**Keywords:** Global REITs; multiresolution analysis; MODWT; scale; diversification

**JEL classification:** C22; F21; G1; G32

## 1. Introduction

A huge conundrum that continue to hang on the necks of funds managers and investment practitioners across the world borders on how integrated low risk and high returns have been. In order to achieve a harmonious integration, portfolio managers often track the spread of returns as frequently as possible. Investors are subsequently advised on which assets to buy based on this spread of returns. Even though volatility is measurable, actual prices of stocks are difficult to predict definitely. In an attempt to mitigate this situation, portfolio managers usually diversify their investments. On the international front, ideally, managers seek investments in markets that are well insulated from each other so that, in particular, the effects of a collapse in one market are not transmitted to investment holdings in other markets, i.e. ensuring that the markets do not comove. This has made the concept of market integration or segmentation one of the prime importance (Wilson & Okunev, 1996).

The property of Real Estate Investment Trusts (REITs) as a hybrid of a real (properties) and a financial (shares) asset (Liow, Zhou, & Ye, 2015; Tirtiroglu, Nguyen, Tirtiroglu, & Wee, 2017) engender a close relations with other financial markets. However, other studies have propounded theoretical channels through which REITs could integrate with traditional financial markets. They include the “wealth effect” (Case & Shiller, 2003; Kapopoulos & Siokis, 2005; Quan & Titman, 1999), “credit-price effect” (Chen, 2001; Hui & Ng, 2012; Sim & Chang, 2006), “capital switching effect” (Lizieri & Satchell, 1997; Oikarinen, 2006), “financial contagion theory” (Tsai, 2015), among others.

An argument beyond financial modelling is often the problem of contagion and shock transmission (Chiang, Jeon, & Li, 2007). According to Forbes and Rigobon (2002), contagion is defined as “significant increases in cross-market co-movement”; it is a significant increase in correlation between asset returns in different markets. Babecky et al. (2013) also argue that market integration enhances investment opportunities and allows higher returns at the same level of risk. This is the mainstay of risk management techniques (such as diversification) seek to attain. Investors want to allocate portfolios with different levels of risk and with minimal possibilities of shock and volatility transmission.

Globally, REITs markets have been gaining remarkable attention. Global market capitalisation now stands at approximately US\$1.7trillion, up from US\$734billion in 2010 (Ernst and Young, 2017). Investors are beginning to consider the numerous benefits REITs present and the diversification potentials associated with it. The REIT markets have become an attractive trading avenue to add real estate exposure to a portfolio because of their historically high returns and high dividend payouts, but a review of extant literature by Stelk, Zhou, and Anderson (2017) document evidence that the link between REIT returns and physical real estate returns is mixed. A school of thought supports the notion that “risk reduction” is possible with portfolio holdings of REITs with stocks (see, Boudry, deRoos, & Ukhov, 2016; Chen, Ho, Lu, & Wu, 2005; Grissom, Kuhle, & Walther, 1987; Kuhle, 1987; Lee & Stevenson, 2005). On the flip side of the argument, some studies such as Wang, Erickson, and Chan (1995) and Glascock, Michayluk, and Neuhauser (2004) question the diversification potentials of REITs. They argue that REITs are highly correlated to stocks and bonds and hence diversification is not optimal.

Physical real estate is unarguably a good investment; however, institutional or international investors have expressed various challenges that technically prevent them from investing directly in real estate, hence another benefit of REITs. There have been different methods and techniques adopted in the literature to explore whether or not diversifying into international REITs improves the efficiency of portfolio.

However, these studies provide limited insights, particularly because they do not account for time-scale dynamics in investor/investment behaviour. It is inherently possible that direction and magnitude of the links between REITs markets across the globe vary over the short-, medium-, and the long-terms (frequencies) because financial markets have many time-scales (Liow, Huang, & Song, 2019; Loh, 2013). In this light, this research discovers the dynamic correlations and inter-dependences of global REIT markets. With the help of multivariate wavelet methods, we examine the interrelationships among five global REITs markets. The multivariate wavelets approach is deemed appropriate as the wavelet transforms offer a particularly appealing data transformation, as a preliminary to data analysis. The research analyses daily REITs returns for United States, Hong Kong, Belgium, South Africa and Australia's, as proxies for North America, Asia, Europe, Africa and the Oceania continents, respectively. Daily closing price data from 8 July 2013 to 3 November 2017 was used to generate daily returns series for the five REITs markets. The results are classified by regions. Our findings showed that global REITs provide greater diversification opportunity for international investors in the short-to-medium runs; and a bounteous diminished investment advantage in the long-run.

The paper offers four key contributions. Aside adding to the literature on dynamic correlation, shock transmission, and contagion effect of international REITs markets, this research firstly answers the fundamental question of whether or not the inclusion of global REITs offers significant diversification benefit to investors. Secondly, using the Maximal Overlap Discrete Wavelet Transform (MODWT) in a wavelet multiple correlation (and cross-correlation) for the REITs market analysis overrides the limitations of the conventional coherence and the wavelet-based pairwise methods. Thirdly, from a return-to-variability ratio analysis, we answer the question of which regional REIT market(s) gives higher prospects of yielding greater daily returns with correspondingly lower risk-bearing? And finally, we review to unveil any form of dynamic correlation across different time-scales between international REIT markets, by situating a fast-embryonic Africa's REIT, coupled with well-developed and/or scrutinised REITs in the international cross market analysis.

We summarise results from the study as follows: (1) Evidence of almost a perfect market integration at long-run periods for the REIT markets is revealed. However, such strong market coherences dissipate significantly to moderate and weaker linkages at the medium-, and short-run periods. This signifies that REIT markets linkages increases with investment scales or horizons. As such, when designing international portfolios, investors' profile with respect to trading horizons must be duly incorporated. (2) The global market is characterised by interdependency, where the European REIT has greater likelihood to become a market leader or follower at short-, and long-run horizons; whereas the REIT markets of Asia and North America take a turn as leaders or followers in the medium-runs. This is suggestive of global linkages where developed REITs tend to lead/lag relatively smaller or less developed market, especially Africa's REIT. (3) There exist prospects of gaining higher expected daily returns with correspondingly lower risk-bearing from Europe and Asia's REIT markets. However, highly volatile and thus riskier markets (Africa and Oceania, respectively) are less compensated through expected returns on such assets. These findings proffer several practical implications for international investors.

The rest of the study is structured as follows: section 2 covers a brief review of the extant body of literature on REITs and co-movement of equities. In section 3, we present a description of the multiple wavelets approach and the stochastic properties of the data. Section 4 captures the wavelet coherence analysis of the markets. The last section details the conclusion and policy implications of the findings.

## 2. Literature review

There are many forms of REITs. Common amongst them include residential, equity, mortgage and private REITs. REITs are true total return investments. They provide high dividend yields along with moderate long-term capital appreciation. A common reference point in portfolio risk diversification using REITs is Kuhle (1987). The author concluded that the risk reduction capabilities of REITs were



lower than those of common stocks. This research has spurned many other similar researches. Reason for this is due to the fact that there is a common notion on the all-good nature of REITs, and so it is difficult to accept the fact that REITs might not be as safe as they have been sold to investors.

There have been many studies on the correlation of real estate assets as part of a diversified investment portfolio. Many of these studies have used different methodologies for their analysis, and different proxies for what they referred to as real estate. Hartzell, Hekman, and Miles (1986) adopted capital appreciation return to evaluate the diversification benefits of US residential property investment in a portfolio context for 1973 to 1983. They concluded that aside inflation hedging, the inclusion of real estate assets in a portfolio offered “attractive diversification opportunities for stock and bond portfolios”. In a research by Liu, Hartzell, and Hoesli (1997) and Zhou and Clements (2010), both disproved the findings of Hartzell et al. (1986), and found evidence that property securities (Property Trusts, Real Estate Mutual Funds, Shares of Real Estate Operating/Development Companies) provide a bad hedge against inflation. That means, the general assumption of inflation hedging characteristics of physical real estate cannot be generally assumed for securitised real estate. Grissom et al. (1987) found non-systematic risk diversification effects of between 83% and 90%, respectively, when the portfolio size is increased to include 10 real estate objects. This figure could even be as many as 400–500, in order to reduce the risk of a property portfolio down to the market level (Byrne & Lee, 2001).

More recently, Reddy and Wong (2016) using intertemporal capital asset pricing model (ICAPM), reported that both the diversified and retail sector exhibited strong exposure to market risk, and short-, and long-term interest rates within the Australia REITs (A-REITs). With such assertions on the need for the inclusion of many properties, many investors are looking to global REITs as a medium for both risk reduction and portfolio risk elimination. The International Monetary Fund reports that more than 70% of global growth of REITs comes from emerging markets, while 65% of REITs tracked by the NAREIT comes from outside the USA. The Australian REITs (A-REITs) has seen mixed returns over the years. According to Newell and Peng (2009), even though the global financial crisis hits A-REITs very hard, the crisis has had a major impact on A-REITs, both in terms of stock market volatility and concerns over the structure of A-REITs. The authors further reported that the A-REITs market capitalisation reduced from A\$132 billion to A\$52 billion in December 2008. However, the market recovered in the 2009, and now constitutes around A \$125 billion (10%) of the total Australian share market value (Reddy & Wong, 2016).

Elsewhere, Akinsomi, Balcilar, Demirer, and Gupta (2017) explored the effect of gold market speculation on South African REITs. Historically, South Africa's listed properties asset class has outperformed cash, equities and bonds for more than 10 years (SA REITs Association, 2015), however, using the Markov switching time-varying parameter (MS-TVP), Akinsomi et al. (2017) found that there is evidence indicating that the South African market entered into a long-run herding pattern, starting with the global financial crisis period in mid-2008; and that the herding pattern lasted until mid-2013. They also found that higher level of speculation in gold significantly contributes to herding in the South African REITs.

Niskanen and Falkenbach (2010) examined the sensitivity of European REIT returns to returns in other asset classes (including equities, bonds, and commodities). Their results suggest that there is a “significant positive correlation” between European REITs and equities; although they found REIT correlation to fixed income securities to be negative. To reduce exposure due to instabilities within countries, international diversification of REITs investment is proposed. However, the question asked by this research is “are there any forms of interdependence or dynamic correlation between international markets”?

Gordon and Canter (1999), in a study covering data from 1984 to 1997, concluded that the correlation coefficients of REITs and property stocks on a country-by-country basis for 14 countries are not stable over time. Chang and Chen (2014) noted that global financial crises can impose

contagion on markets, however, the results of this remain inconclusive. For example, Bond, Dungey, and Fry (2006) studied contagion in the REITs markets and property stock markets of Singapore, Hong Kong, Japan, Australia, and the United States. Using the 1997 financial crisis in East Asia as a reference point, they found evidence of contagion. This made them conclude that international diversification in global property investment provides only limited benefits. However, Hatemi-J and Roca (2011) investigated the US, UK, Japan, and Australia REIT markets during the 2008 subprime crisis, and find no evidence for contagion. In the Central and Eastern European CEE REITs market, Gilmore and McManus (2002) examined the short-, and long-term relationships between the US stock market and three CEE emerging markets (Hungary, Poland, and Czech Republic) with weekly data covering July 1995 to August 2001. They found that low short-term correlations between the CEE markets and the US existed. This is consistent with Gelos and Sahay (2001), Schotman and Zalewska (2006), and Wang and Moore (2008).

Employing co-integration methods, Yunus and Swanson (2007) explored long-run and short-run causal relationships among four public property markets in the Asia-Pacific, and with similar market from the US, over the period from January 2000 to March 2006. They reported of a greater portfolio diversification benefits over the Hong Kong and Japanese markets for US investors at the long-run period. Their findings also pointed to a wide range of diversification opportunities at the short-run, as no significant linkages were identified for the US and the Asia-Pacific property markets.

On the study of international REITs co-movement, Zhou (2010) considered six REITs (US, UK, Japan, Australia, Hong Kong, and Singapore), and later analysed each REIT with its country's stock market. Asserting to be the maiden paper to have used bivariate wavelet method in REIT market analysis, the author found co-movement of international REIT returns to be frequency-dependent. His findings again revealed that larger REITs tend to become market leaders over smaller markets with varying degree across frequencies. Relatively current, Begiazi et al. (2016) used BEKK-GARCH and DCC-GARCH models to investigate return and volatility nexuses of two US REIT sub-sectors, and their linkages with Europe, Americas, and Asia-Pacific REIT markets. Their study concluded by surmising that investors should duly account for time-varying correlations and volatility across several world market jurisdictions in a situation to achieving optimal portfolio allocation.

Using seven international REIT markets—France, Singapore, Japan, UK, Hong Kong, Australia, and US in a multiscale analysis, Zhou (2012) found strong evidence of scale-varying market linkages for the daily REIT returns, which covered periods from 1 January 1990 to 31 December 2009. The author concluded in favour of greater diversification benefits for investors in the short time horizons. However, his work on international REITs excluded the African continent which has produced one the world's fastest-growing REIT market—South Africa's REIT. Although Zhou (2012) claimed to be the first paper to have applied Maximal Overlap Discrete Wavelet Transform in REIT market analysis, yet the use of pairwise wavelet-based correlation method flooded the author's work with 21 market-paired correlations. Similar pairwise wavelet multiple correlation approach was also used by Liow and Zhou (2016), as they studied cross market correlation dynamics among three public REITs (Hong Kong, Mainland China, and Taiwan in Greater China), and their respective linkages with US, UK and Japanese public REITs, using data from 1995 to 2015. The authors found scale-dependent market return and volatility linkages which give higher diversification opportunity at the short-run horizon.

Chang and Chen (2014) noted that previous studies which have dealt with dynamic correlations in the presence of contagion using simple correlation coefficient analysis are fraught with limitations relating to volatility clustering, weights to return data points in estimations, and more importantly, an underlying Gaussian distribution assumption of asset returns and linear dependences.

To mitigate against these apparent drawbacks, this paper applies the MODWT with Daubechies asymmetric wavelet filter in a multiresolution analysis (MRA) and includes an emerging Africa's REIT in the international market analysis. With single diagrammatic representations, the wavelet



multiple correlation and cross-correlation methods appear to be robust and complement each other in finding dynamic international REITs market behaviour across time and frequency. These methods are explained in the next section.

### 3. Empirical methodology and data

Beside the earlier mentioned methodological drawbacks, several empirical studies on (cross) market integration of REITs have widely resulted to the use of popularly known conventional methods such as correlation coefficient and co-integration analyses (Gordon & Canter, 1999; Gilmore & McManus, 2002; Yunus & Swanson, 2007; Niskanen & Falkenbach, 2010; etc.), GARCH-type models (Begiazi, Asteriou, & Pilbeam, 2016; Kyriaki et al., 2016; etc.) and intertemporal capital asset pricing model (Reddy & Wong, 2016). However, most of these methods do not possess time-varying and/or time-frequency properties to completely analyse market integration. For instance, the latter models are somehow designed to capture relationships in mainly two investment periodicities, short and long-terms, yet the behaviour of REIT markets look heterogenous across time-scales. This becomes more apparent as market traders seek to divulge varying trading strategies across different investment horizons to make higher returns with correspondingly lower risk. Hence, the use of wavelet multiple correlation and cross-correlation with an MODWT across seven time-scales is in the right perspective to capture the heterogeneous behaviour of these markets.

#### 3.1. Wavelet multiple correlation and cross-correlation framework

Following the work of Fernández-Macho (2012), which builds on the wavelet-based pairwise correlations, we introduce the multivariate case. Let the random variable  $X_t = \{x_{1t}, x_{2t}, \dots, x_{nt}\}$  denote a multivariate data generating process (DGP), and let its correspond scale,  $\lambda_j$  be given as  $W_{jt} = \{w_{1jt}, w_{2jt}, \dots, w_{njt}\}$ . Then, by the application of the Maximal Overlap Discrete Wavelet Transform (MODWT) to each  $x_{it}$ , wavelet coefficients are derived from the process. The MODWT transforms realisations of a given market series into wavelet coefficients associated with variations over a collection of scales, and provides for a multiresolution analysis. Unlike other filtering methods, the MODWT does its transformations without making strong assumptions about the data generating process (DGP), thereby avoiding possible information loss.<sup>1</sup>

The wavelet multiple correlation (WMC) denoted by the symbol  $\phi_X(\lambda_j)$ , and explained by Fernández-Macho (2012) as a single collection of multiscale correlation, could be obtained from the DGP  $X_t$  through the subsequent procedure. Given each wavelet scale  $\lambda_j$ , the square root of the regression coefficient of determination is computed in a linear combination of  $w_{ijt}$ ,  $i = 1, \dots, n$ , by which a maximum value for such coefficient of determination is achieved. The coefficient of determination which relates to the regression having a dependent variable  $z_i$ , over a defined set of predictors  $\{z_k, k \neq i\}$ , is expressed as  $R_i^2 = 1 - 1/\rho^{ii}$ , for which  $\rho^{ii}$  represent  $i$ -th diagonal component of the inverse of correlation matrix  $P$ . Hence, we compute WMC as:

$$\phi_X(\lambda_j) = \sqrt{1 - \frac{1}{\max \text{diag } P_j^{-1}}}, \quad (1)$$

From (1),  $P_j$  denote correlation matrix of  $W_{jt}$ ; whereas the optimal component in the diagonal of the argument is chosen with the  $\max \text{diag } (\cdot)$ . By deducing from the regression of the dependent variable  $z_i$  over the regressors in the system of equations, the derived  $R_i^2$  measure could be of the same value as the square correlation for the observed realisations of  $z_i$  and it's fitted realisations,  $\hat{z}_i$ . Therefore, we may again express WMC as:

$$\phi_X(\lambda_j) = \text{Corr}(w_{ijt}, \hat{w}_{ijt}) = \frac{\text{Cov}(w_{ijt}, \hat{w}_{ijt})}{\sqrt{\text{Var}(w_{ijt})\text{Var}(\hat{w}_{ijt})}}, \quad (2)$$

Here, we select  $w_{ij}$  in order to maximise the coefficient of determination; and  $\hat{w}_{ij}$  gives the realisations from the fitted regression for  $w_{ij}$  on the other wavelet coefficients over scale  $\lambda_j$ . We further deduced the wavelet multiple cross-correlation (WMCC) from (2) by simply introducing a lag term, say  $\tau$ , in-between the observed and fitted realisations for the chosen criterion variable; and expressed the resultant as:

$$\varphi_{X,\tau}(\lambda_j) = \text{Corr}(w_{ijt}, \hat{w}_{ijt+\tau}) = \frac{\text{Cov}(w_{ijt}, \hat{w}_{ijt+\tau})}{\sqrt{\text{Var}(w_{ijt})\text{Var}(\hat{w}_{ijt+\tau})}}, \quad (3)$$

where all parameters remain as explained.

### 3.2. Data and stochastic properties

The REIT market data for this paper was gleaned from the Bloomberg database terminal, and spans 8 July 2013 to 3 November 2017, with a total data point of 1122. A daily REIT data was chosen for our analysis because we believe volatility and other dynamic behaviour in the market could best be observed with shorter frequency data (daily or lesser time-interval data). Also, the assigned reason for our data sample is to avoid any possible influences of major historical economic and/or financial cycles on market coherencies. Though data spanning longer periods may provide better information, a great deal of space may have to be devoted to account for structural breaks and financial crises episodes. Only a cursory mention will not be enough. We have kept the scope and the content terse by avoiding these.

In analysing possible stochastic trend or co-movement of the global markets, we used the REIT market data for Australia, United States, Hong Kong, Belgium and South Africa to proxy for Oceania, North America, Asia, Europe and Africa, respectively. The REIT market data of these aforementioned countries was selected to represent the various continental REIT markets based on market size and availability of reliable and well-behaved data for the sample period.

The daily REIT market data was transformed into compounded asset returns using  $\text{returns} = \ln(R_t/R_{t-1}) * 100$ , where  $R_t$  and  $R_{t-1}$  are REIT market price index at day  $t$  and  $t-1$  respectively. The time properties of these market returns are displayed in Table 1. From the estimated results of the table, the daily average market returns for the Asian REIT (0.06%) is almost twice that of Europe (0.039%) and Oceania (0.025%); and thrice higher than REIT market returns of Africa (0.02%) and North America (0.017%). With standard deviations of over 1%, Africa's and the Oceania REIT market returns are observed to have been the most volatile markets. Besides, the North American market is relatively the less volatile market, followed in that order by Europe and the Asian markets.

It is a common practice in the financial realm to postulate that investors' expectations for higher returns on an asset should directly be linked by desires to harbour similarly higher risk, and vice versa. With that notwithstanding, following the risk-return trade-off theory, we used the Sharpe-ratio, sometimes referred to as return-to-variability ratio to quantify the risk-return trade-off for holding investments in the global REIT markets. It could be observed from Table 1 that, all the markets recorded positive Sharpe-ratios, with Asia (0.065%) and Europe (0.043%) having the highest measures, respectively. These measures suggest that holding investments in the Asian and/or European REIT markets shows higher prospects of yielding greater expected daily returns with correspondingly lower risk-bearing. This could also mean that holders of the most volatile and thus riskier markets (Africa and Oceania REITs) might not be comparably well-compensated for bearing such high-risk asset.

From the sample moments in Table 1, all the REIT markets except the Asian market recorded negative skewness measures. The markets also show evidence of relatively high and sharp peaks, and had traces of fat tails (especially the African market), which contains most of these market fluctuations. These distributional properties depict that international investors have high

**Table 1. Summary properties of global REIT returns**

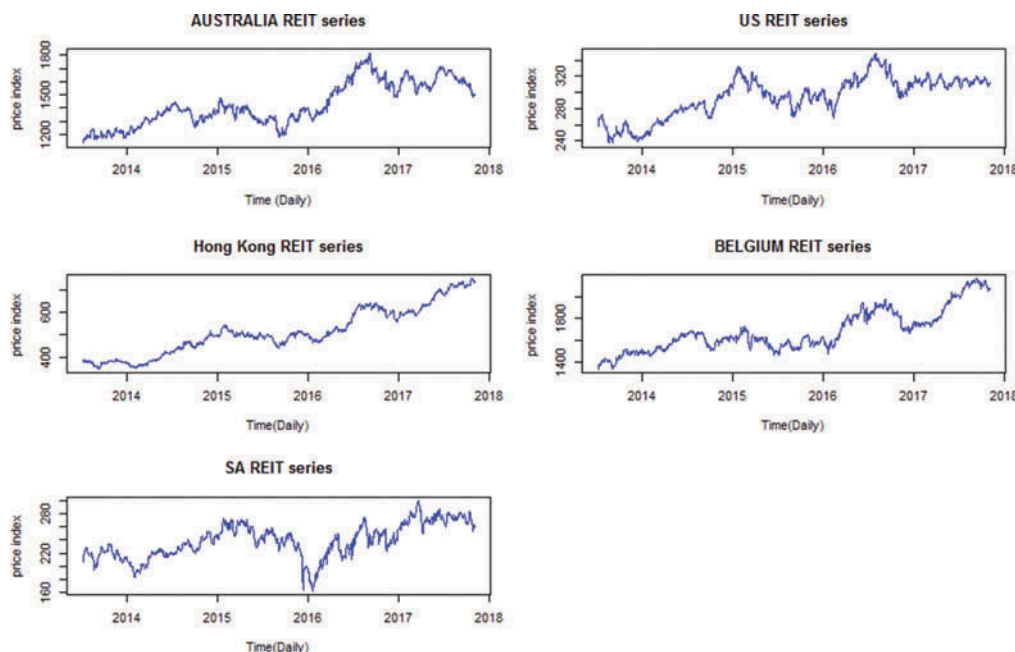
	AUST	US	HONG	BEL	SA
mean	0.025	0.017	0.060	0.039	0.020
std deviation	1.087	0.907	0.920	0.915	1.733
sharpe-ratio	0.023	0.019	0.065	0.043	0.012
kurtosis	2.386	1.809	1.662	2.391	12.795
skewness	-0.064	-0.411	0.179	-0.287	-0.609
$Q_r(5)$	10.267***	4.230	4.931	10.123***	11.719**
$Q_r(10)$	12.292	9.918	7.987	11.706	14.766
$Q_r(20)$	21.743	12.582	20.124	17.848	32.383**
JB	266.6*	184.4*	134.9*	282.4*	7715.4*

JB denote Jarque–Bera statistic for normality;  $Q_r(k)$  represent Box–Ljung Portmanteau statistic using 5-, 10-, and 20-squared autocorrelations for the REIT returns; “\*”, “\*\*\*”, and “\*\*\*\*” signify statistical significance at 1%, 5% and 10%, respectively.

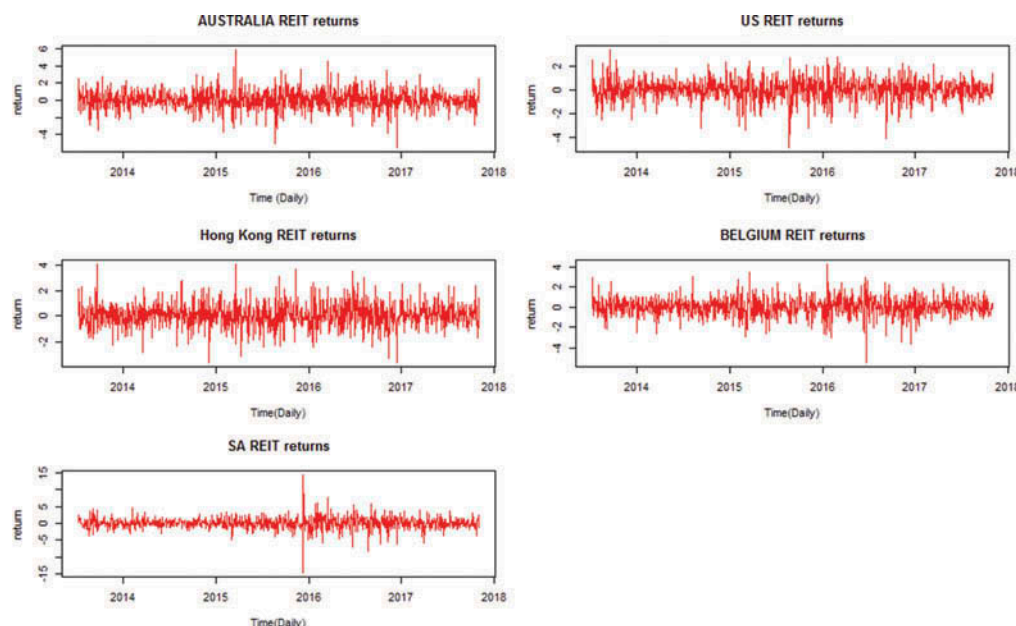
tendencies to reap positive expected daily returns from investing in the Asian REIT market, compared to the remaining global markets. With highly significant test statistics, all the market returns noticeably deviate from the normality distributional assumption—a situation which is common for most asset returns. With few significant test statistics from the Box–Ljung Portmanteau test, we could generally conclude in favour of weaker serial correlation in the daily REIT market returns.

Figures 1 and 2, respectively display the time variation patterns of the observed daily REITs market series and returns. A careful scrutiny of the time plots in Figure 1 shows a somehow similar time movement for Oceania–North America, and Asia–Europe market pairs. Moreover, the Asia’s REIT market exhibits a relatively smooth and steadily increasing pattern in its time evolution. Also, whereas the Oceania and North America’s REITs recorded peak market period prior to 2017, the remaining REITs showed traces of peaks around post-2017. However, Asia and Europe’s REITs had their peaks at the latter periods of 2017, while Africa’s REIT witnessed its peak around the first-quarter of the same year. The peak in late 2016 in Australia may be explained by its recovery after

**Figure 1. Time variations of international REIT price indices.**



**Figure 2. Time variations of international REIT returns.**



the global financial crisis (GFC). There was a partial restoration of GDP growth and reduction in interest rates and reflected in the rise in REITs (Wong & Reddy, 2018). A similar analogy can be made for the US. The US commercial property market was one of the hardest hit by the GFC and the quickest to rebound in the aftermath (Marzuki & Newell, 2017). The remaining markets peaking after 2017 may be attributed to slower recovery from the GFC as compared to the US and Australia, for instance, Belgium (Marzuki & Newell, 2019).

Another domineering pattern could again be seen from the sharp decreases for the markets around early and ending periods of 2016. These common abrupt decreases are much conspicuous for Africa, North America, Oceania, and the European REITs. Perhaps, such identified mimicking co-patterns could be suggestive of possible stochastic time trend or co-variation (co-movement)—a phenomenon which is under investigation in this study.

As witnessed in Figure 2, the daily returns of the international REIT markets are moderately clustered with visibly few intermittent spikes across time. Comparably, Africa's daily REIT returns looks fairly clustered than all other markets.

#### 4. Wavelet coherence analysis

To begin our correlation analysis, we simply decomposed each of the daily REIT market returns into several time scales using the Maximal Overlap Discrete Wavelet Transform (MODWT) with the Daubechies Least-asymmetric wavelet filter of length 8 LA(8). The MODWT, rather than the conventional Discrete Wavelet Transform (DWT) was used due to the assigned advantageous reasons: (i) The former is applicable for any sample size  $T$ , but a DWT of level  $j$  only turns to restrict the size of the sample to a multiple of  $2^j$ ; (ii) The MODWT produces relatively lesser and more efficient variable estimates; (iii) The smooth coefficient and multiresolution detail of the MODWT are linked with zero phase filters; and (iv) Its scaling and wavelet coefficients are invariant to a shift of the market series in a circular manner (see, Fernández-Macho, 2012;; Zhang, Telesford, Giusti, Lim, & Bassett, 2016). We have chosen to use, the LA(8) because it is the most widely favoured wavelet filter. It is also the default filtering method in the package (W2CWM2C) used in our estimation (Polanco-Martinez & Fernández-Macho, 2014). Using the expression  $\log_2(T)$ , where  $T$  is 1122 for our data sample, the maximum decomposition level  $j$  was computed to be 10. However, we carried out our analysis with  $j$  as 7, backed by the reason that wavelet coefficients

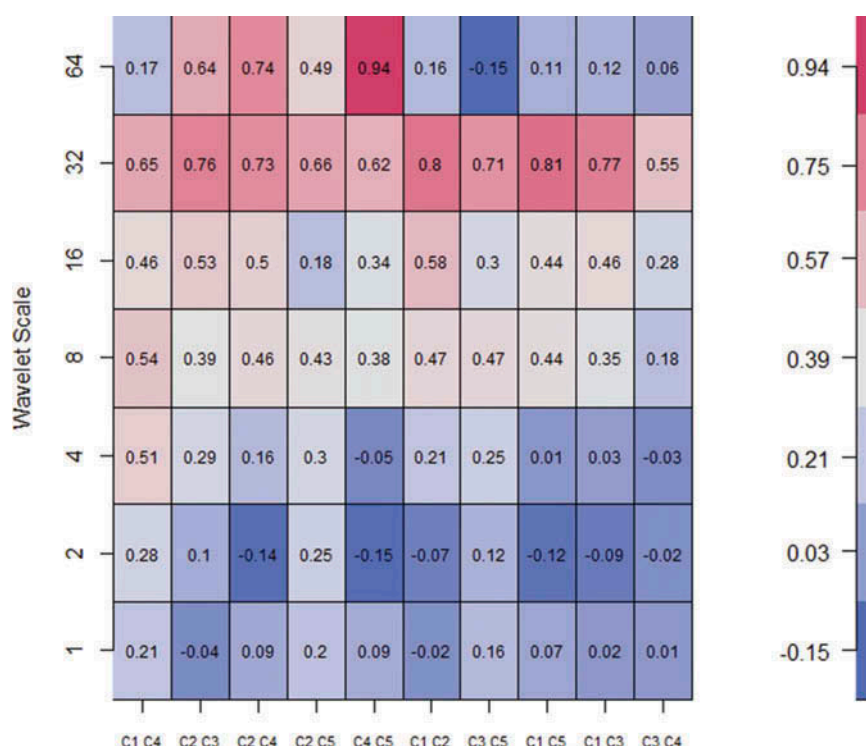
get very smaller for higher scales. Hence, seven wavelet coefficients and a single scaling value are used for our multiresolution wavelet plots.

Therefore, we present summary of the time dynamics associated with the chosen wavelet coefficients. Wavelet scale 1: 2 ~ 4 days (intra-week); wavelet scale 2: 4 ~ 8 days (weekly); wavelet scale 4: 8 ~ 16 days (fortnightly); wavelet scale 8: 16 ~ 32 days (monthly); wavelet scale 16: 32 ~ 64 days (monthly to quarterly); wavelet scale 32: 64 ~ 128 days (quarterly to biannual); and wavelet scale 64: 128 ~ 256 days (biannual).

Before we analyse the wavelet multiple correlations and cross-correlations we provide a glimpse into the pairwise correlations for the global REITs for short-, medium-, and long-term. These are presented in

**Figure 3. Pairwise wavelet correlation between global REITs.**

**Note:** The pairs are in the same order as arranged in Table 2.



**Table 2. Pairwise wavelet correlation between global REITs**

Pair/Wavelet scale	1	2	3	4	5	6	7
Australia-Belgium	0.21	0.28	0.51	0.54	0.46	0.65	0.17
US-Hong Kong	-0.04	0.10	0.29	0.39	0.53	0.76	0.64
US-Belgium	0.09	-0.14	0.16	0.46	0.50	0.73	0.74
US-South Africa	0.20	0.25	0.30	0.43	0.18	0.66	0.49
Belgium-South Africa	0.09	-0.15	-0.05	0.38	0.34	0.62	0.94
Australia-US	-0.02	-0.07	0.21	0.47	0.58	0.80	0.16
Hong Kong-South Africa	0.16	0.12	0.25	0.47	0.30	0.71	-0.15
Australia-south Africa	0.07	-0.12	0.01	0.44	0.44	0.81	0.11
Australia-Hong Kong	0.02	-0.09	0.03	0.35	0.46	0.77	0.12
Hong Kong-Belgium	0.01	-0.02	-0.03	0.18	0.28	0.55	0.06

**Note:** The pairs are in the same order as arranged in Figure 3.

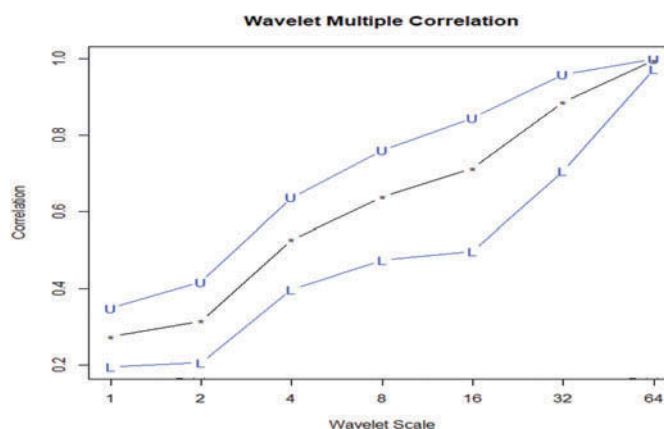
Figure 3 and Table 2. By convention in heatmaps, the magnitude contemporaneous correlations are indicated by the scale on the right of Figure 3 from blue to wine colour in ascending order.

We observe that bivariate wavelet correlations generally increase in degree and are positive after wavelet scale 4. Thus, global REITs inversely and weakly correlated in the short-term as opposed to directly and strongly correlated in the long-term. In the long-term (wavelet scale 64) we find only Hong Kong-South Africa pair being inversely correlated at about 15%. But the strongest positive correlation is recorded for the Belgium-South Africa pair at about 94%. These imply that African REITs seem to be strongly related to European REITs as opposed Oceania, Asia, and the US. A suspecting explanation will be geographical proximity which translates in economic and financial spillovers.

Figure 4 displays graphical results of the wavelet multiple correlation for the global REITs returns at seven different time-scales. Table 3 is the rendition of Figure with give exact correlation values at the wavelet scales. The almost perfect integration in the long-run (wavelets scale 64) is among the REITs is Figure 4 is also shown in Table 3 as 99.9%. Multiple correlation is observed to be significantly very low (0.40) at the highest frequency (lowest scale), but steadily increases to around 0.60 for the intermediate frequency, thus the monthly scale. There is visible momentarily downtrend in multiple correlation as the markets move up from scales 8 to 16 (monthly to quarterly periods). This result gives an indication that the REIT markets exhibit some form of market differences in the medium-run. Moreover, multiple correlation quickly rises and peaks at the highest scale (i.e., long-run time-scale), reaching the correlation coefficient closer to one (perfect correlation). Thus, showing the existence of strong linear coherence for global REIT markets at time periods longer than half a year. In other words, the discrepancies among the markets significantly dissipate over investment time-

**Figure 4. Wavelet correlation between five global REIT market returns with Daubechies LA wavelet filter of length 8, at several time scales.**

Note: The blue lines denote upper (U) and lower limits (L) of the 95% confidence interval, respectively. “\*” correspond with lead/lag market return linkages at each time scale.



**Table 3. Wavelet multiple correlation of global REITs**

Scale	Lower	Correlation	Upper
Daily			
$w_{I1}$	0.196	0.274	0.349
$w_{I2}$	0.206	0.316	0.417
$w_{I3}$	0.397	0.528	0.637
$w_{I4}$	0.475	0.639	0.760
$w_{I5}$	0.498	0.713	0.845
$w_{I6}$	0.706	0.886	0.959
$w_{I7}$	0.973	0.995	0.999

Note: Upper and Lower indicate upper and lower 95% confidence values, respectively.



horizons lesser than half a year. Hence, there is greater opportunity for diversification in the markets across the short-to-medium run periods.

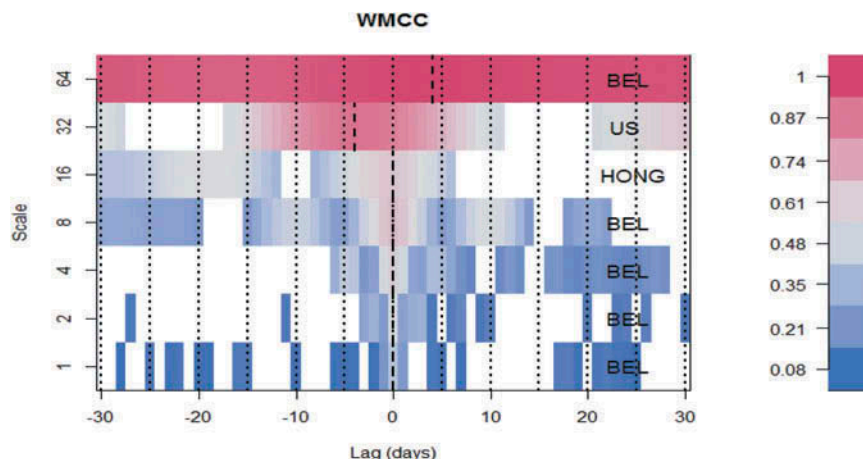
Moreover, the underlying rationale for the identified discrepancies among the REIT markets may be accounted for by varying factors which often exert influence on market linkages over trading scales. As argued by Zhou (2012), market linkages at lower time-scales are predominantly influenced by factors operating at high-frequency levels, and are expected to results in short-term changes in market characteristics. Such factors are termed ephemeral, and broadly cover (but not limited to) market sentiment, market “occurrences” or “events” (for instance, mergers, dividends or earnings announcements, shocks or surprises, etc.), and psychological factors. Their collective effect on market linkages is expected to be balanced-out, thereby resulting in lower market correlations at short-term periods.

On the contrary, market linkages at the higher time-scales (long-run periods) are also influenced by factors operating at lower-frequency levels. These factors are mainly macroeconomic in nature, and have tendencies of increasing correlations in markets at the long-run scales. Therefore, following these argument, the significantly lower correlations and market differences of the global REITs at the shorter scales do not pose much surprises, as such happenings could be attributed to varying ephemeral variables. There gain, the evidence of high correlations at the long-runs could perhaps be linked to influences of macroeconomic factors like the nature of monetary policy, business cycle, inflation and market volatility, among others which causes increases in market linkages.

The graphical display in Figure 4 gives the result of the wavelet multiple cross-correlation for the global REITs returns at different frequencies (wavelet scales) and across time lags, up to 30 trading days. For each wavelet correlation, the wavelet coefficients are found within 95% confidence interval. Zones or portions within the confidence interval which spans zero are shown in white. The time lags at where the strongest or exact wavelet correlation coefficient are localised could be observed with the use of the vertical black-dashed lines. Localisation means that the maximum wavelet multiple correlation occurs in the linear combination of the REITs. The REIT that achieves this becomes the lead/lag and the names are indicated on the WMCC heatmap. The heatmap indicates wavelet correlation from weak (blue-coloured zone) to perfect (red-coloured zone). For each wavelet scale, the specific REIT market that maximises multiple cross-correlation over a linear combination of the remaining markets is displayed at the right side of the scale. The WMCC does not just indicate potential lead/lag, it shows the actual leading or lagging REITs. We can insinuate spillover effects among the global REITs since all localisations do not occur at the point of symmetry (i.e. zero time lag). Thus, positive time lags are indicative of the lagging REITs markets at the particular scale and the opposite is true for negative time lags.

From Figure 5, it is much clearer to notice that correlation gets very weakened as one move from the highest to the lowest scale, and fairly along the trading days (time lags). We further note that

**Figure 5. Wavelet cross-correlation of five global REIT market returns: Australia, United States, Hong Kong, Belgium and South Africa, with Daubechies LA wavelet filter of length 8 at different several time lags and scales.**



integration is quite weak between the REITs markets especially in the short-term (of higher frequencies below wavelet scale 16). We only see cross-correlations beyond 0.74 from the medium-term (after wavelet scale 16). These suggest that information flow between the markets may be slow and hence shocks to one market are transmitted to and felt in other markets only after a month. This makes sense since our study period is off any specific crisis period where market tend to be otherwise highly correlated.

Specifically, at the lowest scale (intra-week to fortnightly periods), there is conspicuous evidence of few significant pockets of weaker correlations, with Europe having the potential to lead or lag the remaining REIT markets. Correlation steadily increases from around 0.21 to somewhere around 0.61 at the intermediate scales (monthly to quarterly periods). The Asian and North American markets showed greater prospects of leading or lagging the global markets for these periods. Moreover, at the lower-to-medium scales, correlation turns to be statistically not different from zero for day 15 of trading, thereby giving greater opportunity for portfolio diversification. Similar evidence of non-significant coherencies dominates zones across the trading days, and are much glaring at scales below 32 (intra-week to monthly investment periods). Nonetheless, wavelet correlations recorded significant coefficients across all time lags for the highest scale (lowest frequency), with the European market being a potential leader or follower at this investment period, as seen also for the lower scales. This suggests that, any likely shocks that hit Europe's REIT market may in-turn be transmitted down to REIT markets of Africa, North America, Oceania and Asia, and perhaps vice versa for these periods of investment.

However, in terms of actual lead/lag, we find where Belgium (BEL) lags (at time 4) and the US leads (at time -4) all the other markets in the monthly and quarterly scale. That is to say, the two market have the maximum wavelet multiple correlations at these time. We mention again that short transmission are slow and persistent as they do not occur in the short-term (at high frequencies). The leading of the US can be attributed to the fact that the commercial property market was one of the hardest hit by the GFC and the quickest to rebound in the aftermath (Marzuki & Newell, 2017). The large size of US REITs market (EPRA, 2017, 2017; Marzuki & Newell, 2017) is also a plausible explanations. This goes to reinforce why Belgium and Hong Kong only show potential of leading but never actually lead in the short-term. Nevertheless, the series potential lead and the eventual lag of Belgium is not surprising. Since the Belgian REITs debuted only two decades ago, it has seen significant growth. It now stand at the 5th largest REIT market in Europe by both market capitalisation and number of active REITs (EPRA, 2017; Marzuki & Newell, 2019).

With respect to time-varying (frequency-dependent) our study corroborate (Anoruo & Murthy, 2017; Karatas, Unal, & Yilmaz, 2017; Liow & Angela, 2017; Liow, Zhou, Li, & Huang, 2019a; Liow, Zhou, Li, & Huang, 2019b; Zhou, 2012) which show that integration in REITs markets are dynamic in the frequency-domain. Ozun, Ertugrul, and Coskun (2018) also support our study in the sense of dynamic correlations the REITs market space. Our results align with Liow and Angela (2017) and Liow, Zhou, Li, & Huang (2019a) that REITs exhibit stronger links in the medium- to long-terms at lower frequencies. Finally, the importance of the US REITs markets in connection with as seen in this study is also highlighted by Liow (2008).

In concluding our analysis, we provide key highlights from the results presented. With respect to the summary stochastic properties, the Asian and European REIT markets revealed themselves as prospective markets which offer greater expected daily returns per unit of risk. Moreover, the African REIT market is seen as the most volatile of all the global REIT markets, but turns to provide investors with comparatively lesser expected daily average returns with an associated higher risk-bearing phenomenon.

Focusing on the coherence dynamics of the REIT markets, stretches of significantly high correlations were found to have been segmented at the highest scale (lowest frequency), and viewed

uniformly over all trading days. However, the evidence of strong correlations turns to disappear as we move downwards from the highest to lowest scales. Noticeable zones of non-significant correlations dominate the lower scales, at where the European market either leads or lags the remaining markets. Conspicuously moderate significant correlation zones are found within the medium scale (intra-week to monthly investment periods), with trading day 15 showing no sign of correlation. For this latter trading horizon, the North American and Asian markets have prospect of being leaders or followers of the REIT markets. In summary, our coherence analysis with lead-lag market relationships offers important diversification opportunity, as investors adopt varied trading strategies, aimed at gaining higher positive returns with minimised risk-bearing. Further, our results imply that diversification and policy measures should be frequency-dependent. This will ensure that different actions are directed time-scales where global REITs integration levels are weak vis-à-vis strong.

## 5. Conclusion and implications

Using multivariate wavelet methods, we explore correlation and market interdependence of five global REIT markets across seven trading scales (or investment horizons). The daily REIT returns of the United States, Hong Kong, Belgium, South Africa and Australia are used to proxy for North America, Asia, Europe, Africa and the Oceania markets, respectively. Over here, we must emphasise that the inclusion of a fast-embryonic Africa's REIT market, coupled with well-developed and/or scrutinised REITs in an investigation for global market integration and interdependence is a major contribution of this work. Another contribution could be aligned to the use of MODWT in a multiresolution analysis—thus, the adoption of wavelet multiple correlation and cross-correlation. These methods complement each other for robustness purposes and address the setback of the overly used multivariate wavelet-based correlations, whose analysis involve several number of pairwise comparison.

We therefore summarise our main findings as follows: (1) Higher expected daily market returns with correspondingly lower risk-bearing are much likely to be gained from investments in Europe and Asia's REIT markets, whereas lesser compensations are to be rewarded for holding Africa's highly volatile or riskier REIT. (2) Multiple correlations are found to have increase with time horizons, thus, moving from significant pockets of weaker correlations in the short-run, to moderate and stronger correlations across trading days (time lags) for the medium-, and long-runs, respectively. The evidence of significantly weaker correlations at the shorter scales, and the increasingly higher correlations at long-run scales could perhaps be attributed to ephemeral and macroeconomic factors. Whereas the latter factors cause correlations in market to increase, ephemeral variables exert influence on markets that often result in lower correlations. (3) The results also revealed that the European REIT market has a greater potential to lead or lag the global markets at the short-, and long-run investment horizons, while the Asian and North American markets show same prospects at intermediate periods. (4) Apparently, no significant correlation zones are found for trading day 15 of the medium to lower scales, hence, promising of an advantage to diversify and minimise portfolio risk. From the month and quarter wavelet scales we find the US and Belgium leading and lagging, respectively. These can be attributed to the largest size of the US REITs market as well as rebounding very strongly after the GFC. Belgium has also been a strong in the European REITs space by rising to 5th position by market size and active number of REITs.

Generally, our results have several significant practical implications for investors and market makers. Thus, it offers greater diversification possibility for international investors in the short-, to medium-runs; and a copious diminished investment advantage in the long-run. Portfolio risk of international investors may also be minimised by incorporating the trading scale dynamics when designing global portfolios using the REIT markets. These imply that since integration levels in the REITs markets are frequency-dependent so should policy and investment decisions. On the policy side, this can forestall crisis in the REITs markets given that will ensure that different actions are directed time-scales where global REITs integration levels are weak vis-à-vis strong.

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## Note

1. See Section 4 for brief explanation. Readers are also directed to see Percival and Walden (2000) for further details of the methodology.

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