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Nonlinear contagion between stock and real estate markets: International evidence from a local Gaussian correlation approach

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Abstract

In this paper, we analyze contagion over the daily period of January 1, 1998 to September 13, 2018 between Real Estate Investments Trusts (REITs) and the equity markets of 19 countries, which are at their different stages of development in terms of the REITs market. For our purpose, we use the local Gaussian correlation approach during the dot-com, global financial, European sovereign debt crises and the more recent period involving the Brexit in the UK. The employed method not only avoids the bias of the conditional correlation, but also describes any nonlinear structure in dependence and the deviation from global normality. In general, we find strong evidence of nonlinear contagion between equities and REITs of not only matured and established markets, but also in economies with an emerging REITs sector, especially during the global financial and sovereign debt crises. Further, when we considered contagion across REITs of the US and the other countries, and between US REITs and equities of the remaining 18 countries, a similar pattern emerges. Our results have important implications for investors and policymakers alike.

KEYWORDS

contagion, equities, financial crises, local Gaussian correlation, REITs

1 | INTRODUCTION

In the wake of extreme events that unfolded in the worldwide financial markets during the recent global financial and the European sovereign debt crises, there has been a renewed interest among researchers to better understand contagion, whereby, loosely speaking, contagion can be defined as a rapid shock spillover that increases cross-market linkages.[1] There exists large number of (earlier and recent) studies on contagion (surrounding older and newer crises episodes) involving bonds, stocks, currencies, commodities and more recently, hedge funds (see e.g., Pericoli & Sbracia, 2003; Tai, 2004, Dungey, Fry, Gonzalez-Hermosillo, & Martin, 2005; Pesaran & Pick, 2007; Forbes, 2012; Mollah, Quoreshi, & Zafirov, 2016; Bampinas & Panagiotidis, 2017; Chuliá, Guillén, & Uribe, 2017; Samarakoon, 2017; and Caporin, Pelizzon, Ravazzolo, & Rigobon, 2018 for detailed reviews). There are some literatures studying on contagion within real estate markets (see e.g., Chang & Chen, 2014; Fry, Martin, & Tang, 2010; Gerlach, Wilson, & Zurbruegg, 2006; Guo, Chen, & Huang, 2011; Hoesli & Reka, 2013; Kallberg, Liu, & Pasquariello, 2002; Liow, Ho, Ibrahim, & Chen, 2009; Lu, Tse, & Williams, 2013). In general, these studies confirm the existence of contagion in the United States (US) with the domestic financial market, and across international real estate markets (like Australia and the United Kingdom (UK)), during the Asian crisis of 1997 and the financial crisis of 2007–2008.

The benefits of including real estate in mixed-asset portfolios are now well-recognized (Bouri, Gupta, Wong, & Zhu, 2018; Hoesli, Lekander, & Witkiewicz, 2004; MacKinnon & Al Zaman, 2009). However, investing in real estate can be problematic due to the high unit value and illiquidity of properties. Thus, it is not surprising that the importance of the securitized real estate market, that is, Real Estate Investment Trusts (REITs), has grown substantially during the past decades, with a total market capitalization of US $1.7 trillion (Ernst, & Young, Global Real Estate Report, 2016). Though the US continues to remain the leader in REITs, the number of countries now offering REITs[2] as an investment vehicle has almost doubled in the last 10 years to 37. Given the well-accepted importance of REITs in investment portfolios now, we aim to extend the limited literature on contagion involving the real estate sector of primarily the US, by studying contagion between REITs and the equity markets of 19 countries. The included countries, based on data availability, are at their different stages of development in terms of the REITs market, and correspond to mature (US), established (Australia, Belgium, Canada, France, Germany, Hong Kong, Japan, The Netherlands, New Zealand, Singapore and the UK) and emerging (Ireland, Italy, Malaysia, Mexico, South Africa, Spain and Turkey) categories (Ernst & Young, 2018). In addition, we also conduct contagion analyses between US REITs and the other international REITs, as well as between US REITs and equity markets of the 18 remaining countries in our sample. In sum, unlike the existing studies, we provide a more comprehensive analysis with a wider international dimension, which in turn, would allow us to draw better inferences about contagion involving REITs market.

In terms of the econometric methodology, we study contagion by using the local Gaussian correlation approach introduced by Tjøstheim and Hufthammer (2013) in four periods around the dot-com, global financial, European sovereign debt crises and the more recent period involving the Brexit in the UK, spanning the daily period of January 1, 1998 to September 13, 2018. Though this framework is conceptually close to the traditional correlation analysis, it differs being a dependence measure that is localized and nonlinear. Unlike linear dependence measures, local Gaussian correlation not only avoids the bias of the conditional correlation, but also describes any nonlinear structure in dependence and the deviation from global normality. In addition, our approach does not suffer from additional bias that might result from the increased volatility observed during periods of turmoil. Further, the method can also capture the asymmetric response associated with shocks of different magnitudes, as it measures lower, median and upper tail dependencies. Finally, within the context of the local Gaussian correlation, we can also test for contagion by comparing the local correlation of the stable and the crisis periods based on a bootstrap procedure of Støve, Tjøstheim, and Hufthammer (2014).

There are a number of studies explored the contagion between real estate and equity markets. For example, Cotter and Stevenson (2006) employ a multivariate VAR-GARCH model and document the return and volatility linkage between REIT sub-sections and equity in the US. Hoesli and Reka (2015) apply a binomial logit model and find strong evidence of contagion between real estate and financial markets in the US during 1999–2011. They further provide empirical evidence of the contagion channels from liquidity dynamics and investors' sentiment. In terms of Asian markets, Hiang Liow (2012) use the DCC-GJR-GARCH model to study the co-movements between real estate and stock and conclude that their conditional correlation is time-varying in eight Asian countries over 1995–2009. In contrast to the literature, our analysis contributes to the existing understanding of contagion between REITs and equities in three ways. First and foremost, we employ the local Gaussian correlation approach to study the nonlinear contagion, rather than the linear way such as in the VAR-GARCH model. This method controls for various types of biases observed in the contagion literature due to studies ignoring heteroscedasticity (Forbes & Rigobon, 2002), nonlinearity (Bae, Karolyi, & Stulz, 2003; Baur, 2013) and asymmetry (Bodart & Candelon, 2009). Second, we study the contagion from a global perspective, involving 19 countries with different developed stage in different continents, while existing literature tend to focus on the US market or other single continent. Lastly, we investigate the contagion surrounding the four extreme events of last two decades. To be specific, we revisit and update our understanding on the contagion (in a nonlinear way) during the dot-com, global financial, European sovereign debt crises and the more recent period involving the Brexit.

The remainder of the paper is organized as follows. Section 2 outlines the basics of the methodology of local Gaussian correlation. Section 3 shows the data and illustrate how we select the periods of study. Section 4 presents and discusses the empirical results. Section 5 concludes the paper.

2 | METHODOLOGY

2.1 | Local Gaussian correlation

The objective of this paper is to investigate the dependence structure in the pairs involving REITs and equity returns, and whether a contagion existed in those two markets during four different periods. It is not legitimate to use the standard correlation approach because: (a) the correlation is primarily meaningful under the Gaussian assumption; and (b) the correlation can only capture the linear dependence. There are many empirical evidence against the Gaussianity of the financial returns and indeed non-Gaussianity is one of the stylized fact of the daily financial returns (Bulla & Bulla, 2006; Liu & Wang, 2017; Rydén, Teräsvirta, & Åsbrink, 1998). Additionally, the dependence between REIT and equity returns has also been found to be nonlinear (Hoesli & Reka, 2013, 2015; Li, Chang, Miller, Balcilar, & Gupta, 2015).

In this regard, Tjøstheim and Hufthammer (2013) proposed a new approach called local Gaussian correlation to measure the local dependence and reveal the full dependence structure. The central idea of the new approach is to approximate an arbitrary bivariate return distribution with a family of Gaussian bivariate distributions. At each point of return distribution, there is a Gaussian distribution that approximates that point (approximating the density locally rather than the correlation). The correlation of the approximating Gaussian distribution is taken as the local correlation in that neighbourhood.

Given two *i.i.d.* random variables, u and v, the bivariate density $f(x, y)$ at the location point (x, y) can be approximated by a bivariate Gaussian density

$$\Phi_{x,y} = \Phi\{u, v, \mu_1(x,y), \mu_2(x,y), \sigma_1(x,y), \sigma_2(x,y), \rho(x,y)\}$$
$$= \frac{1}{2\pi\sigma_1(x,y)\sigma_2(x,y)\sqrt{1-\rho(x,y)^2}} \exp\left\{-\frac{1}{2\left(1-\rho(x,y)^2\right)}\left[\left(\frac{u-\mu_1(x,y)}{\sigma_1(x,y)}\right)^2 + \left(\frac{v-\mu_2(x,y)}{\sigma_2(x,y)}\right)^2 - 2\rho\left(\frac{u-\mu_1(x,y)}{\sigma_1(x,y)}\right)\left(\frac{v-\mu_2(x,y)}{\sigma_2(x,y)}\right)\right]\right\}, \quad (1)$$

where $\mu_1(x, y)$, $\mu_2(x, y)$ are the local means of u and v, $\sigma_1(x, y)$, $\sigma_2(x, y)$ are the local standard deviation, and $\rho(x, y)$ is the local Gaussian correlation.

The five parameters $\mu_1(x, y)$, $\mu_2(x, y)$, $\sigma_1(x, y)$, $\sigma_2(x, y)$, $\rho(x, y)$ are the functions depending on the location point (x, y), and thus $\Phi_{x,y}$ is able to approximate the density function $f(x, y)$ only in a neighbourhood of (x, y). Given another location point (x', y'), it is thus necessary to find another Gaussian $\Phi_{x',y'}$ to get close to the density function $f(x',y')$ in a neighbourhood of (x',y'). Moving the location point to all possible regimes of u and v, we can complete the full approximation for the bivariate density by a family of bivariate Gaussian densities. Since the local Gaussian correlation $\rho(x, y)$ captures the dependence in a neighbourhood of (x, y), the collection of all local Gaussian correlations can fully reveal the dependence structure between the underlying two random variables. Such a way of studying dependence structure is flexible in that it can capture the nonlinear dependence and it is free of the Gaussian assumption on the underlying variables. Additionally, it is robust than the conditional correlation approach.

To implement the local Gaussian approach, it is necessary to employ an appropriate method to fit a Gaussian density in a neighbourhood of (x, y). In the literature, Tjøstheim and Hufthammer (2013) and Støve et al. (2014) suggested that the local likelihood method developed by Hjort and Jones (1996) is adequate in fulfilling this task. One essentially issue is that the local Gaussian correlation estimator $\hat{\rho}(x,y)$ is based on the two kernel smoothing devices with the arbitrary choice of bandwidth $h = (h_1, h_2)$, which needs to be specified by the user. Interested readers can refer to the cited publication for technical details.

2.2 | Marginal model

It is crucial to ensure that the assumption of *i.i.d.* is satisfied in order to use the local Gaussian approach (Støve et al., 2014). As a matter of fact, financial returns have heteroskedasticity, and the typical way is to apply GARCH-family models to capture the dynamics in the volatility (Bollerslev, Chou, & Kroner, 1992; Nyakabawo, Gupta, & Marfatia, 2018). Additionally, there could be weak dependence in the mean of financial returns via an ARMA structure (Wei, 2006). Overall, the marginal model of returns is specified as an ARMA(p_1, q_1) − $GARCH(p_2, q_2)$ model:

$$R_{k,t} = \mu + \Sigma_{i=1}^{p_1}\phi_{k,i}R_{k,t-i} + \Sigma_{j=1}^{q_1}\theta_{k,j}\varepsilon_{k,t-1} + \varepsilon_{k,t}, k = 1,2, \quad (2)$$

$$\sigma_{k,t}^2 = \omega_{k,0} + \Sigma_{i=1}^{p_2}\alpha_{k,i}\varepsilon_{k,t-1}^2 + \Sigma_{j=1}^{q_2}\beta_{k,j}\sigma_{k,t-1}^2, \quad (3)$$

$$\eta_{k,t} = \frac{\varepsilon_{k,t}}{\sigma_{k,t}}, \eta_{k,t} \mid \Omega_{t-1} \tilde{t}(\upsilon_k), \quad (4)$$

where $R_{k,t} = 100 \times \{log(P_{k,t}) - log(P_{k,t-1})\}$, $P_{k,t}$ is the price of REIT or equity at time t, and $\eta_{k,t}$ is the standardized residuals which follows the Student-t distribution with υ_k degrees of freedom. The computed standardized residuals from the selected model are consequently used in the following analysis. The maximum of ARMA lags p_1 and q_1 are capped at 5 and the maximum of GARCH lags p_2 and q_2 are capped at 2. In order to find the most appropriate lag lengths for p_1, q_1, p_2, q_2, we employ a sequential search procedure detailed in Appendix A.

To empirically check the *i.i.d.* assumption (at least no serial correlation and heteroskedasticity), we consider three diagnosis tests[3] developed by Fisher and Gallagher (2012) on the standardized residuals. Specifically, we apply the *weighted Ljung-Box test* to examine the hypothesis of no serial correlation. We also use the *weighted Ljung-Box test* on squared standardized residuals and the *weighted ARCH-LM test* to check the hypothesis of no heteroskedasticity. If the standardized residuals from the ARMA(p_1, q_1) – GARCH (2, 2) fails to pass any one of the tests at the significance level (5%), then no marginal model is deemed to be adequate.

2.3 | Bootstrap test for contagion

Støve et al. (2014) developed a bootstrap test for contagion based on the local Gaussian approach. We briefly summarized this method here. Denote that $\{R_{1,t}, R_{2,t}\}$, $t = 1, ..., T$ as the pair of the log returns of REITs and equity indices. To ensure the *i.i.d.* assumption of the local Gaussian approach, we apply the ARMA-GARCH model to filter the log returns, and extract the standardized residuals $\{\eta_{1,t}, \eta_{2,t}\}$, $t = 1, ..., T$. Then, the standardized residuals are split into two subperiods, the period before the crisis (denoted as BP) and the period after it (denoted as AP).

According to Forbes and Rigobon (2002), a contagion can be defined as a significant increase in cross-market linkages after a shock to one market (or a group of markets). Following the logic, a contagion is believed to occur if the local correlation function in the BP is significantly above the local correlation function in the AP. Hence, the contagion test is formulated as follows:

$$H_0 : \rho_{AP}(x_i, y_i) = \rho_{BP}(x_i, y_i) \text{ for } i = 1, ..., n, \quad \text{i.e., no contagion}, \quad (5)$$

$$H_A : \sum_{i=1}^{n} (\rho_{AP}(x_i, y_i) - \rho_{BP}(x_i, y_i)) > 0, \quad \text{i.e., contagion}, \quad (6)$$

where (x_i, y_i) are the selected location points where the local correlations are estimated. For the choice of the location points, we follow Støve et al. (2014) and use a diagonal grid, that is, $x_i = y_i$ in order to reduce the computational time. It is natural to have the test statistic:

$$D = \frac{1}{n} \sum_{i=1}^{n} \{\hat{\rho}_{BP}(x_i, x_i) - \hat{\rho}_{AP}(x_i, x_i)\} w(x_i, x_i), \quad (7)$$

where $w(x_i, x_i)$ is a weight function such that the distance between the grid points and the observations is not too large.

However, the proposed test statistic has a non-analytical asymptotic distribution. In order to obtain the p-value of the test, Støve et al. (2014) suggested to use the following bootstrap procedure:

Step 1. Randomly draw samples from the standardized residuals $\{\eta_{1,t}, \eta_{2,t}\}$ with replacement

Step 2. Split the resampled data into BP and AP and compute $\hat{\rho}^*_{AP}(x_i, x_i)$ and $\rho^*_{BP}(x_i, y_i)$

Step 3. Calculate the bootstrapped test statistic

$$D^* = \frac{1}{n} \sum_{i=1}^{n} \{\hat{\rho}^*_{BP}(x_i, x_i) - \hat{\rho}^*_{AP}(x_i, x_i)\} w(x_i, x_i). \quad (8)$$

Repeat Step 1 to Step 3 for a large number of times, B, and collect all bootstrapped statistics D^*. Finally, the p-value of the test can be found by comparing D in terms of the distribution of bootstrapped statistics D^*, and a decision of rejecting H_0 can be made if it is below a given significant level α.

In this regard, the following practical settings were used: (a) For the bandwidth, we follow Støve et al. (2014) to choose the bandwidth using a simple rule of thumb – the global standard deviation times a constant close to one; (b) The number of repetition times in the bootstrap test is set to be $B = 1{,}000$; (c) The diagonal grid is set to be between −2.5 and 2.5 with step-size 0.05; and (d) Our implementation is based on the R package "localgauss" (Berentsen, Kleppe, & Tjøstheim, 2014).[4]

3 | DATA

Our analysis involves two variables namely, the REITs and stock indices of 19 economies (Australia, Belgium, Canada, France, Germany, Hong Kong, Ireland, Italy, Japan, Malaysia, Mexico, The Netherlands, New Zealand, Singapore, South Africa, Spain, Turkey, UK, and US) covering the daily period of January 1, 1998 to September 13, 2018. The data is sourced from the DataStream database of Thomson Reuters, with the real estate data corresponding to the S&P REITs indices for each country, while the stock market data are the MSCI indices. Notably, our data set is obtained already in a cleaned-form from the source and does not suffer from any problems such as stale quotes, liquidity issues, missing values and outliers. Given this, the data does not bias the econometric estimations and thus does not adversely affect inference. To avoid the impact of exchange rate movements, both the REITs and stock indices for each country are in US dollar terms. As pointed out earlier, we work with log-returns of these two series. However, the starting date of REITs varies, and not all countries have data available for REITs back in 1998, unlike the equity market data. Tables B1 and B2 in the Appendix B of the paper provides the individual sample period of each country (for REITs and stock returns) and also summarizes the basic statistical properties of the data. As can be seen, what stands out is the non-normality of the all the raw log-returns series based on the strong rejection of the null of normality under the Jarque-Bera test.

There is plenty of evidence towards large structural changes[5] on those two markets over the last two decades. Thus, we turn our attention to the local Gaussian approach for the investigation of the dependence structure and the existence of contagion between the REIT return and equity returns during four different periods: Period 1 (dot-com crisis), Period 2 (global financial crisis), Period 3 (European sovereign debt crisis), and Period 4 (Recent, or Brexit in the UK). The contagion is analysed in the context of cross-markets within a country, cross-country relative to the US within the REITs sector, and cross-market-cross-country, whereby we look at US equities and REITs of the remaining 18 countries.

We identify the chronology of the different crisis periods from the literature. The timeline of the dot-com crisis and global financial crisis follows Phillips, Wu, and Yu (2011). The period surrounding the dot-com crisis covers January 1, 1998 to December 31, 2002, with the before-crisis sub-period spanning January 1, 1998 to March 10, 2000 and the after-crisis subperiod running from March 11, 2000 until December 31, 2002. As also suggested by Støve et al. (2014), in terms of the global financial crisis due to the subprime mortgage turmoil, we define the before-crisis subperiod to be from January 1, 2005 to August 8, 2007 and the after-crisis subperiod ranging between August 9, 2007 and August 7, 2009. Following Bampinas and Panagiotidis (2015), the European sovereign debt crisis starts from October 24, 2007 and ends at July 31, 2012, and the cutting date for before-crisis and after-crisis subperiods is October 4, 2009 (i.e., elections in Greece). Finally, we also include a recent period from Jan 1, 2014 to September 13, 2018 (corresponding to the last day of our data sample). Within this period, one of the major events is the Brexit, that is, the voting result of the British Referendum on withdrawing its membership from the European Union, as announced on June 23, 2016. Thus, we use this date as the cutting line to distinguish the before-crisis and after-crisis subperiods in Period 4. This also allows us to have more than 2 years of data in the sub-period after the announcement of the Brexit vote result.

As a motivating illustration, we present and discuss the standard correlation (i.e., Pearson's correlation coefficient) of our data, before the formal analysis based on the local Gaussian correlation. Table B3 in the Appendix B shows the Pearson's correlation between REITs and equity market returns within a specific country. The existence of contagion might be determined by an increase of the Pearson's correlation in a certain period, but there are three drawbacks in terms of using the Pearson's correlation for determining contagion in our empirical data. First, the Pearson's correlation is primarily meaningful for normally distributed data, while the returns of REITs and equities are highly non-normal, as shown in Tables B1 and B2 in the Appendix. Second, a contagion can still occur even there is no change in the Pearson's correlation. For instance, the Pearson's correlation in South Africa remained the same (0.77) in Period 3, while there is strong evidence for the contagion based on the local Gaussian approach, shown in Section 4. This is because the Pearson's correlation is limited to capture the linear dependence and cannot take nonlinear dependence into account. Third, the Pearson's correlation is defined in terms of moments and cannot reveal the information in the tails of distribution, while the local Gaussian approach can provide the “full picture” over the entire distribution by inspecting the local Gaussian correlation curves.

4 | EMPIRICAL RESULTS

Our empirical results are organized in three sets. The first set investigates the contagion between REITs and equity within one country. The second set focus on the US REITs and examines its contagion with REITs in other countries. The third set explores the contagion between US REITs with equity in other countries. In this way, we provide “multi-dimensional” insights in the contagion between the two markets in different countries.

4.1 | (Cross-market) Contagion between REITs and equity

We start our analysis by investigating the cross-market local Gaussian correlation between returns of the REITs

TABLE 1 *p*-values of the bootstrap test between REITs and equity returns in the same country

Country	Period 1	Period 2	Period 3	Period 4
United States	1.60%	0.10%	94.71%	100.00%
Australia	69.03%	0.80%	0.60%	100.00%
Belgium	19.48%	9.19%	0.10%	25.47%
Canada	92.81%	0.10%	0.70%	72.03%
France	—	0.10%	0.10%	100.00%
Germany	—	—	3.50%	93.91%
Hong Kong	—	0.10%	100.00%	55.34%
Japan	—	0.30%	97.30%	36.96%
The Netherlands	37.16%	0.10%	0.10%	96.30%
New Zealand	~	0.40%	94.71%	97.40%
Singapore	—	0.10%	96.80%	92.31%
United Kingdom	—	—	0.10%	99.10%
Ireland	—	—	—	/
Italy	—	—	—	85.71%
Malaysia	—	—	~	100.00%
Mexico	—	—	—	0.70%
South Africa	—	—	0.30%	/
Spain	—	—	—	0.50%
Turkey	—	—	46.55%	84.72%

Note: This table shows the *p*-values of the bootstrap test between REITs and equity market returns within a specific country, that is, cross-market contagion in a particular country. Strong evidence, that is, *p*-values less than 5% is highlighted in red background, and weak evidence implied by *p*-values between 5 and 10% is highlighted in yellow background. The symbol "—" denotes no available data in that period; the symbol "~" denotes the non-convergence of the local Gaussian approach; and the symbol "/" denote that no adequate ARMA-GARCH could be obtained for the marginal model. The chronology of the four periods are denoted as: Period 1 (dot-com crisis; before: Jan 1, 1998–Mar 10, 2000; after: Mar 11, 2000–Dec 31, 2002), Period 2 (global financial crisis; before: Jan 1, 2005–Aug 8, 2007; after: Aug 9, 2007–Aug 7, 2009), Period 3 (European sovereign debt crisis; before: Oct 24, 2007–Oct 4, 2009; after: Oct 5, 2009–Jul 31, 2012), and Period 4 (Recent, or Brexit in the UK; before: Jan 1, 2014–Jun 23, 2016; after: Jun 24, 2016–Sep 13, 2018).

and equity markets for each country. For the sake of brevity, we concentrate on Table 1, which presents the bootstrap test of contagion for the 19 counties in the four periods. It must be noted that results are available for all or certain periods depending on data availability of the REITs.

For the US, the bootstrap test indeed shows that there is significant evidence of contagion that occurred between REITs and equity in Period 1 and 2, while there is no evidence of contagion in periods 3 and 4. As demonstration, Figure 1 shows the (nonlinear) local Gaussian correlation curves between REITs and equity returns of the US in each of the four periods. In Period 1 (dot-com crisis), there is a substantial increase of the local Gaussian correlation from −0.03 to 0.34 in the right tail after the crisis, while there is only a slight increment in the left tail and the middle regime of the distribution. The global financial crisis is also observed to have significantly increased the linkage between the US REITs and US equity in Period 2. The European sovereign debt crisis and Brexit occurred in Europe and have small impact on the US market, and we observe that the local Gaussian correlation curve decreased after the crisis in periods 3 and 4. Barring the initial pre-dot-com crisis period, with the correlation between REITs and stock returns always being positive, tends to suggest that diversification opportunities are considerably reduced across securitized real estate and equity markets in the US during periods of turmoil, irrespective of whether these markets are in bearish (lower tail), normal (median), or bullish (upper tail) phases.[6] The lack of contagion in the US during Period 3 and 4 can be explained in the following way. REITs in the US are mainly investing in commercial real estate (except for Mortgage REITs). Although the US residential housing markets were slowly recovering from subprime crisis, commercial real estate was not negatively affected as severe as residential ones. Thus, the lack of contagion in the US may not related to the European debt crisis or

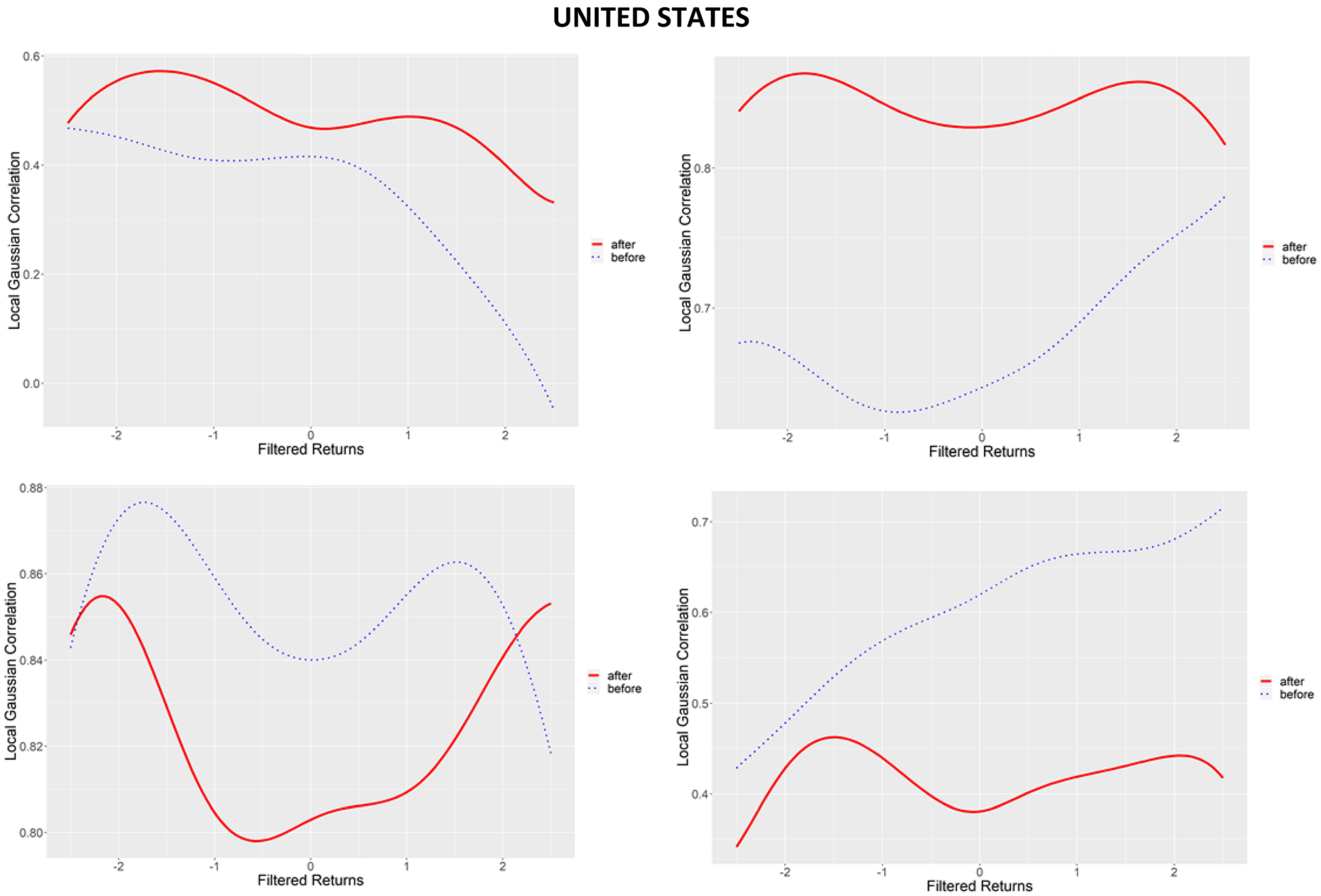

FIGURE 1 Local Gaussian correlation curves between REITs and equity returns in the US in four periods: Period 1 (upper-left); Period 2 (upper-right); Period 3 (lower-left); and Period 4 (lower-right) [Colour figure can be viewed at wileyonlinelibrary.com]

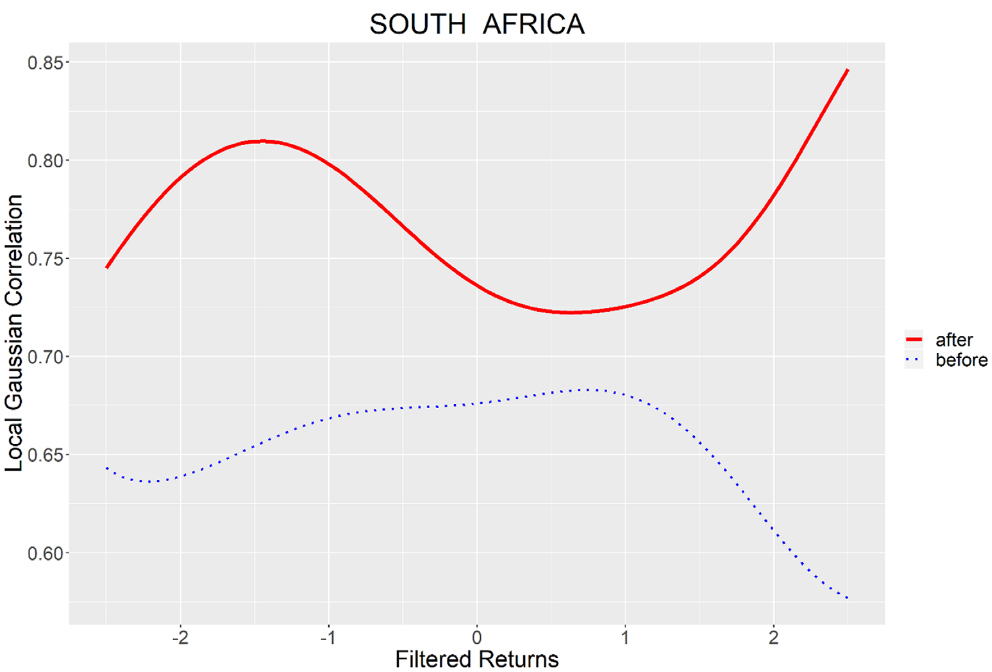

FIGURE 2 Local Gaussian correlation curves between REITs and equity returns in South Africa for the third period [Colour figure can be viewed at wileyonlinelibrary.com]

Brexit because REITs' investing in commercial real estate offer the inflation-free and high tax-efficient returns.

As for other countries, that is, the established markets of Australia, Canada, France, Hong Kong, Japan, The Netherlands, New Zealand and Singapore, for which REITs data is available, there is strong evidence of contagion for almost all countries during the global financial crisis. For Belgium, weak evidence is observed at the 10% level of significance. In terms of the European sovereign debt crisis (Period 3), not surprisingly all the European countries for which REITs data is available, that is, Belgium, France, Germany, The Netherlands and the UK, we observe strong evidence of contagion. In addition, contagion across real estate and equity markets are also observed in Australia, Canada and the emerging market of South Africa, which could be a result of the equity and REITs markets in these economies being affected by a common factor, that is, global slowdown ("double-dip" following the "Great Recession" of 2008) due to this shock in the sovereign bonds market.

Given that South Africa has a relatively well-functioning REITs sector among the emerging markets (Akinsomi, Balcilar, Demirer, & Gupta, 2017), in Figure 2, we plot the (nonlinear) local Gaussian correlation curve for South Africa, as a representative of emerging REITs markets. As can be seen there is strong evidence of contagion in the post European sovereign debt crisis episode, and with the Gaussian correlation being positive, indicating that diversification opportunities are very limited between equities and the securitized real estate market.[7]

Interestingly, there is no evidence of contagion in the UK after the Brexit vote, which in turn, can possibly be explained by the fact that the negotiations for the process was still in process during Period 4. Surprisingly, contagion is observed in the two emerging markets of Mexico and Spain, likely due to the fact that REITs as an alternative and new investment instrument in these two economies got introduced during this period, and was relatively more susceptible to negative news shocks.

TABLE 2 *p*-values of the bootstrap test between US REITs and REITs of other countries

Country	Period 1	Period 2	Period 3	Period 4
Australia	66.13%	8.59%	1.00%	41.36%
Belgium	4.00%	0.10%	1.50%	46.65%
Canada	86.11%	0.10%	12.59%	65.93%
France	—	0.10%	1.00%	57.64%
Germany	—	—	6.69%	64.44%
Hong Kong	—	24.98%	10.99%	69.63%
Japan	—	75.32%	56.84%	1.50%
The Netherlands	15.18%	0.30%	0.30%	97.00%
New Zealand	~	0.90%	3.50%	22.38%
Singapore	—	3.70%	8.99%	33.07%
United Kingdom	—	—	2.50%	86.81%
Ireland	—	—	—	52.35%
Italy	—	—	—	56.34%
Malaysia	—	—	~	78.12%
Mexico	—	—	—	45.15%
South Africa	—	—	3.30%	/
Spain	—	—	—	~
Turkey	—	—	21.08%	92.01%

Note: This table shows the *p*-values of the bootstrap test between US REITs and REITs in other countries, that is, cross-country contagion for the REITs sector. Strong evidence, that is, *p*-values less than 5% is highlighted in red background, and weak evidence implied by *p*-values between 5 and 10% is highlighted in yellow background. The symbol "—" denotes no available data in that period; the symbol "~" denotes the non-convergence of the local Gaussian approach; and the symbol "/" denote that no adequate ARMA-GARCH could be obtained for the marginal model. The chronology of the four periods are denoted as: Period 1 (dot-com crisis; before: Jan 1, 1998–Mar 10, 2000; after: Mar 11, 2000–Dec 31, 2002), Period 2 (global financial crisis; before: Jan 1, 2005–Aug 8, 2007; after: Aug 9, 2007–Aug 7, 2009), Period 3 (European sovereign debt crisis; before: Oct 24, 2007–Oct 4, 2009; after: Oct 5, 2009–Jul 31, 2012), and Period 4 (Recent, or Brexit in the UK; before: Jan 1, 2014–Jun 23, 2016; after: Jun 24, 2016–Sep 13, 2018).

4.2 | (Cross-country) Contagion between US REITs and REITs of other countries

We proceed with our analysis by studying the cross-country linkage in the REITs markets, that is, the US with other countries, given the dominance of the former in the REITs sector (as indicated by the NAREIT: the worldwide representative voice for REITs)[8] and the global economy in general. Table 2 presents the bootstrap test of contagion between US REITs and the REITs in the other 18 countries in the four periods. In the dot-com crisis, the contagion only took place between US and Belgium. In terms of the global financial crisis, we find strong evidence of contagion between US and Canada, and also between US and most established European markets except for Germany and the UK. While there is weak evidence between US and Australia, the effect is strong for New Zealand and Singapore. Contagion during the European sovereign debt crisis is observed between the US with Australia, France, the Netherlands, New Zealand, South Africa and the UK, with weak effects on Germany and Singapore. Interestingly, the contagion between US and Japan is found to be significant in Period 4.

To analyze nonlinear contagion between the mature US REITs market with the established Canadian securitized real estate sector, we present in Figure 3 the (nonlinear) local Gaussian correlation curves between US and Canada during the four different periods. In Period 1, the local Gaussian correlation curve drops after the burst of the dot-com bubble, but there is a rise in the local Gaussian correlation curve after the subprime mortgage crisis, especially in the middle regime of the distribution, but the increment in the right tail is marginal. Conversely and interestingly, there is a surge in the right tail of the local Gaussian correlation curve in the third period, while the curve keeps the similar level in the middle regime and left tail. Subsequently, the high local Gaussian correlation in the right tail dropped in Period 4. But more importantly, with the correlation being positive in all periods between REITs returns across the North American borders, imply that inter-country diversification benefits are very limited.

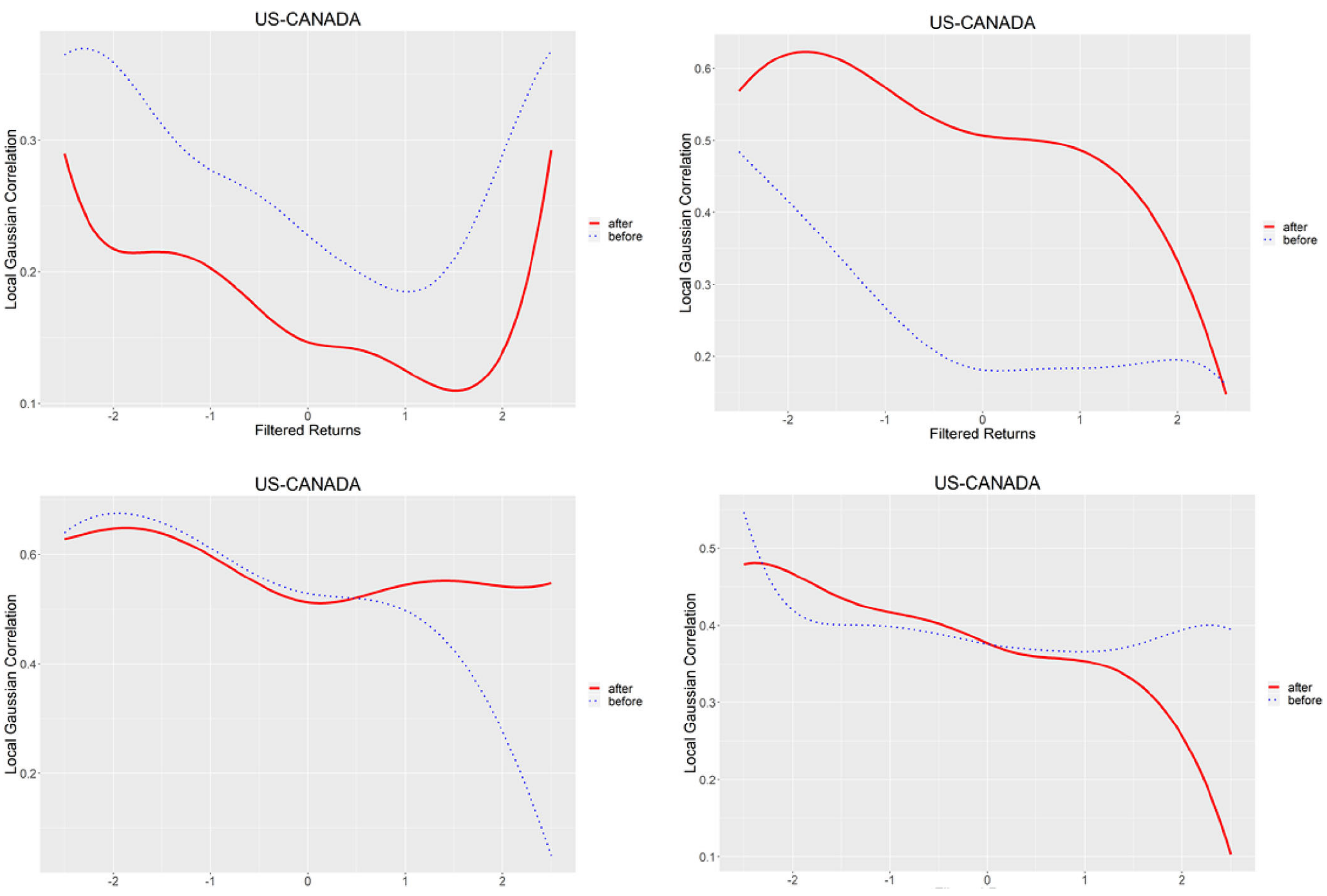

FIGURE 3 Local Gaussian correlation curves between the US and Canadian REITs in four periods: Period 1 (upper-left); Period 2 (upper-right); Period 3 (lower-left); and Period 4 (lower-right) [Colour figure can be viewed at wileyonlinelibrary.com]

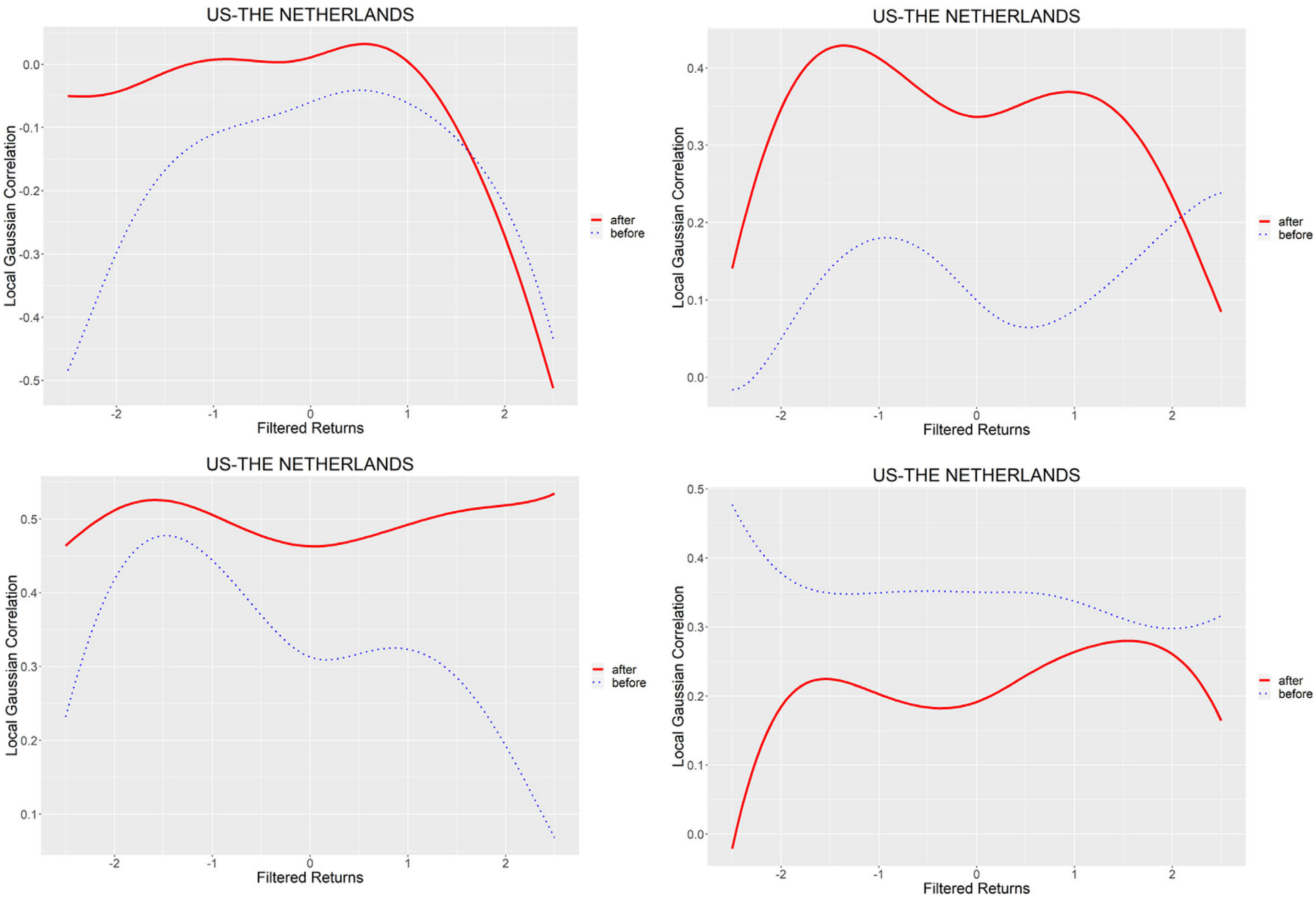

FIGURE 4 Local Gaussian correlation curves between REITs of the US and the Netherlands in four periods: Period 1 (upper-left); Period 2 (upper-right); Period 3 (lower-left); and Period 4 (lower-right) [Colour figure can be viewed at wileyonlinelibrary.com]

In order to demonstrate the linkage in the REITs markets of the US and Europe, Figure 4 presents the (nonlinear) local Gaussian correlation curves with the Netherlands, as an example. We choose the Netherlands, as the bootstrap test had provided strong evidence of significance during the periods spanning the global financial and sovereign debt crises. For periods 1, 2 and 3, we observe higher local Gaussian correlation estimates for the majority of the distribution, although in periods 1 and 2 the curves cross each other at the upper tail, which in turn could have made the contagion insignificant during the dot-com crisis. There is an obvious shrinkage of local Gaussian correlation in Period 4. Barring the lower-tail, that is, bearish state of the REITs markets during the dot-com crisis, any possibility of diversification benefit seems to have frittered away during the recent episodes of financial market crises. The consistent evidence of lack of diversification benefits relative to the US REITs market,[9] especially during recent periods, is an indication of the integration in the REITs market across the world, that is, they are driven by common shocks (Bardhan, Edelstein, & Tsang, 2008; Ji, Marfatia, & Gupta, 2018).

4.3 | (Cross-market-cross-country) Contagion between US REITs and equity markets of other countries

Again given the dominance of the US real estate sector, malfunctioning of which basically led to the global financial crisis, there could be contagion between US REITs and equity markets in other countries, that is, cross-market-cross-country contagion. Hence, we now study the local Gaussian correlation between US REITs and equity markets in the other 18 countries during the four period. Table 3 exhibits the bootstrap test of contagion between US REITs and the equity in the other 18 countries in the four periods. During the dot-com crisis, strong evidence of contagion for equity markets is observed in the three European countries of France, Germany and Italy, with weak evidence for Canada and Mexico. In terms of the global finance crisis, the bootstrap test suggests that

TABLE 3 *p*-values of the bootstrap test between US REITs and equity markets in other countries

Country	Period 1	Period 2	Period 3	Period 4
Australia	31.68%	1.98%	1.98%	8.91%
Belgium	45.54%	0.99%	3.96%	94.06%
Canada	5.94%	0.99%	2.97%	44.55%
France	2.97%	9.90%	4.95%	100.00%
Germany	0.99%	7.92%	1.98%	97.03%
Hong Kong	45.54%	23.76%	28.71%	40.59%
Japan	56.44%	54.46%	13.86%	13.86%
The Netherlands	14.85%	1.98%	9.90%	99.01%
New Zealand	33.66%	11.88%	6.93%	24.75%
Singapore	43.56%	8.91%	2.97%	26.73%
United Kingdom	37.62%	0.99%	1.98%	98.02%
Ireland	12.87%	1.98%	1.98%	/
Italy	4.95%	6.93%	14.85%	98.02%
Malaysia	78.22%	49.50%	12.87%	79.21%
Mexico	5.94%	0.99%	84.16%	77.23%
South Africa	62.38%	4.95%	0.99%	38.61%
Spain	32.67%	/	/	98.02%
Turkey	37.62%	0.99%	51.49%	75.25%

Note: This table shows the *p*-values of the bootstrap test between US REITs and equity markets in other countries, that is, cross-market-and-cross-country contagion. Strong evidence, that is, *p*-values less than 5% is highlighted in red background, and weak evidence implied by *p*-values between 5 and 10% is highlighted in yellow background. The symbol "/" denote that no adequate ARMA-GARCH could be obtained for the marginal model. The chronology of the four periods are denoted as: Period 1 (dot-com crisis; before: Jan 1, 1998–Mar 10, 2000; after: Mar 11, 2000–Dec 31, 2002), Period 2 (global financial crisis; before: Jan 1, 2005–Aug 8, 2007; after: Aug 9, 2007–Aug 7, 2009), Period 3 (-European sovereign debt crisis; before: Oct 24, 2007–Oct 4, 2009; after: Oct 5, 2009–Jul 31, 2012), and Period 4 (Recent, or Brexit in the UK; before: Jan 1, 2014–Jun 23, 2016; after: Jun 24, 2016–Sep 13, 2018).

contagion from US REITs is significant for the equity markets in the majority of countries (with weak effects in France, Germany, Italy and Singapore), except for New Zealand and the three Asian countries of Hong Kong, Japan and Malaysia. All the mainland European countries (with weak effect on the Netherlands), Ireland and the UK, other than Italy, shows evidence of contagion in their equity market with the US REITs market during the sovereign debt crisis. Additionally, we also observe strong evidence of contagion in Australia, Canada, Singapore and South Africa in Period 3, with weak affects also observed for New Zealand. Lastly, there is no strong evidence of contagion in the equity markets of any other 18 countries in the recent period, barring a weak impact on Australia.

To reflect the cross-market-cross-country linkages, we display the local Gaussian correlation curves between US REITs and equity market of the UK in Figure 5. Period 1 is shown to exhibit an interesting pattern, in the sense that there is a rise in the right tail and a drop in the left tail, making possibly the overall impact insignificant, as found in Table 3. We can clearly observe the upward movement in the local Gaussian correlation curves in both periods 2 and 3, while there is a reduction in the local Gaussian curve in the recent period (Period 4). In Figure 6, we select the pair of US REITs and equity market of Singapore and present their (nonlinear) local Gaussian correlation curves for the four periods. In Period 1, there is a fall of local Gaussian correlation in the right tail of the distribution. It is intriguing to observe that Period 2 experiences a rise in the middle of the distribution and a reduction in both tails, resulting in a weak overall effect as observed in Table 3. There is a universal increase in the whole distribution in Period 3, especially for the right tail and the regime between −2 and −1 in the distribution. In Period 4, the two local Gaussian correlation curves cross each other. In general again, due to the correlation being positive across US REITs return and equity return of the other countries,[10] cross-market-cross-country diversification, will barely help in improving the profitability of the portfolio during these periods of global crises. This is possibly due to the fact that though REITs market is indeed

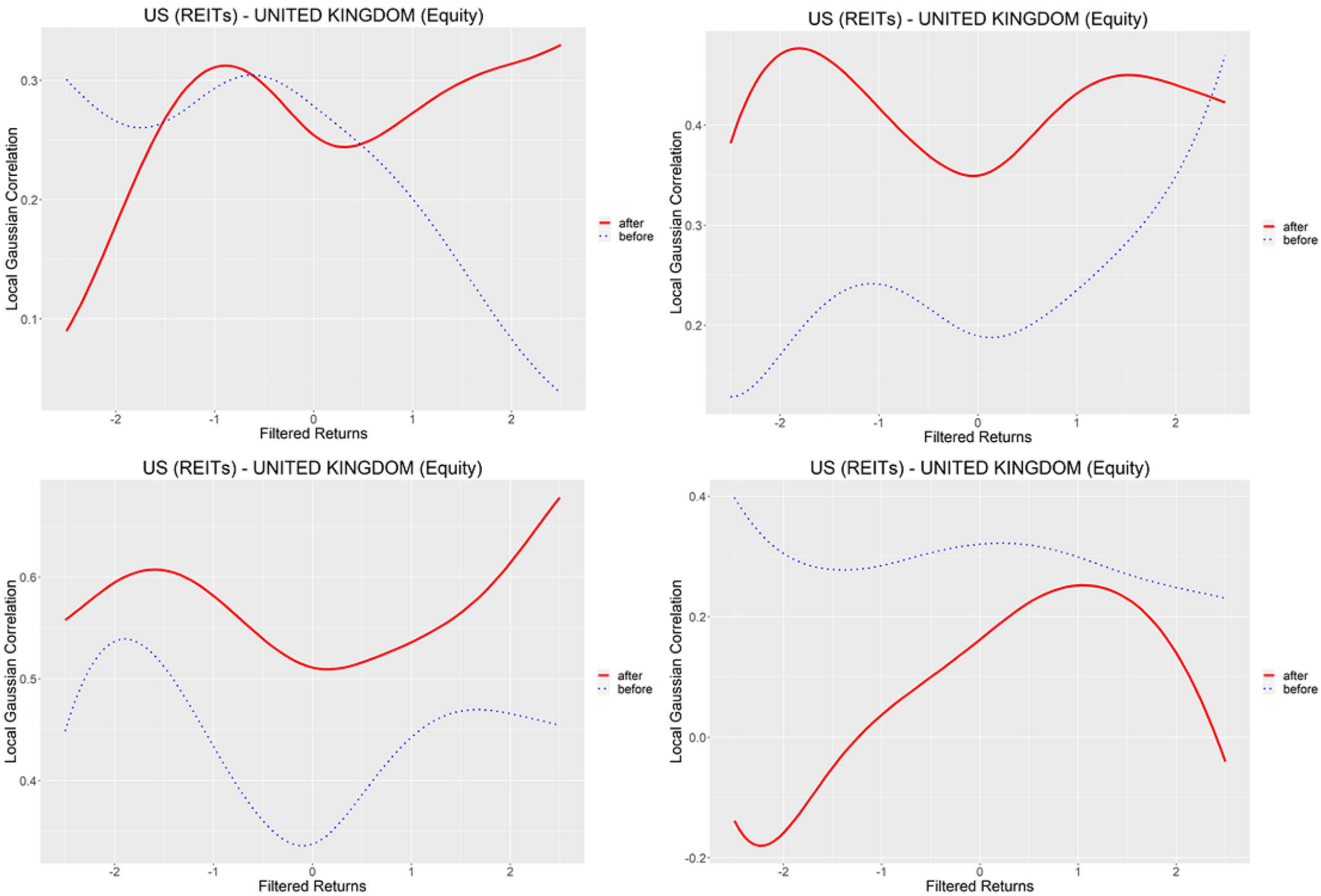

FIGURE 5 Local correlation curves between REITs of the US and equity of the UK in four periods: Period 1 (upper-left); Period 2 (upper-right); Period 3 (lower-left); and Period 4 (lower-right) [Colour figure can be viewed at wileyonlinelibrary.com]

associated with the real estate market, characteristically it is much similar to standard equity markets (Ghysels, Plazzi, Torous, & Valkanov, 2013).

Since US has the most advanced REITs market, our analysis in Section 4.2 and Section 4.3 focuses on the contagion between US REITs and REITs and equity markets in other countries. The contagion of other combinations could also be interesting for some certain periods. For example, there could be an impact on German REITs market due to European sovereign debt crisis, and Brexit may also affect the UK REITs market. Thus, we present additional results of the bootstrap test of contagion in Table B4 in the Appendix B, with interests in German and UK REITs markets.[11] Based on the strong evidence for German REITs market during Period 3, we can observe that it only had cross-country contagion with French REITs market, but had cross-market-cross-country contagion with the equity markets in the major European countries, such as France, the Netherlands, UK and Italy. This indicates that the linkage between German REITs and equity markets in Europe was stronger than the linkage in REITs markets. Based on the test results for UK in Period 4, we can hardly find any evidence of contagion with either REITs or equity markets in other economies. Again, this can be possibly explained by the fact that the negotiations for the deal between UK and EU was still in process during Period 4.

Overall, there is strong evidence of contagion between equities and REITs of the 19 countries considered, between US and other country REITs, and between US REITs and equities of the remaining 18 countries. The detected evidence of contagion can be explained via three possible theories of contagion namely, through financial linkages, trade links, and herding behaviour (Kaminsky, Reinhardt, & Végh, 2003). The financial linkages theory stipulates that contagion might occur through three mechanisms: information correlation, liquidity correlation and portfolio rebalancing. The information correlation channel (King & Wadhwani, 1990) is based on the price discovery process, which assumes immediate price effects in the markets affected by a financial collapse elsewhere. The model of King and Wadhwani (1990) shows that rational agents, by inferring information from price changes in some markets, can affect other markets, while the theoretical underpinning

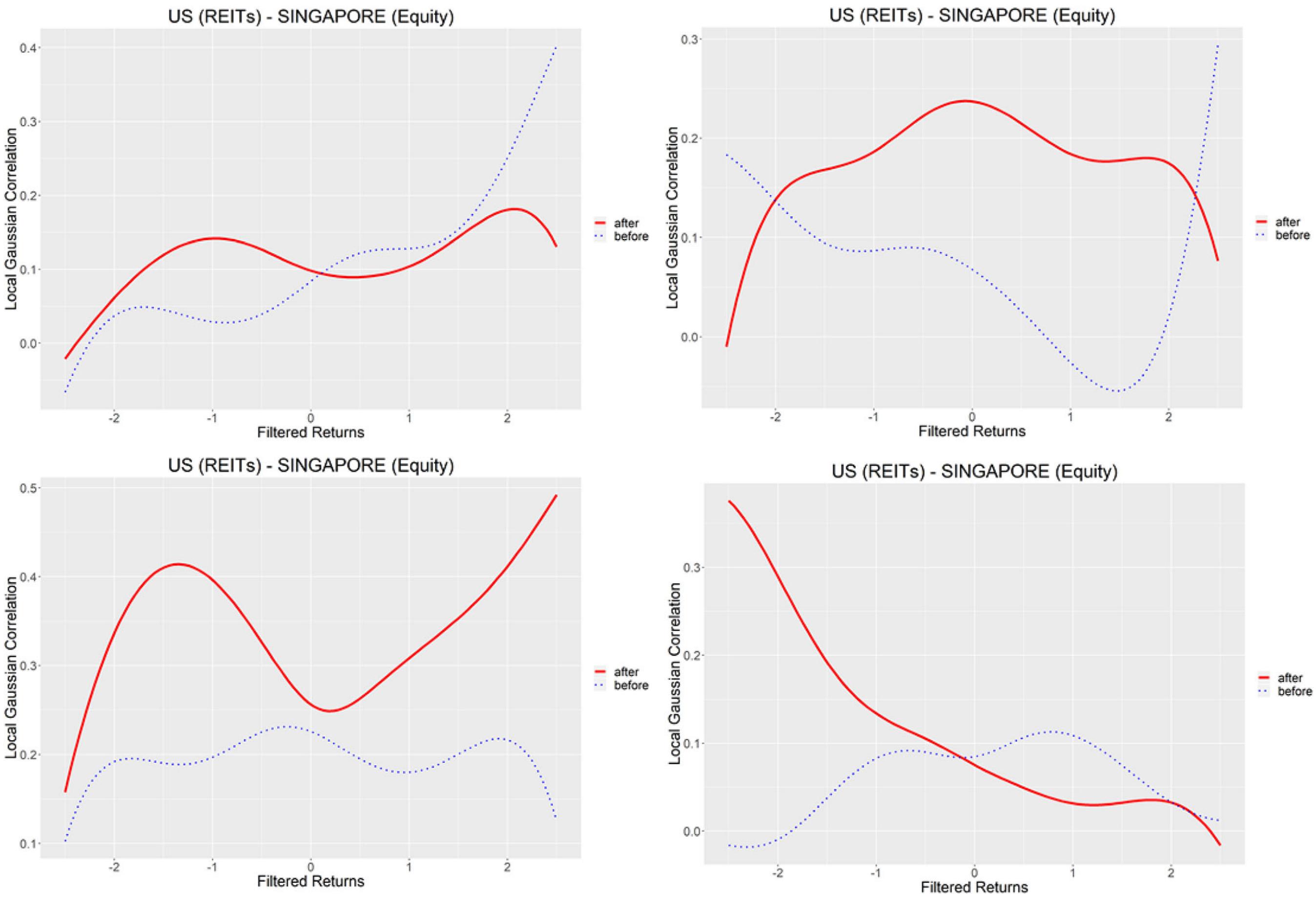

FIGURE 6 Local correlation curves between REITs of the US and equity of Singapore in four periods: Period 1 (upper-left); Period 2 (upper-right); Period 3 (lower-left); and Period 4 (lower-right) [Colour figure can be viewed at wileyonlinelibrary.com]

for the liquidity correlation channel investigation is provided by Brunnermeier and Pedersen (2009). The authors explain how liquidity spirals (funding liquidity and asset liquidity issues self-reinforcing) could emerge and explain a contagion phenomenon. The portfolio rebalancing channel suggests that contagion emerges when agents reallocate their portfolio in response to large losses in one or several markets (Kodres & Pritsker, 2002). As we study contagion across various asset classes in one country, the trade links theory cannot play any role in the propagation of shocks. In contrast, the third theory, that is, the herding behaviour theory (correlated trading activities across agents), may influence our findings, especially given evidence of herding in equity and REITs markets in the wake of heightened uncertainty, which is likely to exist during crises (Babalos, Balcilar, & Gupta, 2015; Balcilar & Demirer, 2015).

5 | CONCLUDING REMARKS

In this paper, we study the nonlinear contagion between REITs and the equity markets of 19 countries, which are at their different stages of development in terms of the REITs market. In addition, we also conduct the nonlinear analyses in contagion between US REITs and the other international REITs, as well as between US REITs and equity markets of the 18 remaining countries in our sample. We analyze contagion by using the local Gaussian correlation approach during the dot-com, global financial, European sovereign debt crises and the more recent period involving the Brexit in the UK, spanning the daily period of January 1, 1998 to September 13, 2018. In general, we find strong evidence of nonlinear contagion between equities and REITs of not only matured and established markets, but also in economies with an emerging REITs sector, especially during the global financial and sovereign debt crises. Further, when we considered contagion across REITs of the US and the other countries, and between US REITs and equities of the remaining 18 countries, a similar pattern emerges. These results tend to suggest that REITs and equity markets within and across economies have become more integrated post the dot-com crises, to the extent that the local Gaussian correlations are positive, implying limited diversification opportunities for investors. It is suggested that policymakers should closely monitor contagion of especially negative shocks emanating from not only domestic, but also foreign REITs (and equity) markets, as this is likely to deepen recessions or slowdown the recovery process. Naturally, policy authorities might need to be proactive with expansionary (monetary) policies to revive the economy.

Given that REITs markets around the world seem to have become integrated in recent years, as part of future research, it would be interesting to obtain common time-varying components of returns and volatilities following the procedure of Bhatt, Kishor, and Ma (2017), and then analyze the factors that drive these comovements. Further, one could do a similar analysis for equity markets, and then compare whether the driving factors across REITs and equity markets are common or not. These would serve as important information for investors and policymakers alike. Additionally, we use the bootstrap test for contagion which detects the existence of contagion in an *ex post* manner and can retrospectively reveal the contagion in this study. It is possible to develop a testing procedure *á la* Chu, Stinchcombe, and White (1996) to real-time monitor the change from non-contagion to contagion. If the contagion can be detected in real-time, it becomes interesting to study the possible opportunities of trading and arbitrage.

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ENDNOTES

[1] The existing literature has recognized at least three possible theories of contagion, that is, through financial linkages (which in turn has three channels, that is, information correlation, liquidity correlation and portfolio rebalancing), trade links, and herding behaviour (Hoesli & Reka, 2015). We discuss these channels in greater detail in Section 4 of the paper.

[2] REITs are required to follow regulations of individual countries regarding investment, income distribution and tax treatment.

[3] In our case, all our chosen models for the various cases considered satisfied the *i.i.d.* assumption. The results of all these tests are available upon request from the authors and have been suppressed to save space.

[4] We appreciate Bård Støve and Dag Tjøstheim for providing the R codes of the contagion bootstrap test.

[5] In addition to the extreme events of last two decades, we are also aware that many countries (e.g., UK) have had an established market of real estate companies that were listed on the stock exchange but did not have the REIT status at that time.

[6] The figures for the local Gaussian curves of all countries for the various periods can be obtained upon request from the authors. In general, as in the case of the US, with the correlation being positive between REITs and stock returns, any possibility of diversification is nullified.

[7] Note that, as no adequate ARMA-GARCH framework could be obtained for the marginal model in the last period, and no data on REITs is available for the first and the second crises in South Africa, we are only restricted to the third period of European sovereign debt crisis.

[8] See: https://www.reit.com/investing/global-real-estate-investment

[9] The figures for the local Gaussian curves of the remaining 16 countries for the various periods, showing similar positive correlation patterns in general, are available upon request from the authors.

[10] The figures for the local Gaussian curves of the remaining 16 countries for the various periods, depicting positive correlation in general, are available upon request from the authors.

[11] Note that there could be small differences in the *p*-values of the bootstrap test of contagion between REITs markets in the US, UK, and Germany, due to the nature of bootstrap procedure.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are openly available in the DataStream database of Thomson Reuters at http://datastream.thomsonreuters.com/dsws/1.0/DSLogon.aspx?persisttoken=true&appgroup=DSExtranet&srcapp=Extranet&srcappver=1.0&prepopulate=&env=&redirect=https://infobase.thomsonreuters.com/infobase/.

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APPENDIX A.: SEQUENTIAL SEARCH PROCEDURE

We elaborate the sequential search procedure to determine the appropriate orders for ARMA(p_1, q_1) – GARCH(p_2, q_2) in the following. The maximum of ARMA lags p_1 and q_1 are capped at 5, that is, $p_1 \le 5$, $q_1 \le 5$. The maximum of GARCH lags p_2 and q_2 are capped at 2, that is, $p_2 \le 2$, $q_2 \le 2$. Firstly, we run all models in the setting of ARMA(p_1, q_1) – GARCH(1, 1) and select the best model by the Bayesian information criterion (BIC), within the adequate models that can pass various diagnosis tests. If there is no adequate model in the setting of ARMA(p_1, q_1) – GARCH(1, 1), then we will try to find the best model by BIC within the models that can pass various diagnosis tests subsequentially in the settings of ARMA(p_1, q_1) – GARCH (2, 1), ARMA(p_1, q_1) – GARCH(1, 2), ARMA(p_1, q_1) – GARCH(2, 2). If there is still no adequate model in the setting of ARMA(p_1, q_1) – GARCH(2, 2), then we skip the analysis for this country in this period. The motivation for the above procedure is that the model with a smaller number of parameters are preferred and typically ARMA(p_1, q_1) – GARCH(1, 1) is adequate to produce a satisfactory model. In rare cases, we will have higher orders in the GARCH part.

APPENDIX B.: SUMMARY STATISTICS AND ADDITIONAL RESULTS

TABLE B1 Summary statistics of equity return

Country	Mean	Median	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	*p*-value	Obs.
Australia	0.0002	0.0005	0.0881	−0.1598	0.0144	−0.749	12.6115	20,577	0	5,219 (September 14, 1998–September 13, 2018)
Belgium	0	0.0003	0.1066	−0.1546	0.0145	−0.3835	10.8849	13,648	0	5,219 (September 14, 1998–September 13, 2018)
Canada	0.0002	0.0007	0.1028	−0.1425	0.0138	−0.6783	12.4423	19,788	0	5,219 (September 14, 1998–September 13, 2018)
France	0.0001	0.0005	0.1184	−0.1157	0.0152	−0.0802	9.2711	8,558	0	5,219 (September 14, 1998–September 13, 2018)
Germany	0.0001	0.0004	0.1159	−0.0964	0.0157	−0.0907	7.7706	4,956	0	5,219 (September 14, 1998–September 13, 2018)
Hong Kong	0.0003	0.0001	0.1045	−0.1257	0.0134	−0.1331	9.645	9,617	0	5,219 (September 14, 1998–September 13, 2018)
Ireland	−0.0001	0.0001	0.136	−0.1893	0.0172	−0.6845	13.0615	22,422	0	5,219 (September 14, 1998–September 13, 2018)
Italy	−0.0001	0.0002	0.1247	−0.1569	0.0164	−0.2109	9.5727	9,433	0	5,219 (September 14, 1998–September 13, 2018)
Japan	0.0001	0.0001	0.1227	−0.0951	0.0139	−0.0138	7.9173	5,258	0	5,219 (September 14, 1998–September 13, 2018)
Malaysia	0.0003	0	0.1797	−0.3697	0.0125	−4.0721	168.9842	6,005,566	0	5,219 (September 14, 1998–September 13, 2018)
Mexico	0.0004	0.0006	0.1516	−0.109	0.0167	0.0836	9.8755	10,286	0	5,219 (September 14, 1998–September 13, 2018)

(Continues)

TABLE B1 (Continued)

Country	Mean	Median	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	*p*-value	Obs.
Netherlands	0.0001	0.0003	0.1053	−0.1151	0.0145	−0.175	9.3865	8,896	0	5,219 (September 14, 1998–September 13, 2018)
New Zealand	0.0001	0.0005	0.102	−0.1007	0.0135	−0.3625	7.1696	3,895	0	5,219 (September 14, 1998–September 13, 2018)
Singapore	0.0003	0.0003	0.0856	−0.0981	0.0132	−0.1367	7.798	5,022	0	5,219 (September 14, 1998–September 13, 2018)
South Africa	0.0003	0.0009	0.1235	−0.1357	0.0178	−0.289	7.1634	3,842	0	5,219 (September 14, 1998–September 13, 2018)
Spain	0.0001	0.0001	0.1601	−0.1604	0.0166	−0.0631	10.5854	12,516	0	5,219 (September 14, 1998–September 13, 2018)
Turkey	0.0001	0.0003	0.2202	−0.2742	0.0281	−0.1786	11.0058	13,965	0	5,219 (September 14, 1998–September 13, 2018)
United Kingdom	0	0.0003	0.1216	−0.1147	0.0133	−0.2358	12.2133	18,507	0	5,219 (September 14, 1998–September 13, 2018)
United States	0.0002	0.0003	0.1104	−0.0951	0.0118	−0.2262	11.5557	15,962	0	5,219 (September 14, 1998–September 13, 2018)

TABLE B2 Summary statistics of REITs return

Country	Mean	Median	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	*p*-value	Obs.
Australia	0.0001	0.0004	0.105	−0.1848	0.015	−1.1566	17.8391	49,048	0	5,219 (September 14, 1998–September 13, 2018)
Belgium	0.0001	0.0003	0.1067	−0.0867	0.0116	−0.0966	8.9083	7,599	0	5,219 (September 14, 1998–September 13, 2018)
Canada	0.0002	0.0003	0.0852	−0.1183	0.0115	−0.5916	13.3374	23,542	0	5,219 (September 14, 1998–September 13, 2018)
France	0.0003	0.0006	0.0955	−0.1036	0.0158	−0.1452	6.8434	2,415	0	3,902 (October 01, 2003–September 13, 2018)
Germany	−0.0001	0.0002	0.2765	−0.2254	0.0246	0.3228	19.2504	31,320	0	2,842 (October 24, 2007–September 13, 2018)
Hong Kong	0.0004	0	0.1008	−0.1325	0.0117	−0.4057	14.4024	20,178	0	3,706 (July 01, 2004–September 13, 2018)
Ireland	−0.0001	0	0.0564	−0.0764	0.014	−0.1768	5.4248	308	0	1,232 (December 25, 2013–September 13, 2018)
Italy	−0.0002	0	0.2267	−0.138	0.0243	0.1446	9.3411	4,504	0	2,683 (June 03, 2008–September 13, 2018)

TABLE B2 (Continued)

Country	Mean	Median	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	*p*-value	Obs.
Japan	0.0002	0.0001	0.106	−0.1181	0.0136	−0.218	11.3108	12,767	0	4,424 (October 01, 2001–September 13, 2018)
Malaysia	0.0001	0	0.0998	−0.0886	0.0104	0.0636	12.9803	12,855	0	3,097 (November 01, 2006–September 13, 2018)
Mexico	−0.0002	0	0.0749	−0.1093	0.0141	−0.4056	7.9165	1,611	0	1,557 (September 26, 2012–September 13, 2018)
Netherlands	0	0.0004	0.0862	−0.0828	0.0138	−0.2967	8.1037	5,741	0	5,219 (September 14, 1998–September 13, 2018)
New Zealand	0.0001	0	0.0797	−0.0939	0.0117	−0.5779	7.7619	5,221	0	5,219 (September 14, 1998–September 13, 2018)
Singapore	0.0003	0.0002	0.2042	−0.1774	0.0129	0.2813	34.2087	161,085	0	3,968 (July 01, 2003–September 13, 2018)
South Africa	0	0.0004	0.1426	−0.1491	0.0167	−0.5725	10.8111	9,045	0	3,483 (May 10, 2005–September 13, 2018)
Spain	0.0001	0	0.0464	−0.175	0.0087	−5.5489	111.9655	1,199,163	0	2,399 (July 06, 2009–September 13, 2018)
Turkey	−0.0007	0	0.1715	−0.1846	0.0263	−0.4955	8.9918	5,029	0	3,272 (March 01, 2006–September 13, 2018)
United Kingdom	−0.0003	0.0001	0.1171	−0.2428	0.0191	−1.0259	16.828	24,680	0	3,031 (Febraury 01, 2007–September 13, 2018)
United States	0.0002	0	0.1712	−0.2195	0.0173	−0.2222	26.3021	118,120	0	5,219 (September 14, 1998–September 13, 2018)

TABLE B3 Pearson's correlation coefficient between REITs and equity returns in the same country

	Period 1		Period 2		Period 3		Period 4	
	Before	After	Before	After	Before	After	Before	After
United States	0.32	0.50	0.68	0.83	0.83	0.86	0.65	0.46
Australia	0.67	0.65	0.77	0.81	0.80	0.86	0.82	0.67
Belgium	0.26	0.24	0.55	0.53	0.53	0.80	0.54	0.61
Canada	0.38	0.33	0.56	0.78	0.78	0.80	0.71	0.68
France	—	—	0.64	0.79	0.80	0.89	0.77	0.70
Germany	—	—	—	—	0.47	0.54	0.57	0.57
Hong Kong	—	—	0.29	0.58	0.57	0.42	0.54	0.51
Japan	—	—	0.42	0.64	0.63	0.58	0.46	0.35
The Netherlands	0.23	0.30	0.66	0.78	0.78	0.84	0.63	0.69
New Zealand	0.21	0.38	0.59	0.76	0.75	0.66	0.71	0.65
Singapore	—	—	0.62	0.74	0.74	0.82	0.80	0.66
United Kingdom	—	—	—	—	0.74	0.86	0.77	0.79
Ireland	—	—	—	—	—	—	0.29	0.43
Italy	—	—	—	—	—	—	0.55	0.57
Malaysia	—	—	—	—	0.42	0.44	0.72	0.43
Mexico	—	—	—	—	—	—	0.75	0.85
South Africa	—	—	—	—	0.77	0.77	0.81	0.85
Spain	—	—	—	—	—	—	0.42	0.72
Turkey	—	—	—	—	0.79	0.77	0.86	0.88

Note: This table shows the Pearson's correlation coefficient between REITs and equity market returns within a specific country. The symbol "—" denotes no available data in that period. The chronology of the four periods are denoted as: Period 1 (dot-com crisis; before: Jan 1, 1998–Mar 10, 2000; after: Mar 11, 2000–Dec 31, 2002), Period 2 (global financial crisis; before: Jan 1, 2005–Aug 8, 2007; after: Aug 9, 2007–Aug 7, 2009), Period 3 (European sovereign debt crisis; before: Oct 24, 2007–Oct 4, 2009; after: Oct 5, 2009–Jul 31, 2012), and Period 4 (Recent, or Brexit in the UK; before: Jan 1, 2014–Jun 23, 2016; after: Jun 24, 2016–Sep 13, 2018).

TABLE B4 *p*-values of the additional bootstrap tests

	Period 3		Period 4	
	Germany REITs vs other REITs[a]	Germany REITs vs other equity[b]	UK REITs vs other REITs[c]	UK REITs vs other equity[d]
United States	5.29%	5.69%	87.01%	99.90%
Australia	6.49%	17.98%	11.69%	73.43%
Belgium	19.58%	6.29%	74.53%	99.80%
Canada	17.68%	16.58%	61.64%	91.61%
France	2.20%	0.80%	94.21%	100.00%
Germany	†	2.20%	77.52%	100.00%
Hong Kong	86.51%	97.10%	75.12%	82.72%
Japan	91.51%	21.88%	17.78%	30.97%
The Netherlands	11.39%	0.60%	91.81%	100.00%
New Zealand	25.07%	18.18%	15.98%	31.67%
Singapore	5.49%	11.39%	23.38%	98.60%
United Kingdom	13.99%	0.50%	†	99.50%
Ireland	—	5.19%	19.78%	/
Italy	—	1.80%	78.62%	99.90%
Malaysia	~	49.75%	88.81%	27.27%
Mexico	—	30.17%	90.71%	93.21%
South Africa	15.58%	14.79%	/	86.71%
Spain	—	/	~	100.00%
Turkey	18.58%	48.25%	83.92%	98.10%

Note: Strong evidence, that is, *p*-values less than 5% is highlighted in red background, and weak evidence implied by *p*-values between 5 and 10% is highlighted in yellow background. The symbol "—" denotes no available data in that period; the symbol "~" denotes the non-convergence of the local Gaussian approach; the symbol "/" denotes that no adequate ARMA-GARCH could be obtained for the marginal model; and the symbol "†" denotes not applicable. The chronology of the four periods are denoted as: Period 1 (dot-com crisis; before: Jan 1, 1998–Mar 10, 2000; after: Mar 11, 2000–Dec 31, 2002), Period 2 (global financial crisis; before: Jan 1, 2005–Aug 8, 2007; after: Aug 9, 2007–Aug 7, 2009), Period 3 (European sovereign debt crisis; before: Oct 24, 2007–Oct 4, 2009; after: Oct 5, 2009–Jul 31, 2012), and Period 4 (Recent, or Brexit in the UK; before: Jan 1, 2014–Jun 23, 2016; after: Jun 24, 2016–Sep 13, 2018).

[a]This column shows the *p*-values of the bootstrap test between Germany REITs and REITs in other countries in Period 3.

[b]This column shows the *p*-values of the bootstrap test between Germany REITs and equity markets in different countries in Period 3.

[c]This column shows the *p*-values of the bootstrap test between UK REITs and REITs in other countries in Period 4.

[d]This column shows the *p*-values of the bootstrap test between UK REITs and equity markets in different countries in Period 4.