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Market Integration Among the US and Asian Real Estate Investment Trusts in Crisis Times

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The market integration of real estate investment trusts (REITs) in the US and four Asian markets as well as between their local stock and REIT markets are investigated in this paper. Using a number of modern econometric techniques on three integration indictors/proxies: time-varying conditional correlations, dynamic risk connectivity (variance-covariance) and cause and effect dependency of linear /nonlinear spillover and connectedness, we find that the five REIT markets show less integration than their corresponding stock markets. Moreover, the modelling of the portfolio risk spillover and connectedness (with covariance) shows a higher average level of market integration for the Asian REIT group. The REIT markets have experienced some significant shifts in their net total and net-pairwise directional risk connectivity. Additionally, investors and policymakers are reminded that any modelling of the cause and effect dependency of the REIT markets should be implemented with linear regression equations and a nonlinear value at risk system in risk spillover and connectedness (with covariance). Finally, significant contagious effects are identified across the REIT markets and stock and REIT portfolios during the global financial crisis and China stock market crash.

Keywords

Market Integration, Time-Varying Conditional Correlation, Portfolio Risk Spillover and Connectedness, Variance-Covariance, Nonlinear Causality, Real Estate Investment Trust

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1. Introduction

Understanding the nature and degree of market integration among real estate investments trusts (REITs) and between their local stock and REIT markets have important implications for portfolio diversification, risk management and future development of this potentially important securitized real estate investment vehicle. REITs are a relatively young asset class in Asia and internationally. With few studies in the literature that provide insights into regional /global market integration, the aim of this paper is to address this important topic by comprehensively investigating three market linkage indicators/proxies (hereinafter the 3Cs): (a) time-varying conditional co-movements, (b) dynamic conditional risk (variance-covariance) connectedness and (c) dependence on linear and nonlinear causal relationships. The study period is between January 2004 and June 2019.[1] During this period of time, the world experienced at least three major financial crises: the 2007-2009 global financial crisis (GFC), 2010 European debt crisis (EDC)[2] and 2015 stock market crash in China (CSTCRASH). We include the US REIT market (US REITs) and four established REIT markets in Asia: Australia (AREITs), Japan (JREITs), Singapore (SREITs) and Hong Kong (HK REITs).[3] In particular,

[1] Although a large body of literature has investigated financial market integration, the link to financial market integration should be investigated through proper testing of an asset pricing model such as the capital asset pricing model (CAPM) or arbitrage pricing theory (APT). As defined by Stulz (1981): "asset markets are said to be perfectly financially integrated internationally if two assets which have perfectly correlated returns in a given currency but belong to two different countries have identical expected returns in that currency". The three indicators investigated in this paper measures market relationships or interdependence. However, higher market interdependence indicates a tendency to move towards higher levels of "market integration". While a certain level of capital /asset market integration among different asset markets may be beneficial for the purposes of market growth, excessive integration could inadvertently facilitate financial contagion which is undesirable (Parker et al., 2018). Empirically, market spillover measures such as return correlation, volatility connectedness and causality dependence are three popular integration proxies.

[2] During the EDC period, several REIT markets such as the American, Japanese, Asian and European markets, became highly interactive to remedy the EDC and banking crisis, which extended from the GFC due to the highly interest-rate sensitive characteristics of real estate financing. Thus, the inclusion of the EDC in this study is justified by its possibility of affecting Asian market integration.

[3] These five REIT markets are included mainly due to the following reasons: (i) Australia, Japan, Singapore and Hong Kong have the four largest and most developed REIT markets in the Asia-Pacific region. Their REIT markets also have the longest time series data required for the study and are the most appropriate to assess regional (Asian) integration dynamics, (ii) the US REIT market (also the largest REIT market in the world) is also included as a global proxy to assess the degree of market integration with the Asian REIT markets. Its inclusion in this study will help to determine the importance of the contribution of the US REIT market to REIT "market integration" in this region, and (iii) since we use a representative "Asian" sample, the results of this study could be generalized to other "emerging" or "developing" REIT markets that are searching for an

market integration is evaluated for two groups: (i) among the US and four Asian REIT markets, and (ii) between the local stock and REIT markets of the five countries. Specifically, we will examine the following questions regarding market integration in a more general setting:

(a) How do the identified dynamics of co-movement/connectedness/cause and effect dependency among the REIT markets and between the stock and REIT markets vary over time and among countries?
(b) Was market integration higher during the three crisis events?
(c) What are the specific implications of the study on asset allocation and risk hedging?

To begin, we adopt a VECH-MGARCH model to estimate the conditional volatilities of the REITs and implied time-varying correlations.[4] Then, we investigate the 3Cs for the two groups over the three crisis periods.

This paper contributes to the literature in the following ways. Previous studies in the literature on market integration have mostly focused on the mainstream financial sectors, with inadequate attention given to real estate assets (Hoesli and Reka, 2015). This is especially the case for REITs which are a relatively young asset class. This paper addresses this important topic within the context of international REIT research. Second, in addition to the GFC and EDC, we investigate the effects of the CSTCRASH on the integration of cross-listed REIT and stock-REIT markets. Although real estate markets are quite local, the inclusion of CSTCRASH in this study can be justified due to the geographical proximity of China with the four concerned Asian countries and its close economic ties with the US. Moreover, China has emerged as a major power in the world economy (Wang et al. 2016) and its stock market is the second largest capital market in the world. Consequently, it is anticipated that the Chinese stock market will increasingly influence the integration of the global financial market (including REITs), which is why events in China might have larger impacts on the REIT markets of other countries and the impact of the CSTCRASH is mainly on its own stock market in this instance. By including the CSTCRASH, we can link financial contagion with market integration during the three crisis events. Another contribution of this paper is the methodology that is used for investigation. This paper presents several empirical extensions to proxy for market integration. Previous studies in the literature have used each of these measures separately. The use of all three indicators/proxies in this paper is an important step towards a more clear and holistic understanding on the integration of cross-listed REIT and stock-REIT markets by using recently developed econometric procedures such as time-varying dynamic conditional co-movement (Engle, 2002), rolling windows in bivariate nonlinear causality (Diks and Panchenko, 2006) and multivariate nonlinear Granger causality tests (Bai et al. 2010, 2018) and the spillover and

appropriate level of market integration with other REIT markets and the global REIT market.

[4] VECH means that the model is expressed in terms of vectorized conditional matrices.

connectedness of portfolio risk (variance-covariance) (Diebold and Yilmaz, 2012, 2014; Fengler and Gisler, 2015).

The paper is organized as follows. Section One is the introduction. Section Two is a brief literature review. Section Three reports the data. The econometric methods are explained in Section Four. The results are presented in Section Five. Section Six concludes.

2. Literature Review and Knowledge Gaps

This study on the relationships between cross-listed REIT and local stock-REIT markets expands on current academic research work on financial market integration. The study also contributes to a large body of theoretical and empirical studies on market spillover and contagion during financial crises (Yiu et al. 2010). Here, four key themes are discussed.

First, this study is about REITs. The National Association of Real Estate Investment Trusts (NAREIT, USA) defines a REIT as "a company that owns or finances income-producing real estate. Modelled after mutual funds, REITs historically have provided investors of all types regular income streams, diversification and long-term capital appreciation" (NAREIT 2020). REITs typically pay out all their taxable income as dividends to shareholders. In turn, shareholders pay income taxes on the received dividends. The US Congress first created REITS in 1960 under the Real Estate Investment Trust Act to provide small investors with the opportunity to invest in large scale portfolios of income producing real estate. After almost six decades, the US REIT regime is the most mature market in the world with 246 highly specialized REITs (Parker et al. 2018). Australia established a similar REIT regime in 1971 and has been one of the most successful indirect property investment vehicles (Lee, 2018). As of September 2016, the European Public Real Estate Association (EPRA) reported 35 countries with REIT regimes. SREITs were first introduced in 1999 and became effective in 2002, followed by JREITs in 2002 and HK REITs in 2004 (Ooi and Wong, 2018). SREITs have provided opportunities for small investors to access real estate in a liquid and diversified form. Their market size was US$50.3b in 2016 (Liow and Huang, 2018). Since their debut, both JREITs and HK REITs have shown impressive growth, and reported market capitalization of around US$103.5b and US$25.6b respectively in December 2016 (Ooi and Wong, 2018). However, within the context of economic globalization and financial market integration, Parker (2018) has further highlighted that an ongoing and unresolved issue is the appropriate level of integration between the various REIT markets at both the regional and global levels because excessive integration could inadvertently facilitate contagion while inadequate integration does not contribute to market growth. While it is beyond the scope of this paper to directly address this issue, we investigate three empirical proxies of market integration (i.e., co-movement-connectedness-cause and effect) and their behavior across the three crises of concern in this study.[5]

This follows with another interesting question, which is to ask why a crisis in one country might spill over to the REIT markets in other countries. King and Wadhwani (1990) are the first to examine cross-border volatility spillover in stock markets during the 1987 global-wide stock market plunge. They find that increases in volatility amplified the contagion effects as shown by the increased correlation among the markets just after the 1987 stock market crash. Since REITs are considered to bridge the property and equity asset classes, Hoesli and Reka (2015) examine three channels that affect spillover to study the transmission of shocks between the stock and REIT markets in the US.

The first channel is through financial institutions (Brunnermeier and Pederson, 2008) which refers to the vicious cycle in which initial losses lead to asset sell-offs and result in further losses and additional sell-offs across financial institutions during highly volatile periods. A good example is when numerous international financial institutions were exposed to the vulnerability of the US mortgage market system during the subprime mortgage crisis which caused extreme market illiquidity. The international liquidity spiral significantly spilled over to REITs due to the following reasons: (a) REITs have a relatively higher leverage than other industries (Giacomini et al., 2017) since their underlying properties are pledged as collateral. Second, REITs in many countries are required to distribute a large proportion of income to their investors and consequently have little retained earnings. As a result, many REITs depend on short-term capital to support their operations. Thus, the liquidity constraint of the banking sector directly aggravates the funding environment for REITs.

The second channel is through cross-market rebalancing which increases the risk of contagion across countries as per Kodres and Pritsker (2002) especially to unconnected markets (i.e. closed-off economies that experience very little spillover from the global markets). However, under the correlated information channel in King and Wadhwani (1990), investors rebalance their portfolios in response to crisis shocks in a contagious market. As the momentum of REITs continue, they emerge as an important asset class in the international financial system, so that REIT markets become increasingly affected by the spillover effects of crises in other countries through cross-country rebalancing which acts as a channel to transmit shocks.

Finally, there are conventional economic linkages that transmit shock, such as trade linkages, which are another important component in driving cross-border

[5] Matteo and Rebucci (2007) use a Bayesian time-varying coefficient model to measure contagion and interdependence, which they apply to the Chilean FX market during the 2001 Argentine crisis. They claim that the model can differentiate between contagion and interdependence, as well as unusually strong or weak market co-movement.

spillover in the REIT markets, especially large-scale commercial real estate which is one of the major local assets that reflects the status of the local economy (Tuzel and Zhang, 2017). Since the assets of REITs are subject to local market cycles, a sudden crisis in one economy can affect the REIT markets in other economies due to the linking of economic conditions. For example, if one country very much depends on export and faces a substantial decrease in exports as the economies which they have mutual trade linkages are undergoing crises, this would result in negative spillover effects that would cause a reduction in asset prices, including real estate. In addition, REITs/real estate firms may also suffer from a reduction in foreign direct investment in real estate related projects.

Consistent with the literature, the ex-ante expectation is that increased stock market integration can be measured by using three empirical proxies: (a) increased time-varying co-movement between different stock market returns (Bracker and Koch, 1999), (b) increased shock effects under conditional volatility spillover and connectedness across stock markets (Diebold and Yilmaz, 2009, 2012, 2014), and (c) increased Granger causality of the net spillover effects, which is intrinsically linked to market integration (Granger, 1969; Okunev et al., 2000). The ability to accurately measure the current level of market integration is important to rebalance portfolios through shock transmission channels as discussed above. A question that may interest portfolio investors in this context is the degree of integration in the REIT market and whether the integration is increasing regionally and globally. A study by Liow and Schindler (2014) assesses whether nine developed public real estate and stock markets across three continents in their sample are linked at the local, regional and global levels. Using a number of modern econometric techniques that include dynamic conditional correlation, causality-in mean and causality-in variance, recursive integration score analysis, factor analysis and cross-asset return dispersion/differential, their analysis extends to the recent GFC to assess its impact on the co-movement and integration of the real estate and stock markets. They then remind international investors and financial institutions who are keen to include public real estate and common stocks in their portfolios with a somewhat adverse economic implication in their portfolio decisions, namely portfolio diversification and market integration. As Asteriou et al. (2016) further note, increasing economic globalization and greater integration of the financial markets (particularly the stock markets) over time will cause REIT investors to wonder whether a similar market connectedness is found in the global REIT market and an optimal level of integration can be possible, such as portfolio diversification benefits that can still remain intact without being subjected to “excessive” contagion (Parker, 2018). To the best of our knowledge, aside from Asteriou et al. (2016), Liow and Huang (2018) apply a larger sample of ten REITs to study the volatility connectivity of REITs (without covariance). Here, this study applies the US and four Asian REIT markets to explore a wider range of issues in the integration of global/regional cross-listed REIT and local stock-REIT markets, thereby contributing to current knowledge on the subject topic.

The final part of the literature review is associated with the different approaches and econometric techniques that are used in this study. First, the use of a diagonal VECH-MGARCH specification with rank one matrices will reduce the number of parameters that need to be estimated and ensure that the conditional covariance matrix is positive semi-definite (Sun, 2009). The specification also estimates the conditional variances and the implied correlations at the same time. Second, the dynamic conditional correlations in Engle (2002) are used to determine market integration in crisis times by isolating financial contagious effects from market interdependence with the use of a dummy variable regression approach (e.g. Chiang et al., 2007; Moore and Wang, 2007, Budd 2007, Maghyereh et al. 2015). Third, a risk spillover and connectedness index is used in this study, which is another popular market integration proxy, by using the generalized decomposition in vector autoregression (VaR) estimates in Diebold and Yilmaz (2012, 2014). Unlike the vast empirical literature on the subject (e.g. Alter and Beyer, 2014, Sugimoto et al. 2014, Liow, 2015, Fernández-Rodríguez et al. 2016; Raddant and Kennett, 2016, Liow and Huang, 2018), Fengler and Gisler (2015) propose a method for risk spillover and connectedness by evaluating the role of covariance in transmitting risk spillovers across the US stock, bond and gold markets. They find that by excluding co-variances from their information spillover analysis, the level of system-wide market integration is underestimated by about 54 percent. We are one of very few to adopt their (variance-covariance) risk spillover and connectedness method to examine the integration of the cross listed-REIT and stock-REIT markets. Finally, aside from Choudhry et al. (2015, 2016) who investigate the multivariate nonlinear causal relationship between gold and stock market returns, as well as between stock market volatility and business cycles, we examine both bivariate linear and nonlinear causal relationships (Diks and Panchenko, 2006, Ajmi et al. 2014), as well as multivariate linear and nonlinear causal relationships (Bai et al. 2010, 2018) to provide some practical guidelines for investors in an international environment.

Overall, there is undoubtedly a growing interest in REIT market integration in the literature. However, there are several inconclusive issues that have not been rigorously examined, especially as REITs are a relatively new investment vehicle in many economies. Portfolio investors /financial institutions /policy makers are generally ignorant of the historical and current levels of integration of cross-listed REIT and stock-REIT markets during normal and crisis times and their respective influential factors. As Parker (2018) further notes, a knowledge gap is that we do not know the optimum level of integration (both regionally and globally) to achieve the best trade-off between the benefits of integration (mainly market growth) and potential risks of contagion. Another knowledge gap is the lack of understanding on some theoretically sound and practical indicators/proxies to monitor the current level of integration and its changes over time. While conditional correlation dynamics might be more familiar to many, the econometrics of portfolio risk spillover and connectedness (variance-covariance) and nonlinear causality are not as well understood. The main objectives of this study are to therefore address these important issues.

3. Data

The sample data are daily Standard and Poor (S&P) observations from July 12, 2004 to June 28, 2019, in which the start date is based on the first date of data for HK REITs from the S&P. We collect the S&P REIT and stock price indexes based on the local currency from Datastream. The number of REIT constituents in the S&P REIT index for each of the five REIT markets are: 157 (US), 25 (Australia), 59 (Japan), 31 (Singapore) and 6 (Hong Kong). With a market capitalization in excess of US$1 trillion in 2016, the US is the largest REIT market in the world. The remaining four REIT markets are prominent in the Asian region in terms of market size and maturity, with the JREIT market now the second largest in the world. In the context of competitive international trade and increasing integration of financial markets, these five REIT markets are selected as representation of a strategic securitized real estate investment activity with a global/regional perspective in the international financial markets.

Appendix A-1 provides the rebased price index movements. They indicate that there are some correlations among the REIT markets and between the stock and REIT markets examined. Following various official timelines, the study period is divided into five sub-periods: (a) prior to the GFC (PRE-GFC; July 12, 2004 to August 1, 2007); (b) during the GFC (August 2, 2007 to November 4, 2009); (c) during the EDC (November 5, 2009 to May 9, 2012), (d) during the CSTCRASH: June 12, 2015 to January 7, 2016) and (e) POST crisis (post EDC (POSTEDC) – May 10, 2012 to June 11, 2015 and POST2 (after CSTCRASH) - January 8, 2016 to June 28, 2019). These sub-periods are based on the three crisis periods and used to determine the linkage between market integration and contagion. Over the study period, HK REITs provide the best return (average daily return is 0.043 percent with second lowest risk (1.165 percent compared to the 1.158 percent from SREITs). Moreover, the unconditional correlations among the REIT markets are all positive but only moderately correlated at the lower levels, which range from 0.224 (US/HK) to 0.360 (US/AU). In contrast, the 10 pairs of corresponding local stock markets are more connected from 0.365 (US/SG) to 0.735 (SG/HK). Thus, more diversification opportunities may be available in the REIT markets examined than the underlying stock markets.[6]

[6] The table that contains these basic results is not reported for brevity reasons.

4. Empirical Methodology

In summary, our empirical analysis comprises seven key steps: [7]

(a) We develop conditional VECH-MGARCH models for cross-listed REIT and stock-REIT markets and identify the implied conditional correlations and conditional volatilities.

(b) We evaluate co-movement and financial contagion by using time-varying conditional correlations with and dummy variables for the crises. Co-movement is often used as a proxy for market integration in the literature.

(c) We explore a general method to analyze portfolio risk spillover and connectedness (variance-covariance) as proposed in Diebold and Yilmaz (2012, 2014) and Fengler and Gisler (2015). This departs from the many studies in the literature that focus on purely volatility connectedness. Instead, our approach (variance-covariance) is in full agreement with the modern portfolio theory which estimates portfolio variance as the sum of variances and covariances. Moreover, the inclusion of covariance may lead to an overall increase of the level of risk spillover (and thus connectedness). In contrast, the systematic risk of investment in portfolios will be underestimated if positive covariances are neglected.

(d) We identify a single latent factor of Asian REITs from using a "factor analysis" to implement a selective correlation and portfolio risk spillover (variance-covariance) analysis between this Asian REITs and US REITs.

(e) We examine the market integration of local stock and REIT markets by using selective time varying conditional correlations and portfolio risk spillover (variance-covariance) matrixes. A clear understanding of the relationships of the REITs in the local stock markets is important for investors to diversify portfolios and hedge, and achieve optimum trade-offs.

(f) Since correlations can only provide linear co-movement, cannot capture nonlinearity and do not provide answers about causality, we implement bivariate and multivariate linear and nonlinear Granger causality tests on net total directional connectedness indexes to shed light on which REIT market has contributed most to the identified market integration.

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[7] Due to space constraints, the mathematical details are not provided. Interested readers can refer to the reference section.

(g) We refer to a mean variance portfolio analysis on REITs in Markowitz (1952) and optimal hedging analysis on REITs in stock portfolios to determine the implications of portfolio diversification and risk management.

We carry out these steps because the effects of risk spillover and connectedness are related to market integration and cause and effect, and an analysis on linear and nonlinear causal relationships will shed light on the strength of causal relationships. Empirically, increasing return co-movement, more intense risk spillover and connectedness relationships and higher cause and effect dependency will show that there is a consistent trend of higher levels of market integration. Consequently, the use of the "3 Cs" in this study provides a more complete and coherent answer on the subject topic. Our combined approach further shows that REITs are an important developing asset class that can contribute to portfolio optimization in the current interdependent and contagious financial markets.

5. Empirical Results and Implications

5.1 Estimates from Diagonal VECH-MGARCH Modelling

Overall, the results (Appendix B-1) indicate that the estimated variance coefficients for the conditional variance–covariance equation effectively captures the volatility and cross-volatility spillovers across the five REIT markets. Except for one estimate, all own/cross volatility spillovers (ARCH) are statistically significant and range between 0.34 percent and 7.59 percent, thus implying the presence of volatility clustering. In the GARCH set of parameters, all estimated own lagged volatility persistence and cross-volatility persistence coefficients are at least above 0.92 and highly significant. These estimates thus indicate that the spillovers in each REIT market influence the volatility of other REITs in the system.

5.2 Time-Varying Conditional Co-Movement

The movement of the cross-listed REITs is based on the implied correlations derived from the preceding VECH-MGARCH (1, 1) model. Higher correlations among the REIT markets imply greater co-movement and more market integration (Yu et al. 2010). The pairwise conditional correlations range between 15.7 percent – 34.3 percent and between 35.0 percent-69.0 percent, respectively for the REIT and stock markets. Thus, the five REIT markets show less market integration than their corresponding stock markets. In addition, the average correlation between the US and the four Asian REIT markets (26.4 percent) is higher than the average correlation among the four Asian REIT markets (23.3 percent). SREITs lead in correlation over the study period (average correlation is 30.1 percent) followed by the US REITs (26.4 percent), then AREITs (25.3 percent), HK REITs (21.1 percent) and finally, JREITs (19.7 percent).[8]

5.2.1 *Co-Movement during Crisis Times and Financial Contagion*

Table 1 divides the correlations among the ten market-pairs into estimates for the different crisis periods. The numbers in Panel A show that there is an increase in the average correlation from 0.193 (PRE-GFC) to 0.306 (GFC), 0.193 to 0.245 (EDC) and 0.193 to 0.268 (CSTCRASH). In Panel B, the EDC is associated with a lower average increase in correlation of about 6.1 percent. In contrast, the CSTCRASH shows a higher increase in correlation of 2.3 percent as opposed to the period during the EDC, thus implying that the REIT markets examined might be more sensitive to the CSTCRASH than the EDC. The individual statistics are significantly rejected by the mean t-test at least at the 5 percent significance level. It can thus be concluded that the correlations are primarily during the GFC followed by the CSTCRASH. However, greater market co-movement during crises does not mean that the REIT markets are more integrated; rather, it is a form of financial contagion. Additionally, greater market co-movement is observed for the US-Asia group than the within-Asia group in crisis times.[9] Figure 1 illustrates the changes in the time series patterns of the conditional correlations during the three crisis periods. Some common characteristics of the plotted correlations are that they vary with time, are quite volatile and show evidence of stability or upward or downward trends over time.

5.2.2 *Links between Correlations and Volatilities*

During the three crisis periods when market volatilities were high, the correlations among the many cross-listed REITs were (significantly) higher. The influence of higher conditional volatility might give rise to market contagion to the extent that it was significant enough to mask market integration. Following Maghyereh et al. (2015), we ran Equation (1) to determine whether the conditional correlations among the REIT markets are linked to volatilities, and the extent of a contagious effect on market integration, as follows:

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[8] The average country REIT correlation, e.g. SREIT is the average of the four pairwise time-varying conditional correlations: SGUS, SGAU, SGJP and SGHK). Other four country-REIT average correlations are estimated similarly.

[9] The usual expectation is that the average correlation within the Asian markets should be higher due to regional proximity; however, we find that the average correlation between the US and Asian REIT markets is consistently higher during the three financial crises. In the early stages, the three Asian REIT markets (Japan, Singapore and Hong Kong) closely followed the US REIT model, institutions and regulations to guide their development and maturity of the REIT structure in their respective countries. Therefore, it may not be surprising that these REIT markets comove more with the US REIT market during the initial years.

Table 1 Results of Average Conditional Correlation of REIT Markets in Different Crises

Panel A: Average Time-Varying Conditional Correlations

	FULL (1)	PREGFC (2)	GFC (3)	EDC (4)	POSTEDC (5)	CSTCRASH (6)	POST (8)
USAU	0.3425	0.2999	0.3779	0.3573	0.3333	0.3536	0.3527
USJP	0.2195	0.1162	0.3597	0.2135	0.2057	0.2576	0.2293
USSG	0.3247	0.2527	0.3794	0.3521	0.3417	0.2567	0.3287
USHK	0.1707	0.1144	0.2033	0.1478	0.1753	0.2380	0.2003
AVG	**0.2644**	**0.1958**	**0.3301**	**0.2677**	**0.2640**	**0.2765**	**0.2777**
AUJP	0.1640	0.1350	0.2256	0.1579	0.1422	0.2119	0.1653
AUSG	0.3135	0.2727	0.3326	0.3385	0.3426	0.3584	0.2854
AUHK	0.1938	0.2069	0.1242	0.1773	0.2325	0.1834	0.2069
JPSG	0.2457	0.2112	0.3605	0.2413	0.2335	0.3144	0.2040
JPHK	0.1572	0.1068	0.3214	0.1223	0.1443	0.1478	0.1329
SGHK	0.3207	0.2128	0.3239	0.2981	0.3537	0.3419	0.3970
AVG	**0.2325**	**0.1909**	**0.2814**	**0.2225**	**0.2415**	**0.2596**	**0.2319**
ALL AVG	**0.2484**	**0.1934**	**0.3057**	**0.2451**	**0.2527**	**0.2681**	**0.2548**

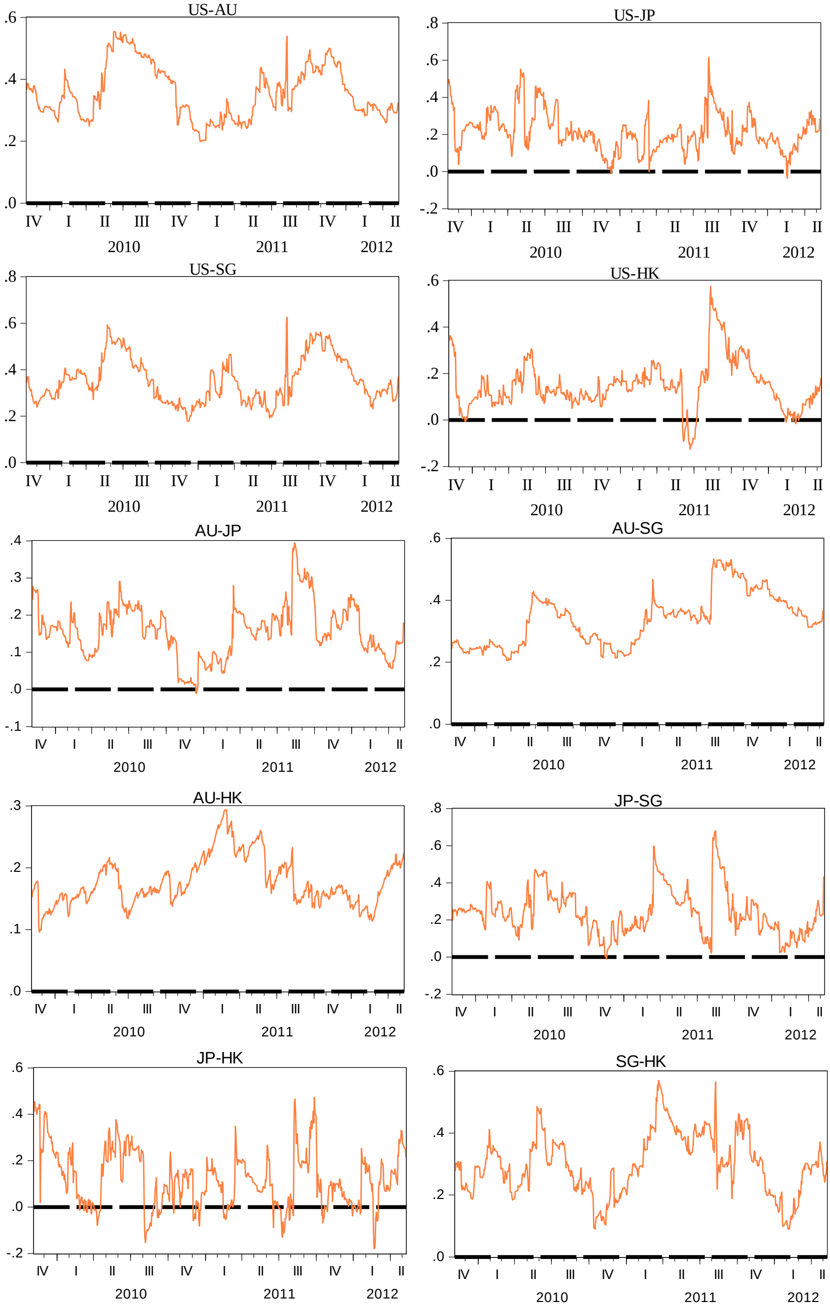
Panel B: Mean Test of Average Conditional Correlations Over Three Crisis Periods

	EDC vs GFC		CSTCRASH vs GFC		CSTCRASH vs EDC	
	Diff.	t-test	Diff.	t-test	Diff.	t-test
USAU	0.0205	4.76***	0.0242	3.78***	0.0037	0.55
USJP	0.1462	19.64***	0.1021	5.67***	-0.0442	-2.54**
USSG	0.0274	4.51***	0.1227	11.67***	0.0953	9.45***
USHK	0.0555	8.45***	-0.0347	-4.24***	-0.0902	-11.88***
AVG	**0.0624**	-	**0.0536**	-	**-0.0088**	-
AUJP	0.0677	15.37***	0.0138	2.53**	-0.0540	-10.64***
AUSG	-0.0059	-1.24	-0.0259	-4.69***	-0.0200	-3.69***
AUHK	-0.0530	-21.93***	-0.0591	-22.26***	-0.0061	-2.52**
JPSG	0.1192	13.88***	0.0461	4.12***	-0.0731	-7.43***
JPHK	0.1991	24.80***	0.1736	17.50***	-0.0255	-2.82**
SGHK	0.0259	3.90***	-0.0180	-2.12***	-0.0438	-5.78***
AVG	**0.0588**	-	**0.0218**	-	**-0.0371**	-
ALL AVG	**0.0606**	-	**0.0377**	-	**-0.0230**	-

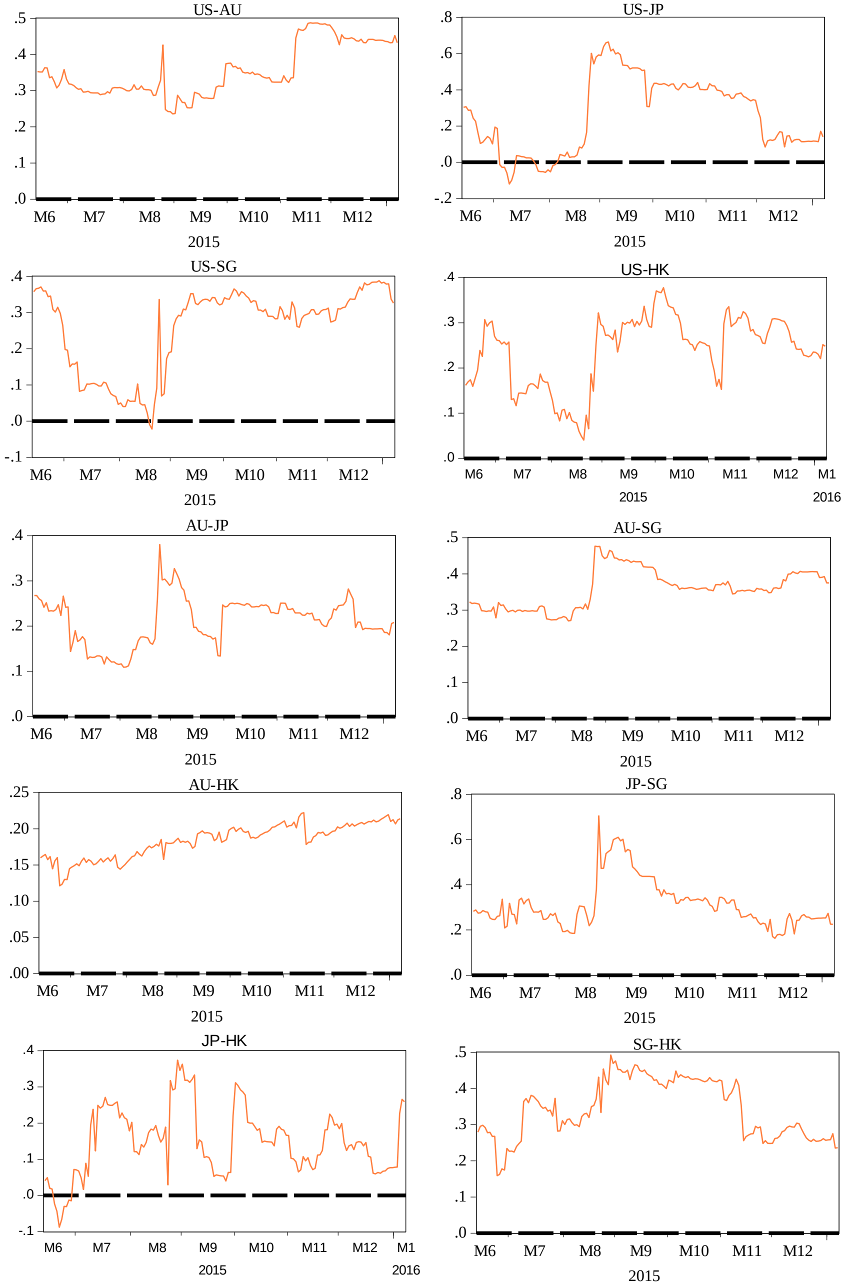
***Note*s: *** and ** denote statistical significance at the 1 and 5 percent levels respectively. The cells highlighted in orange indicate that the numbers are not statistically significant.

Figure 1 REITs: Time-Varying Conditional Correlations During the Three Crisis Periods

Panel A: During GFC

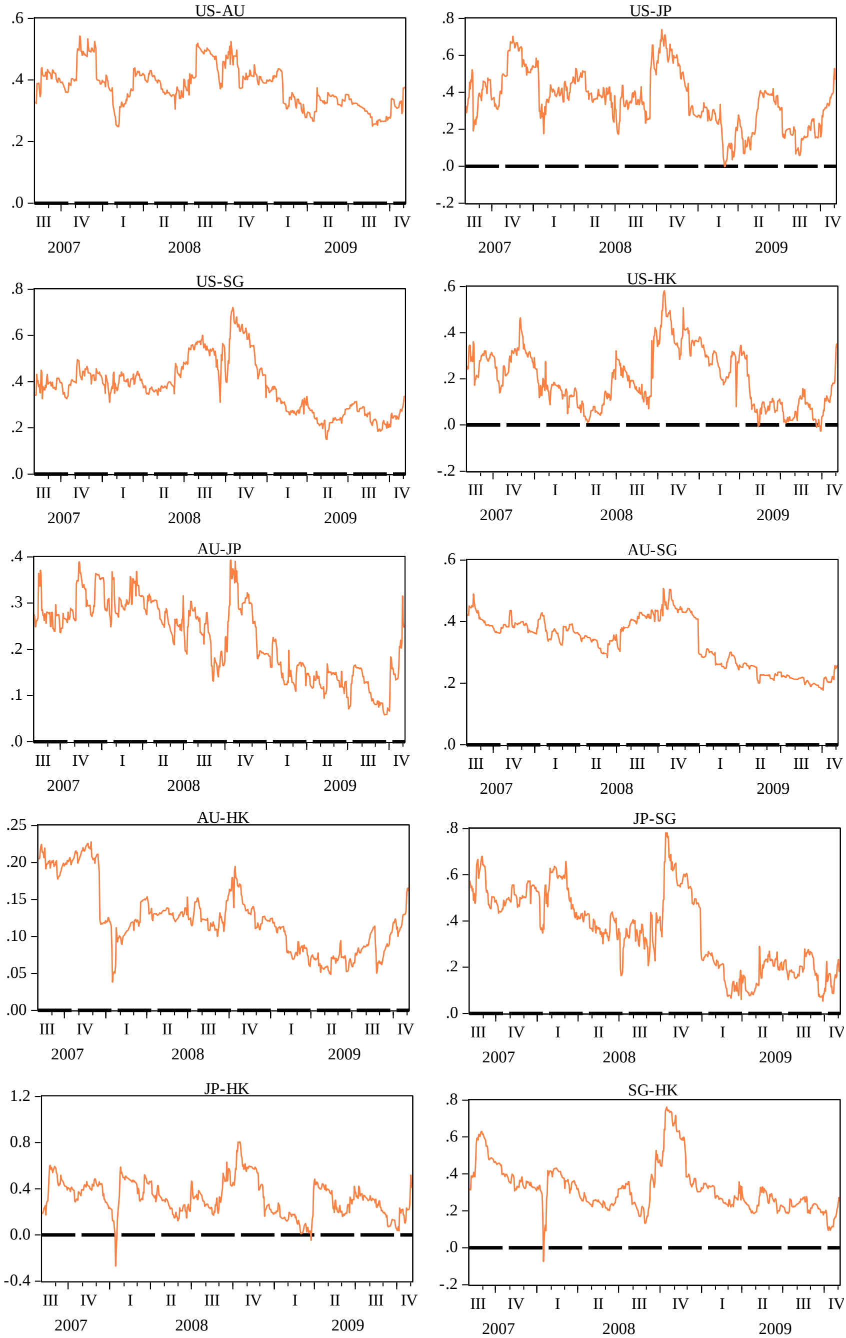


Panel B: During EDC



Source: Derived from VECH-MGARCH models (x-axis: daily; y-axis: dynamic conditional correlation value)

Panel C: During CSTCRASH



$$\rho_{reit,ij,t} = a_0 + a_1(\rho_{ij,-1}) + a_2(Trend) + a_4(CStdDEV_{reit,i,t}) + a_5(CStdDEV_{reit,j,t}) + \varepsilon_{ij,t} \quad (1)$$

where $\rho_{reit,ij,t}$ is the estimated pair-wise conditional correlations and $CStdDEV_{reit,i,t}$ *and* $CStdDEV_{reit,j,t}$ are the conditional standard deviations of $REIT_i$ and $REIT_j$. The time trend (Trend) is included in the model to determine whether the conditional correlations will show more integration with time . $\rho_{ij,-1}$ is included in the model to control for any persistent conditional correlations.

The results shown in Table 2 indicate that except for the US and Australia and Australia and Hong Kong pairs, at least one of the conditional volatilities (represented by conditional standard deviations) in the other eight models is positive and statistically significant at the 10 percent level. Thus, we can conclude that contagious effects are significant in our sample. After controlling for the contagion effect, the time trend coefficient (a2) is statistically significant in four cases, thus implying that they show increased integration with time, albeit at a very slow pace.[10]

Table 2 Time-Varying Conditional Correlation and Contagion Effect

$$\rho_{reit,ij,t} = a_0 + a_1(\rho_{ij,-1}) + a_2(Trend) + a_3(CV_{reit,i,t}) + a_4(CV_{reit,j,t}) + \varepsilon_{ij,t}$$

	a0	a1	a2	a3	a4	Adj R2
USAU	0.0080***	0.9726***	3.13E-07	-0.0054	0.0823	0.951
USJP	0.0025	0.9503***	1,65E-06**	-0.0172	0.4712***	0.926
USSG	0.0042***	0.9771***	9.04E-07*	-0.1101	0.3274*	0.959
USHK	0.0035**	0.9633***	8.40E-07**	-0.0433	9.7820*	0.938
AUJP	0.0043***	0.9625***	1.59E-07	0.0057	0.1351*	0.942
AUSG	0.0042***	0.9881***	-2.01E-07	0.0918*	-0.1196*	0.977
AUHK	0.0074***	0.9730***	2.15E-08	-0.1354***	-0.5777	0.976
JPSG	0.0081***	0.9569***	-6.49E-07	0.5886***	-0.3294**	0.939
JPHK	0.0015	0.9427***	4.71E-07	0.6271***	-0.0657	0.923
SGHK	0.0016	0.9738***	1.47E-06***	0.3948*	-0.0272	0.966

Notes: We use OLS regression based on standard errors that follow a robust procedure for estimating a covariance matrix corrected by heteroscedasticity and autocorrelation (Newey and West, 1987). ***, **, and * indicate statistical significance at the 1, 5 and 10 percent levels.

[10] Over the full study period of about 3904 days, the respective increases in market integration (net contagion) are about 0.64 percent (US and Japan), 0.35 percent (US and Singapore), 0.33 percent (US and Hong Kong) and 0.57 percent (Singapore and Hong Kong).

5.3 Risk Spillover Analysis (Variance-Covariance) and Market Connectedness

5.3.1 Justification for Including Covariance Estimates

The estimated conditional variance (CV) for the five REIT markets is taken from the VECH-MGARCH model. We observe that the CV of each REIT market varies with time and is associated with a spike that indicates a common high volatile period around the GFC period or 2008-2009. Together with the covariance estimates, these CV series are used in the subsequent portfolio risk spillover and connectedness analysis.

Figure 2 shows two 300-day rolling window plots of the corresponding time series of the risk spillover and connectedness indexes: the connectedness plot is based on 15 variance-covariance estimates and the connectedness plot is based on only five variance estimates. We focus on a time horizon of 10 days.

Two important differences are observed. First, the average time-series index value for the REIT variance-covariance connectedness model is about 72.75. This is at least 2.9 times the average index value of the variance connectedness model (index value is 24.96). Consistent with Fengler and Gisler (2015), this obvious risk spillover difference indicates the systematic risk associated with the five REIT markets, and by implication, the effects of market connectedness could be underestimated when positive covariances (due to positive correlations) are neglected. Additionally, even though both models share similar dynamics and react to the same major economic events, there are few other events that are captured at an earlier stage and more precisely by the variance-covariance spillover model than only the variance model. These events include the northern Japan earthquake (August 17, 2005), Singapore stock market plummet (August 25, 2015), Australia stock market plummet (December 17, 2017), HK REIT market surge (January 15, 2018) and others.

Table 3 shows the contributions of the variances and co-variances of the REITs.[11] The sum of the contribution from cross covariance spillovers and own covariance spillover is 72 percent (full study period), 72.4 percent (GFC), 71.4 percent (EDC) and 72.5 percent (CSTCRASH). Moreover, the cross covariance spillovers during the full study period (23.67 percent) and cross variance spillovers (19.17 percent) contribute to 42.84 percent of the risk spillover and

[11] Similar to Fengler and Gisler (2015), this variance-covariance system has our major components: (a) own covariance spillovers: spillovers from co-variances to co-variances, (b) cross covariance spillovers: spillovers from co-variances to variances, (c) own variance spillovers: spillovers from variances to variances, and (d) cross variance spillovers: spillovers from variances to co-variances. An additional point is that they use different static estimates to implement an analysis on the contribution of the co-variance and variance, whereas we use spillover estimates that vary with time, which is more realistic.

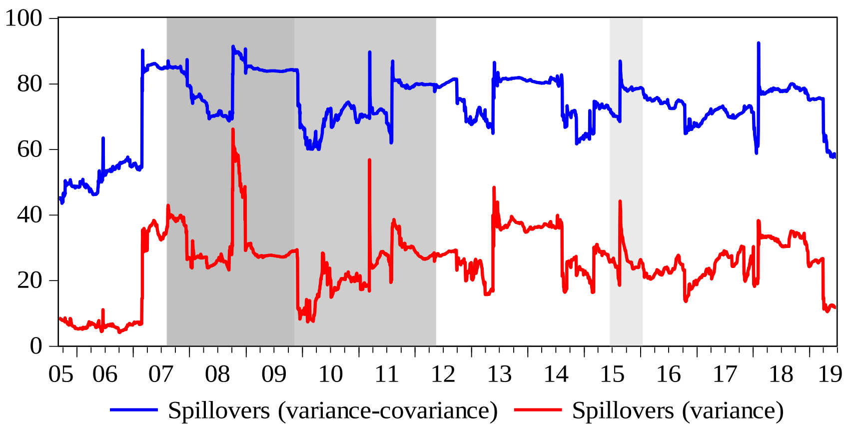
connectedness index. This contribution of the cross covariance spillovers is the highest during the EDC (43.66 percent) followed by the CSTCRASH (41.62 percent) and during the GFC (39.78 percent). Thus, our analysis shows that up to one-quarter of the spillover is based on covariance and around 40 percent of the spillover index is attributed to the spillovers between variances and co-variances. This result is an agreement with that in Fengler and Gisler (2015) who show the important role of covariance in contributing to portfolio risk. Figure 3 shows the profiles of the contribution of the five REIT markets during the three crisis periods with different spillover patterns and fluctuations in information transmission.

Table 3 Spillover Contribution for the Full REIT Sample and Three Crisis Periods

	Full sample	GFC	EDC	CSTCRASH
Cross covariance spillovers	23.67%	22.29%	23.26%	23.27%
Cross variance spillovers	19.17%	17.49%	20.40%	18.35%
Own covariance spillovers	48.33%	50.11%	48.14%	49.20%
Own variance spillovers	8.82%	10.12%	8.21%	9.18%

Note: The raw estimates are derived using a forecast horizon of 10 days and a rolling window of 300 days in dynamic risk connectedness (variance-covariance) analysis.

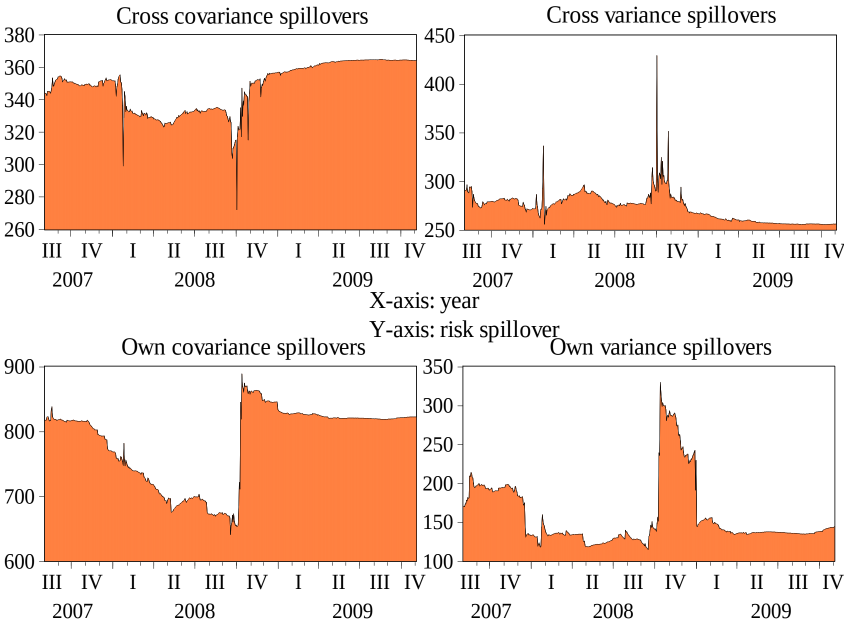
Figure 2 REITs: Two Generalized Total Spillover Plots



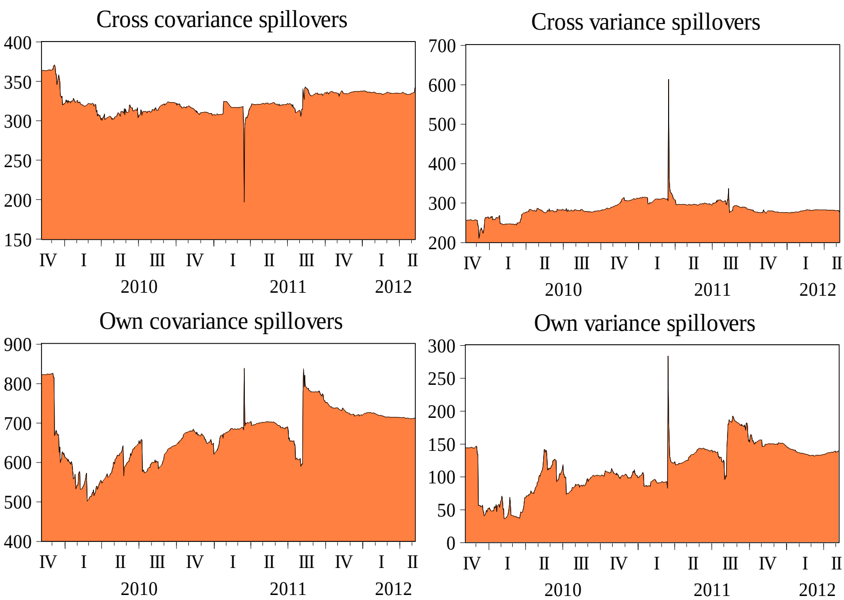
Notes: The figure shows (a) plotted spillover with covariance: thick blue line (average index value = 72.75), (b) plotted spillover without covariance: thin red line (average index value = 24.96) for a forecast horizon of 10 days with a rolling window size of 300 days. The three shaded columns (from the left) denote the GFC, EDC and CSTCRASH (x-axis: daily; y-axis: total generalized spillover indexes).

Figure 3 REITs: Contribution to Time-Varying Spillover-Connectedness During Three Crisis Periods

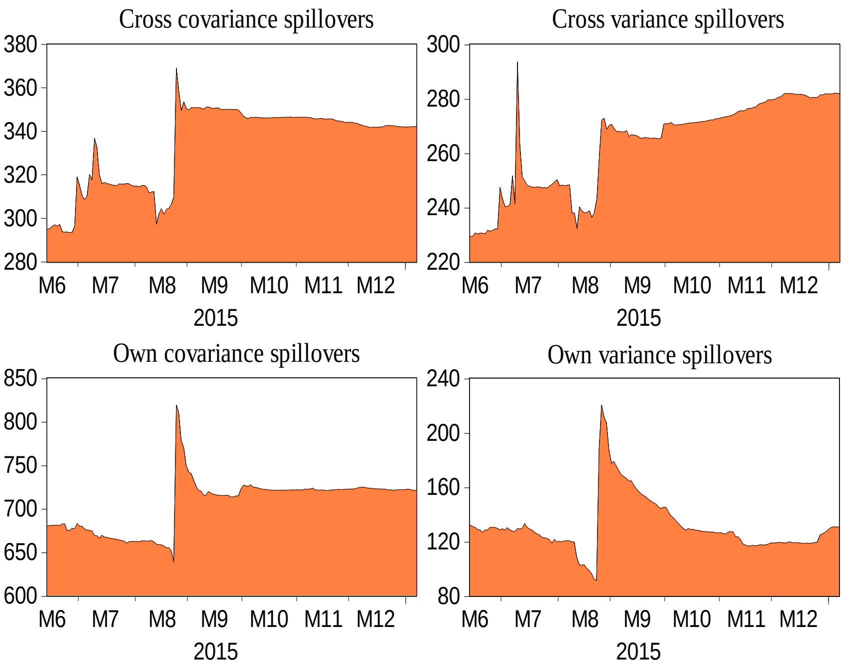
Panel A: GFC



Panel B: EDC



Panel C: CSTCRASH



Notes: Following Fengler and Gisler (2015), the REIT covariance spillovers are decomposed into four components: (a) on covariance spillovers: spillovers from covariance to covariance, (b) own variance spillovers: spillovers from variance to variance, (c) cross variance spillovers: spillovers from variance to covariance and (d) cross covariance spillovers: spillovers from covariance to variance. The spillover-connectedness contribution for the four components are estimated for a forecast horizon of 10 days with a rolling window size of 300 days (x-axis: daily; y-axis: risk spillover intensity)

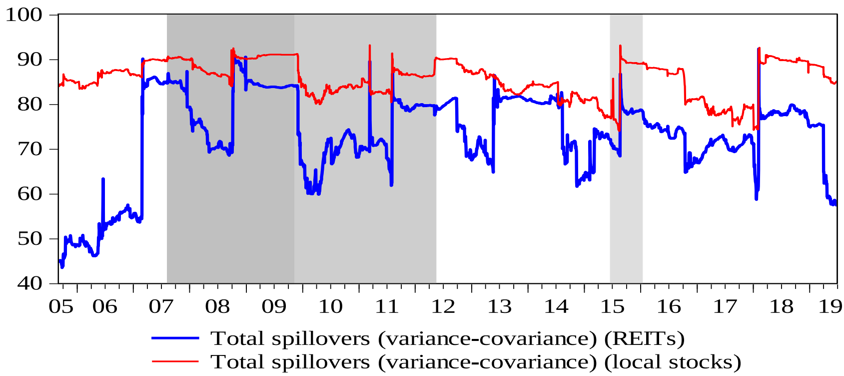
5.3.2 Dynamic Total Spillover and Connectedness (Variance-Covariance) Index Plots

Since covariance is important, our examination of portfolio risk spillover and connectedness would thus include always positive covariance shocks. In Figure 4, the respective average total risk-spillover index values are about 72.75 (REIT) and 85.67 (stock). Thus, the stock markets are more closely connected in risk. With an estimated spillover index of more than 70 percent, the five REIT markets appear to be highly connected but show frequent fluctuating behaviors.

The salient feature of the total volatility REIT spillover is that there are several discrete jumps in the plot during major market events such as the liquidity crisis which took place at about the beginning of June 2007, Lehman Brothers bankruptcy in mid-September 2008, Greek debt crisis in May 2010, West Texas

Intermediate (WTI) oil price collapse in October 2014, global stock market depression due to the CSTCRASH in August 2015 along with the earthquake crisis in Japan and the on-going trade tension between the US and China since February 2018. Through various transmission channels, the crises in a country may spill over into the stock and REIT markets of the countries examined. Overall, volatility spillover and connectedness increase significantly during periods of high uncertainty and financial crises and remain high as long as the data pertain to the crisis periods. Further analysis (results not shown) indicates that the REIT contribution of the respective country to the spillover in the full sample and connectedness index is 21.9 percent (AREITs), 21.2 percent (SREITs), 20.4 percent (US REITs), 19.6 percent (JREITs) and 16.9 percent (HK REITs), thus indicating that AREITs show dominant risk-spillover.

Figure 4 Generalized Total Spillover (Variance-Covariance) Indexes: REITs and Stocks



Notes: The plots are based on a forecast horizon of 10 days and a rolling window size of 300 days. The non-parametric correlation between the (REIT-stock) lines in the full study period is approximately 0.568. The three shaded columns (from the left) denote the GFC, EDC and CSTCRASH (x-axis: daily; y-axis: generalized spillover-connectedness indexes).

5.3.3 Dynamic Total Risk Spillover and Connectedness Shocks During Three Crisis Events

Incorporating the dimension of crisis, Table 4 (Panel A) shows that the total risk spillover and connectedness index for the full REIT sample is most pronounced during the GFC (80.6) and to a lesser degree, the CSTCRASH (75.86) and EDC (72.56), thus implying that the connectedness effects of REIT risk are sensitive to the three crises in different degrees. We run a mean equation; that is, Equation (3), to validate this observation as follows:

$$TS_{i,t} = \mu_i + \gamma * TS_{i,t-1} + a_i DGFC_t + b_i DEDC_t + c_i DCSCRASH_t + \eta_{i,t} \quad (2)$$

where TS_i refers to the total risk spillover and connectedness index of each REIT market. We regress the TS measure on a constant term and three dummy variables DGFC, DEDC and DCSTCRASH, taking the value of one during the period of the respective crises and zero otherwise. The regressions are estimated with robust standard errors and adjusted for one-lag autocorrelation. Panel B of Table 4 shows the regression estimates based on the hypothesis that the respective TSs underwent positive and significant increases during the three crisis periods. Liow (2015) finds that volatility connectedness shocks are pronounced across the developed financial markets examined during the GFC and EDC. During crisis periods, the interactions and inter-linkages of financial markets could contribute to strong connectedness effects that lead to extreme volatility. In this study, our task is to therefore examine the extent that this hypothesis will hold and the consequent impact on the market integration of REITs.

Table 4 REITs: Crisis Behavior of Total Spillovers (Variance-Covariance)

Panel A: Total Spillover (TS) Level (REITs and Stocks)

	Full (1)	GFC (2)	EDC (3)	CSTCRASH (4)	(2)-(1)	(3)-(1)	(4)-(1)
TS (REIT)	72.75	80.6	72.56	75.86	10.79%	-0.26%	4.27%
TS (Stock)	85.87	89.4	84.48	85.02	4.11%	-1.62%	-0.99%

Panel B: The Impact of Three Crisis Periods on REIT spillovers

Dependent variable	Coefficients for independent variables						
	constant	lagged	GFC	EDC	CSTCRASH	F-stat	Adi R2
Total spillovers (all)	0.668***	0.991***	0.088*	0.003	0.087	60,374***	0.985
Total spillovers (USREITs)	0.379***	0.993***	0.021	-0.017	-0.027	75,253***	0.988
Total spillovers (AREITs)	0.386***	0.993***	0.069**	0.006	0.037	93,786***	0.99
Total spillovers (JREITs)	0.549***	0.989***	0.173***	-0.018	0.175*	52,305***	0.983
Total spillovers (SREITs)	0.529***	0.991***	0.044	-0.033	0.117	56,699***	0.984
Total spillovers (HKREITS)	0.262***	0.995***	0.085*	-0.071	-0.017	140,622***	0.994

Notes: Standard errors follow a robust procedure for estimating a covariance matrix corrected by heteroscedasticity and autocorrelation (Newey and West, 1987). The spillover estimates are derived using a forecast horizon of 10 days and a rolling window of 300 days.). ***, **, and * indicate statistical significance at the 1, 5 and 10 percent levels.

A general conclusion is that the dummy variables that correspond to the three crises are positive and statistically significant in four cases (GFC) and one case (CSTCRASH). These results, although not very ideal, nevertheless indicate that during the GFC, the risk connection and thus market integration is quite sensitive to financial contagion (where the average TS increases by 10.79 percent) and associated with more than 50 percent of contagion. In the CSTCRASH period, although the average TS is increased by about 4.3 percent, this positive change in the spillover intensity is statistically insignificant at the conventional level. The only significant contagious case in the CSTCRASH period is JREIT where the TS is associated with a 5.8 percent increase in the full study period.

For each pair of REIT markets, Table 5 provides a decomposition of the full-period pairwise total spillovers. As the numbers in Panel A indicate, the average pairwise total spillover indexes for the Asian REIT group during the GFC and EDC (41.04 and 30.92) is higher than that of the US/Asian REIT group (35.42 and 27.83). Thus, from the perspective of portfolio risk spillover and connectedness, more market integration is observed within the Asian REIT group. In contrast, the market integration levels are rather similar for both REIT groups (i.e. within-Asia and the US/Asia groups) during the CSTCRASH and full study period. Considering that the results with the multivariate approach for portfolio risk spillover and connectedness may be statistically superior in comparison to the bivariate conditional correlation results, we are inclined to place our confidence on the portfolio risk spillover results reported here. In Panel B of Table 5, we show that both groups are quite sensitive to the GFC because their respective average TS increases by more than five percent (cut-off point): i.e., about 29 percent (within Asia group) and 13 percent (the US-Asia group) from the full-period average.

Table 5 Results of Pairwise Total Connectedness (Variance-Covariance) in Different Crises

Panel A: Average Time-Varying Pairwise Total Connectedness Indexes (Variance-Covariance)

Total spillovers	Full(1)	GFC(2)	EDC(3)	CSTCRASH(4)
USAU	42.627	42.556	43.814	45.628
USJP	24.756	29.892	18.159	34.882
USSG	32.126	35.161	29.209	24.275
USHK	25.707	34.059	20.144	22.418
average	31.304	35.417	27.831	31.800
AUJP	31.241	41.952	31.208	33.196
AUSG	39.017	40.797	39.362	45.563
AUHK	27.970	35.274	21.085	29.627
JPSG	32.908	41.733	33.556	34.347
JPHK	23.919	43.345	29.017	17.742
SGHK	35.681	43.110	31.279	30.129
average	31.790	41.035	30.918	31.767
Grand average	31.547	38.226	29.375	31.784

Panel B: Analysis of Changes Over Full Study Period

Total spillovers	GFC vs (1)	EDC vs (1)	CSTCRASH vs (1)
USAU	-0.002	0.028	0.070
USJP	**0.207**	-0.266	**0.409**
USSG	0.094	-0.091	-0.244
USHK	**0.325**	-0.216	-0.128
average	**0.131**	-0.111	0.016
AUJP	**0.343**	-0.001	0.063
AUSG	0.046	0.009	**0.168**
AUHK	**0.261**	-0.246	0.059
JPSG	**0.268**	0.020	0.044
JPHK	**0.812**	**0.213**	-0.258
SGHK	**0.208**	-0.123	-0.156
average	**0.291**	-0.027	-0.001
Grand average	**0.212**	-0.069	0.008

Notes: Figures typed in bold font indicate an increase of 10% or more of the total pairwise connectedness (variance-covariance). Following the literature, it is classified as a case of financial contagion. The raw pairwise total connectedness estimates are derived by using a forecast horizon of 10 days and a rolling window of 300 days.

5.3.4 *Dynamic Effects of Gross and Net Total and Directional Risk Spillover and Connectedness*

To identify the REIT market that contributed the most to market integration, the gross and net total directional spillover and connectedness indexes for each REIT market are evaluated. The net index is estimated by subtracting the gross risk absorption from the gross risk transmission of a REIT market.[12] The results from Table 6 indicate that SREITs rank second in gross risk transmission. SREITs are also the most endogenous and open REITs. Its gross total directional risk information intensity is the highest (about 549.75) and contributes to about 36.7 percent of the risk spillover and intensity of connectedness during the GFC. On the other hand, AREITs transmit the most risk during both the EDC (34.5 percent) and CSTCRASH (36.6 percent).

Panel D is the ranking of the five REIT markets in terms of net total directional risk spillover. Except for the AREIT market, the other four REIT markets transmit net risk spillovers and connectedness during the GFC. The JREIT market has the highest intensity in gross risk transmission of 292.31 (about 19.5 percent of the total spillover intensity) and the lowest gross absorption of

[12] Gross risk transmission refers to the gross amount of risk transmitted from a REIT market to other REIT markets in the VaR system; gross risk absorption refers to the gross amount of risk that other REIT markets transmit to a specific REIT market in the VaR system.

230.45 (about 15.4 percent of the total spillover value) and therefore are the dominant spillover transmitter (net index value = 61.87) that contributes to about 4.1 percent of the net total risk connectedness during the GFC. In contrast, the AREIT market is the dominant spillover transmitter during the EDC and CSTCRASH, attributing for about 10.5 percent and 9.5 percent of the net total risk spillover and connectedness to the other REIT markets respectively. Finally, none of the REIT markets show consistent rankings across the three crisis periods (Table 7), thus implying that the respective net risk spillover and connectedness behavior may shift around the three crisis periods.

Table 6 Analysis of Directional Spillovers (Variance-Covariance) Over the Three Crisis Periods

	USREITs	AREITs	JREITs	SREITs	HKREITs
Panel A:GFC					
net total spillovers	8.8090	-24.8599	61.8659	5.0312	14.8301
gross transmission	242.8959	229.8932	292.3130	277.3895	256.1075
gross absorption	234.0869	254.7530	230.4472	272.3582	241.2774
total flow	476.9828	484.6462	522.7602	549.7477	497.3849
Panel B: EDC					
net total spillovers	-2.2640	157.9100	-27.5370	5.0841	-83.8057
gross transmission	217.6537	337.3367	176.1886	237.6810	166.0164
gross absorption	219.9177	179.4267	203.7255	232.5969	249.8221
total flow	437.5714	516.7634	379.9141	470.2779	415.8385
Panel C: CSTCRASH					
net total spillovers	-38.6793	142.2493	-22.7748	27.1321	-74.0043
gross transmission	226.7279	345.4017	186.5607	260.2911	176.1807
gross absorption	265.4073	203.1525	209.3355	233.1590	250.1849
total flow	492.1352	548.5542	395.8962	493.4501	426.3656

Panel D: Ranking of REITs Based on Net Total Spillovers (with Covariance)

RANK	GFC	EDC	CSTCRASH
1	JREITs	AREITs	AREITs
2	HKREITs	SREITs	SREITs
3	USREITs	USREITs	JREITs
4	SREITs	JREITs	USREITs
5	AREITs	HKREITs	HKREITs

Notes: Total (transmission) flow = gross transmission (spillovers FROM a specific market) + gross absorption (spillovers TO a specific market). The raw estimates are derived by using a forecast horizon of 10 days and rolling window of 300 days.

Table 7 Ranking of Net Directional Pairwise Spillovers (with Covariance) of REIT Markets in the Three Crisis Periods

REIT pair	GFC rank	EDC rank	CSTCRASH rank
US/AU	3	10	5
US/JP	4	8	10
US/SG	5	7	4
US/HK	8	9	2
AU/JP	10	5	6
AU/SG	7	6	8
AU/HK	6	3	7
JP/SG	1	2	9
JP/HK	2	1	3
SG/HK	9	4	1

Notes: The table ranks ten pairs of net pairwise spillovers according to their magnitude over the three crisis periods. A net "sender" pair with the largest positive spillover intensity will be given a rank of one; whereas a rank of 10 is assigned to a net "giver" pair with the highest negative spillover intensity.

5.3.5 Dynamic Risk Spillover and Connectedness between US and Four Asian REIT Markets

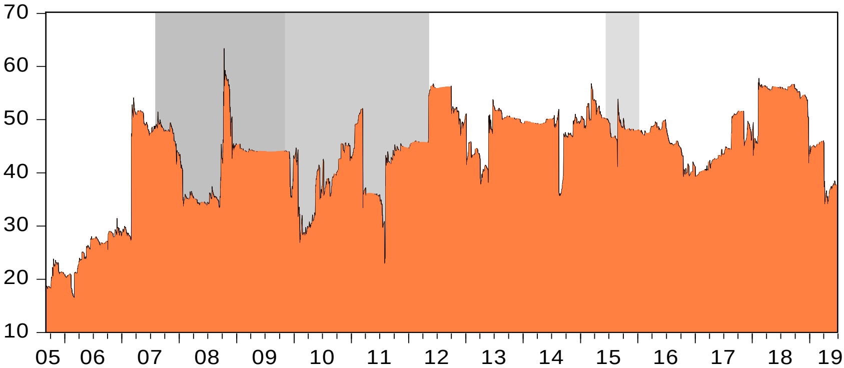
To examine the relationship between the US and four Asian REIT markets as a group, an additional analysis is carried out - a principal component analysis (PCA; a popular form of factor analysis), to derive a single dominant (latent), or an "Asian" factor that can explain for the majority of the variations in the daily return series of the four Asian REIT markets.[13] This "Asian factor" has an eigenvalue of 1.937 and is able to explain about 48.42 percent of the variations in the daily returns of the four REIT markets. Panel A of Figure 5 shows a risk spillover and connectedness plot that varies with time of the US REIT market vs. the derived Asian REIT "factor". With an estimated risk spillover and connectedness index of 43.55 during the full study period, the Asian REIT factor is only moderately connected to the US REIT market. An additional analysis is carried out (not reported) and it is found that the total spillover and connectedness index values over the three crises are 44.05 (GFC), 40.40 (EDC) and 48.44 (CSTCRASH). Panel B shows that the Asian REIT group is the net connectedness transmitter (net index value is 12.28). Moreover, the average net directional connectedness index value (Panel B in Figure 5) is reduced to 4.43

[13] Our objective of estimating an Asian latent variable was not to find out the co-movement of three Asian REITs markets and the Australian REIT market because the single "Asian REIT latent factor" so derived was using the PCA method on the four Asian (AU, JP, SG and HK) REIT return series. Thereafter, this Asian REIT factor was linked with the US REITs in the return co-movement/ market connectedness and causality examinations. Interested readers may consult Pindyck and Rotemberg (1990) on other methodological issues and excess co-movements interpretations concerning latent variables.

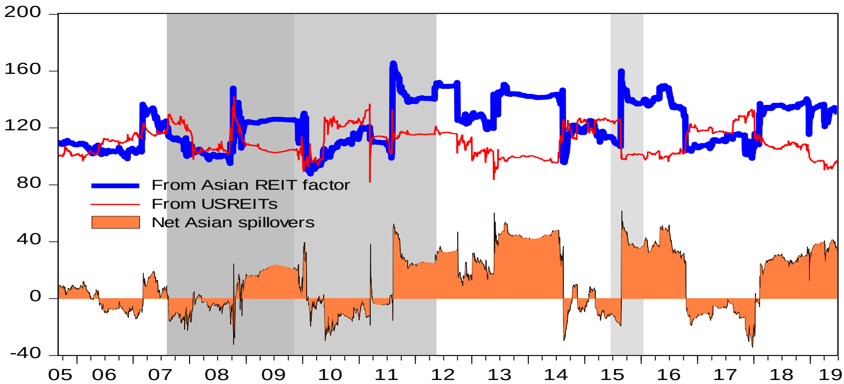
during the GFC, increased to 5.08 during the EDC and the highest (21.08, about 4.2 percent of the spillover for the full study period) during the CSTCRASH. The key results are not reported but summarized for brevity here.

Figure 5 REITs: Risk Spillover (Variance-Covariance) between US and Asian Factor

Panel A: REITs: Total Spillovers (with Covariance) between the US and Asian Factors



Panel B: REITs: Directional Spillovers (Variance-Covariance) between US and First Asian Factor



Notes. We derive the first major Asian systematic factor from a principal components analysis that includes the four Asian REIT markets. The spillover plots (with covariance) between the USREITs and the derived Asian REIT factor are based on a forecast horizon of 10 days and a rolling window of 300 days. The average full period total and net pairwise directional spillover indexes are 43.55 and 12.28 respectively. The three shaded columns (from the left) denote the GFC, EDC and CSTCRASH (x-axis: daily; y-axis: total /directional spillover-connectedness indexes).

5.3.6 *Risk Spillover and Connectedness Network*

Finally, we turn our attention to network diagrams of risk spillover and connectedness as shown in Appendix C-1 where the three crisis are plotted by using the average net pairwise directional spillover and connectedness indexes that vary with time to provide a visualization of the network connectivity among the five REIT markets. One unique feature of these network plots is that they explicitly reflect the connectivity between variances and the corresponding co-variances, with the width of the arrows indicating the intensity of the risk connectedness. Overall, the risk connectivity is relatively substantial around the three crisis periods. They are shown with thicker solid edge lines if the net index value is five percent or more. Moreover, strong risk transmission is dominated by covariance, thus confirming the crucial role of covariance in influencing the risk transmission of the REIT markets.

5.4 Market Integration between Local Stock and REIT Markets

5.4.1 *Co-Movement Results*

Panel A of Table 8 shows that the individual stock and REIT markets are highly correlated in the US (average time-varying correlation is 0.808) and Singapore (0.725) during the course of the GFC. Similarly, a high average correlation of 0.782 is estimated for the US during the EDC. During the CSTCRASH, the stock and REIT markets are strongly linked with average correlation levels of 0.737 (Singapore) and 0.730 (Australia). For the five REIT markets as a whole, the three crisis periods have (much) higher levels of co-movement, with a higher average time-varying co-movement as opposed to the average of the full study period of 18.9 percent (GFC), 12.5 percent (CSTCRASH) and 7.4 percent (EDC).

5.4.2 *Portfolio Risk Spillover- Connectedness (Variance-Covariance) Results*

From the perspective of portfolio risk spillover and connectedness, Panel B shows that the total risk spillover and connectedness indexes range, respectively, from 50.61 (Hong Kong) to 58.87 (US), from 35.96 (Hong Kong) to 62.01 (US) and from 34.13 (Hong Kong) to 55.24 (Singapore) during the GFC, EDC and CSTCRASH for the individual pairs of REIT and stock markets in the five countries. Based on these results, we again conclude that the REITs in the stock markets are moderately risk-connected during the GFC (average index is 55.05), EDC (average index is 51.77) and CSTCRASH (average index is 47.49).

The relationships between the stock and REIT markets are further analyzed by using net total and directional risk spillover (NTOTALS) measurements. As the numbers in Panel C indicate, the US REIT market is ranked “third” in importance as a net risk sender (with a net index value of 8.81 and contributing to only 0.59 percent of the intensity in total spillover and connectedness), even though US stocks are the dominant risk sender during the GFC (net total index = 129.76, about 8.7 percent of the intensity of the total connectedness). For the EDC, both AREIT and Australian stock markets are dominant risk senders. For the CSTCRASH, the AREIT market is again the most influential in contributing to the integration of the stock and REIT markets. Finally, Panel D shows a low negative to moderately positive correlation between the NTOTALS of stocks and REITs in the respective countries. They are -0.216 (Hong Kong), 0.102 (Japan), 0.364 (the US), 0.399 (Australia) and 0.434 (Singapore) for the full study period, thus implying that the integration dynamics of local stock market and REIT risks differ for different countries and deserve to be examined separately.

Table 8 Stock-REIT: Average Time-Varying Conditional Correlations and Net Total Connectedness (Variance-Covariance) Over the Three Crisis Periods

	Full study period	GFC	EDC	CSTCRASH
Panel A: REIT-Stock Conditional Correlation				
US	0.662	0.808	0.782	0.672
AUSTRALIA	0.611	0.640	0.639	0.730
JAPAN	0.321	0.548	0.366	0.372
SINGAPORE	0.631	0.725	0.680	0.737
HONG KONG	0.421	0.427	0.374	0.466
AVERAGE	0.529	0.629	0.568	0.595
Panel B: Total Spillovers (With Covariance)				
GROUP	73.240	79.617	75.458	75.865
US	53.178	58.872	62.205	48.427
AUSTRALIA	50.700	54.902	54.918	52.015
JAPAN	45.195	58.101	49.059	47.653
SINGAPORE	52.682	52.777	56.693	55.244
HONG KONG	38.824	50.613	35.955	34.129
AVERAGE (COUNTRY)	48.116	55.053	51.766	47.494

Panel C: Net Total Directional Connectedness Values Over Three Crisis Periods

	REITs			Stocks		
	GFC	EDC	CSTCRASH	GFC	EDC	CSTCRASH
US	8.81	-2.26	-38.68	129.76	25.95	-27.00
AU	-24.86	157.91	142.25	32.38	43.68	17.49
JP	61.87	-27.54	-22.77	-24.36	-37.63	-30.43
SG	5.03	5.08	27.13	19.28	28.42	63.65
HK	14.83	-83.81	-74.00	-82.03	-20.49	46.86

Panel D: Nonparametric Correlations of Net Total Directional Connectedness Values of Stock-REITs

	Full study period	GFC	EDC	CSTCRASH
Total spillover	0.568	0.604	0.824	0.795
Net total spillover (US)	0.364	0.34	0.59	0.644
Net total spillover (AUS)	0.399	0.082	0.597	0.658
Net total spillover (JP)	0.102	0.697	0.103	0.42
Net total spillover (SG)	0.434	0.271	0.441	0.633
Net total spillover (HK)	-0.216	0.7	0.343	-0.029

Note: The raw estimates (in Panels C and D) are derived by using a forecast horizon of 10 days and a rolling window of 300 days.

5.5 Results of Linear and Nonlinear Granger Causality Tests

5.5.1 Bivariate Causality Results: Pairs of Cross-Listed REIT and Stock-REIT Markets

Using the net total directional spillover and connectedness indexes (NTOTALS) of the five REITs, Panel A of Table 9 indicates that out of the 10 pairs of REIT markets, five pairs show a linear bidirectional causal relationship during the GFC and one pair shows this relationship during the EDC. Moreover, there is a high linear unidirectional causal relationship that can be found in either direction during the EDC. The nonlinear causality test results show much more rich interaction, notably with a significant bilateral causal relationship in nine of the pairs during the GFC and ten of the pairs during the EDC. Finally, both the linear and nonlinear causality test results are much weaker during the CSTCRASH.

The results of the cause and effect dependency of the stock and REIT markets in Panel B show that during the GFC, EDC and CSTCRASH, there are two and five pairs and one pair of markets that have a linear bilateral relationship whereas six pairs during the EDC and four pairs during the GFC have a nonlinear bidirectional causal relationship. Moreover, the nonlinear testing identifies unidirectional causal relationships from the stock market to the REIT market for Australia and from the REIT market to stock market for the US during the GFC. Finally, there is the complete absence of bilateral causal relationships with the nonlinear causality framework during the CSTCRASH.

Table 9 Linear and Nonlinear Causality Tests (Bivariate) on Net Total Directional Connectedness of REITs (Variance-Covariance) in Three Crisis Periods

Panel A: Total Connectedness of Cross-Listed REITs (Variance-Covariance)

Causality direction	GFC			EDC			CSTCRASH		
	l	Linear F -stat	Nonlinear T-stat	*l*	Linear F -stat	Nonlinear T-stat	*l*	Linear F -stat	Nonlinear T-stat
x_{US} => x_{AU}	3	1.00	2.50***	3	10.13***	1.93**	5	44.08***	0.72
x_{AU} => x_{US}	3	1.91	1.72**	3	1.43	3.04***	5	0.80	1.76**
x_{US} => x_{JP}	5	2.67**	1.84**	2	1.18	1.37*	2	0.47	-0.95
x_{JP} => x_{US}	5	4.71***	1.46*	2	10.65***	3.43***	2	0.34	1.03
x_{US} => x_{SG}	3	4.77***	1.88**	2	0.04	2.25**	4	1.01	0.78
x_{SG} => x_{US}	3	1.18	1.30*	2	3.25**	3.32***	4	0.74	1.04
x_{US} => x_{HK}	3	4.18***	2.26**	3	1.56	2.16**	5	0.46	0.14
x_{HK} => x_{US}	3	4.62***	0.96	3	2.72**	2.81***	5	0.67	0.09
x_{AU} => x_{JP}	3	1.00	2.50***	3	10.13***	1.93**	5	44.08***	0.72
x_{JP} => x_{AU}	3	1.91	1.72**	3	1.43	3.04***	5	0.80	1.76**
x_{AU} => x_{SG}	5	2.67**	1.84**	2	1.18	1.37*	2	0.47	-0.97
x_{SG} => x_{AU}	5	4.71***	1.46*	2	10.65***	3.43***	2	0.34	1.03
x_{AU} => x_{HK}	3	4.77***	1.88**	2	0.04	2.25**	4	1.01	0.78
x_{HK} => x_{AU}	3	1.18	1.30*	2	3.25**	3.32***	4	0.74	1.04
x_{JP} => x_{SG}	3	2.10*	1.98**	3	1.22	1.48*	7	0.59	1.05
x_{SG} => x_{JP}	3	11.31***	2.20**	3	13.98***	1.98**	7	22.88***	1.13
x_{JP} => x_{HK}	3	7.42***	2.53***	3	2.97**	2.56***	5	0.44	1.20
x_{HK} => x_{JP}	3	13.77***	1.97**	3	14.26***	3.83***	5	42.77***	0.00
x_{SG} => x_{HK}	5	1.40	2.45***	2	0.80	1.95**	3	4.33***	1.82**
x_{HK} => x_{SG}	5	3.32***	1.90**	2	3.08**	2.72***	3	1.26	0.93

Panel B: Dynamic Net Total Directional Connectedness of Stock and REIT Markets (Variance-Covariance)

Causality direction	GFC			EDC			CSTCRASH		
	l	Linear F-stat	Nonlinear T-stat	*l*	Linear F-stat	Nonlinear T-stat	*l*	Linear F-stat	Nonlinear T-stat
ST_{gp} => $REIT_{gp}$	10	22.70***	2.00**	3	2.31*	1.99**	4	3.66***	-0.03
$REIT_{gp}$ => ST_{gp}	10	20.27***	1.47*	3	11.24***	2.60***	4	0.11	1.95**
ST_{US} => $REIT_{US}$	6	1.67	0.93	3	9.30***	2.30**	1	4.30**	1.98**
$REIT_{US}$ => ST_{US}	6	1.66	2.48***	3	25.50***	3.21***	1	29.29***	-0.03
ST_{AU} => $REIT_{AU}$	3	0.32	3.27***	3	9.35***	3.01***	4	12.73***	0.06
$REIT_{AU}$ => ST_{AU}	3	0.25	1.26	3	10.20***	2.45***	4	1.59	2.044**
ST_{JP} => $REIT_{JP}$	5	4.01***	2.08**	3	13.67***	2.21**	3	1.49	2.32**
$REIT_{JP}$ => ST_{JP}	5	1.30	1.46*	3	41.00***	3.79***	3	0.32	0.32
ST_{SG} => $REIT_{SG}$	5	0.62	2.40***	2	3.22**	2.56***	3	6.92***	1.84**
$REIT_{SG}$ => ST_{SG}	5	0.03	1.76**	2	4.02**	3.64***	3	1.11	0.96
ST_{HK} => $REIT_{HK}$	4	3.80***	2.12**	2	18.90***	3.06***	1	0.16	-0.52
$REIT_{HK}$ => ST_{HK}	4	2.33*	1.76**	2	0.66	1.75**	1	0.81	0.80

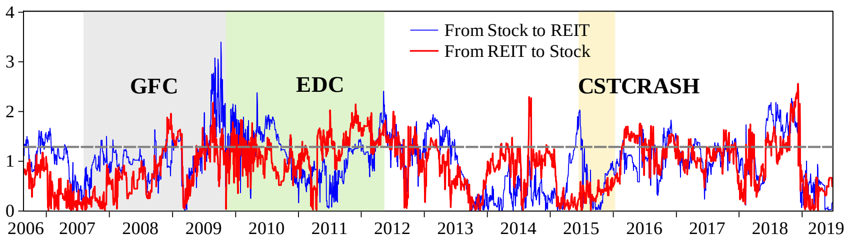
***Note*s**: Bivariate nonlinear causality tests are performed following Diks and Panchenko (2006) with one standard deviation of epsilon. VAR residuals are used to test the null hypothesis of the nonlinear causality test. F-statistics and T-statistics are shown for linear and nonlinear causality tests, respectively. ***, ** and * indicate statistical significance at the 1%, 5% and 10% significant levels, respectively.

5.5.2 *Multivariate Causality Analysis on Links between Stock and REIT Markets*

Using the multivariate linear Granger causality test results reported in Table 10, the estimated significant Wald statistics imply that the stock and REIT markets have a causal relationship in their joint spillover relationships during the three crisis periods. Moreover, by using the multivariate nonlinear testing mechanism in Bai et al. (2010, 2018) and following Choudhry et al. (2016), we identify statistically joint significant nonlinear cause and effect dependency in the NTOTALs between the stock and REIT market indexes during the GFC and EDC.

To delve into the nonlinear joint causality behavior between the stock and REIT markets that varies with time, we also use a rolling window estimation with a two-year time span (504 days) as shown in Panel B of Table 10. We observe full (i.e., 100 percent) linear cause and effect dependence that varies with time between the NTOTALS of the stock and REIT markets over the three crisis periods. Specifically, the stock and REIT markets in the system vary with time and have a nonlinear causal relationship for 39 percent of the time during the GFC and 63 percent during the EDC. Figure 6 shows the nonlinear cause and effect dependence of the stock and REIT markets that varies with time in a multivariate setting.

Figure 6 Multivariate Nonlinear Cause and Effect Dependence of Stock and REIT Markets with Time



Notes: The figure shows the time-varying multivariate nonlinear causality test statistics in Bai et al. (2018) by using net directional risk spillovers (variance and covariance) of five REIT markets and five stock markets over the full study period with a rolling window of 1 year (252-trading days). The value indicates the test-statistics for the null hypothesis that the net total spillover vector of the five stock markets is nonlinearly caused by the net total spillover vector of the five REIT markets and vice versa. The dashed line indicates the 10% significance level (x-axis: daily; y-axis: test-statistics)

Table 10 Stock-REIT: Multivariate Linear and Nonlinear Causality Tests in the Three Crisis Periods

Panel A: Static Test

Causality direction	GFC			EDC			CSTCRASH		
	l	Linear W-stat	Nonlinear T-stat	*l*	Linear W-stat	Nonlinear T-stat	*l*	Linear W-stat	Nonlinear T-stat
$ST_{(US,AU,JP,SG,HK)}$ => $REIT_{(US,AU,JP,SG,HK)}$	1	1166.27***	1.70**	1	266.74***	1.72**	1	67.22***	0.67
$REIT_{(US,AU,JP,SG,HK)}$ =>$ST_{(US,AU,JP,SG,HK)}$	1	2005.46***	1.90**	1	1225.04***	3.26***	1	719.9***	0.55

Panel B: Rolling Test

Causality direction		GFC		EDC		CSTCRASH	
		Linear # (%)	Nonlinear # (%)	Linear # (%)	Nonlinear # (%)	Linear # (%)	Nonlinear # (%)
$ST_{(US,AU,JP,SG,HK)}$ <=> $REIT_{(US,AU,JP,SG,HK)}$	Unilateral	0 (0%)	197 (33%)	0 (0%)	265 (40%)	0 (0%)	9 (6%)
	Bilateral	590 (100%)	36 (6%)	655 (100%)	152 (23%)	150 (100%)	0 (0%)

Notes: This table presents the results of multivariate linear and nonlinear causality test by using a time varying net total directional spillover(variance-covariance) series between the REIT and stock markets of five countries (US, AU, JP, SG, and HK) for three crisis periods, the GFC, EDC, and CSTCRASH. Multivariate nonlinear causality tests are performed by following Bai et al. (2010, 2018). VAR residuals are used to test the null hypothesis of the nonlinear causality test. For each causality test, the lag order is determined by the Schwarz information criteria (SC). Panel A shows the results of static tests in the three crisis periods. Wald-statistics and T-statistics are reported for linear and nonlinear causality tests, respectively. ***, ** and * indicate statistical significance at the 1%, 5% and 10% (one-tail) test levels, respectively. Panel B presents the results of rolling window test using a one-year (252-day) window. The number of significant causalities at the 10% level for each crisis period is presented. Total number of observations of GFC, EDC, and CSTCRASH, are 590, 655, and 150, respectively.

Finally, we confirm a strong linkage in the linear and nonlinear causalities of spillover between the considered variables during the GFC and EDC in which the cause and effect dependence of two other bivariate systems (US REIT market and Asian-REIT factor; Asian stock market-Asian REIT factor) is investigated (Appendix D-1). To understand the time-varying causality behavior over time, Panel B shows that the percentage of significant nonlinear causality links (both bilateral and unidirectional) at the conventional level is between 66 percent and 86 percent (GFC) and 90 percent and 96 percent (EDC) for the two systems. Appendix E-1 shows four time-varying spillover (variance-covariance) plots that could be practically beneficial for portfolio construction and management.

5.6 Implications of Main Findings

Our results highlight the importance of holistically understanding the integration of cross-listed REIT and stock-REIT markets from the perspective of return co-movement, risk spillover and connectedness, and cause and effect dependence. There are at least four economic implications that we wish to highlight.

First, the five REIT markets show less market integration than their corresponding stock markets. This is good news for portfolio investors. However, investors should bear in mind that financial contagion might be significant during crisis periods to the extent that "safe haven" REIT markets may not be spared from financial turmoil.

Second, covariance is important in contributing to the effects of risk spillover and connectedness to the extent that its inclusion in a portfolio risk connectivity analysis will give rise to higher levels of market integration for cross-listed REIT and stock-REIT markets. Although there is only moderate risk connectivity between the stock and REIT markets in the developed countries which might be beneficial for diversifying portfolios, the examined REIT markets (and REIT markets at large) still need a longer time to develop and strengthen their market structure to increase their maturity and reach out to a larger market that is at least comparable to their local stock market.

Third, there are linear and nonlinear causal relationships between the net total connectedness of cross-listed REIT and stock-REIT markets which appear to be even more enhanced under a nonlinear causality process. Therefore, any modelling of cause and effect dependency should be implemented with linear regression equations and a nonlinear VAR system to provide complete (i.e. linear and nonlinear) results. Investors and policymakers may thus predict the future performance of the integration of cross-listed REIT and stock-REIT markets and better strategize their investment and asset allocation by using the findings here.

Finally, investors should design different portfolio strategies (whether "restricted" or "unrestricted") and hedging strategies to meet their diversification and risk management objectives under the "mean-variance" framework during different crisis times. The different impacts of the three crises in this study can be attributed to the origins (US, Southern Europe and China) and type (real estate/sub-prime mortgage, sovereign debt/bond and stock) of crisis. Overall, understanding and optimizing the integration of cross-listed REIT and stock-REIT markets with financial contagion are never easy tasks in international finance.

5.7 Implications for Portfolio Diversification and Risk Management

In this last section, we provide two practical applications of the preceding results for diversifying REIT portfolio and risk management and discuss what they really mean for market participants.

First, we implement a mean-variance process to examine the performance of a REIT portfolio (risk, return and Sharpe ratio) that comprises the US REITs and REITs from the Australian, Japanese, Singaporean and Hong Kong markets, depending on the portfolio weight restrictions imposed on individual REITs during the three crisis periods. We show that the changed return, risk, Sharpe ratio and market relationships influence diversification benefits and portfolio strategies differently during the three crisis periods. Following Maghyereh et al. (2016), we impose eleven allocation restrictions and provide a brief summary of the results in Table 11.

During the GFC (Panel A), in which all of the REIT markets except for Hong Kong report negative returns and higher investment risk due to intensive risk spillovers and higher correlations, investors sought to reduce the loss. Under this volatile market condition, a reallocation of Asian REITs in a portfolio that was originally fully invested in US REITs could significantly improve risk-returns trade-off for US investors. This is because the mean return from the three Asian REIT markets (Japanese, Hong Kong and Singapore) is better than the US REITs and only moderately associated with the US REITs. Under the "unrestricted" strategy, the portfolio return is improved by 1.93 percent and the standard deviation is reduced from 3.93 percent to 1.18 percent. This "unrestricted" portfolio comprises the US REITs (4 percent) and four Asian REITs (15 percent AREITs, 9 percent JREITs, 12 percent SREITs and 60 percent HK REITs). HK REITs secured over 50 percent of the allocation because of its positive return performance and weaker integration with the US REITs. Another strategy that can be considered is to reallocate 100 percent of the US REITs to the four Asian REITs (under "Asian" only). Then portfolio loss is reduced by more than twofolds (from -3.12 percent to -1.21 percent) and risks are reduced by more than 60 percent

The diversification benefits during the EDC among the Asian REIT markets are found in the improved risk-adjusted return performance (higher Sharpe ratio) which came from the risk reduction associated with diversification. Under this crisis condition, a most profitable mixed-asset combination is a "restricted" portfolio strategy that specifies the maximum investment limit of any Asian REIT to be 20 percent. This yields a REIT portfolio that invests in 22 percent US REITs and 78 percent Asian REITs (20 percent each for Australia, Singapore and Hong Kong, and 18 percent for Japan) with approximately a 42 percent reduction in portfolio return (from 1.34 percent to 0.78 percent), while volatility has dropped about 56 percent (from 1.76 percent to 0.77 percent). This greater positive influence on volatility is translated into a positive improvement in the Sharpe ratio which is increased from 0.76 to 1.01 (+33 percent). In contrast, with the highest REIT return of 1.45 percent and highest Sharpe ratio of 1.46, investors in the Hong Kong REIT market were likely to find no improvement in their single-asset portfolio performance associated with any portfolio strategies.

Table 11 Portfolio Allocation: Performance of Mean-Variance REIT Portfolios in Three Crisis Periods

	Optimum Weight					Return (%)	St. dev. (%)	Sharpe ratio
Weight strategy	US	AU	JP	SG	HK			
Panel A: GFC								
US only	1.00	0.00	0.00	0.00	0.00	-3.12%	3.93%	-0.79
Unrestricted	0.04	0.15	0.09	0.12	0.60	-1.19%	1.18%	-1.01
min 70% US 10% Asian	0.70	0.00	0.02	0.00	0.28	-2.22%	2.88%	-0.77
min 70% US 20% Asian	0.70	0.00	0.01	0.00	0.29	-2.22%	2.88%	-0.77
max 10% in Asian	0.60	0.10	0.10	0.10	0.10	-2.75%	2.72%	-1.01
max 20% in Asian	0.23	0.20	0.17	0.20	0.20	-2.36%	1.73%	-1.36
Asian only	0.00	0.16	0.11	0.13	0.60	-1.21%	1.18%	-1.02
Australia only	0.00	1.00	0.00	0.00	0.00	-3.93%	2.61%	-1.51
Japan only	0.00	0.00	1.00	0.00	0.00	-3.04%	2.51%	-1.21
Singapore only	0.00	0.00	0.00	1.00	0.00	-1.81%	2.18%	-0.83
Hong Kong only	0.00	0.00	0.00	0.00	1.00	0.02%	1.37%	0.01
Panel B: EDC								
US only	1.00	0.00	0.00	0.00	0.00	1.34%	1.76%	0.76
Unrestricted	0.04	0.14	0.23	0.31	0.28	0.55%	0.63%	0.87
min 70% US 10% Asian	0.70	0.02	0.07	0.04	0.17	1.16%	1.30%	0.89
min 70% US 20% Asian	0.70	0.01	0.07	0.04	0.18	1.16%	1.30%	0.89
max 10% in Asian	0.60	0.10	0.10	0.10	0.10	1.05%	1.21%	0.87
max 20% in Asian	0.22	0.20	0.18	0.20	0.20	0.78%	0.77%	1.01
Asian only	0.00	0.15	0.24	0.33	0.28	0.53%	0.63%	0.84
Australia only	0.00	1.00	0.00	0.00	0.00	-0.08%	1.18%	-0.07
Japan only	0.00	0.00	1.00	0.00	0.00	0.58%	1.17%	0.49
Singapore only	0.00	0.00	0.00	1.00	0.00	0.44%	0.84%	0.52
Hong Kong only	0.00	0.00	0.00	0.00	1.00	1.45%	0.99%	1.46

(***Continued…***)

(Table 11 Continued)

Weight strategy	Optimum Weight					Return (%)	St. dev. (%)	Sharpe ratio
	US	AU	JP	SG	HK			
Panel C: CSTCRASH								
US only	1.00	0.00	0.00	0.00	0.00	0.91%	1.15%	0.79
Unrestricted	0.12	0.10	0.18	0.41	0.19	-0.66%	0.61%	-1.07
min 70% US 10% Asian	0.74	0.02	0.07	0.12	0.05	0.37%	0.89%	0.42
min 70% US 20% Asian	0.70	0.03	0.08	0.13	0.06	0.36%	0.89%	0.40
max 10% in Asian	0.62	0.10	0.10	0.08	0.10	0.44%	0.85%	0.51
max 20% in Asian	0.29	0.17	0.16	0.19	0.19	-0.01%	0.68%	-0.01
Asian only	0.00	0.13	0.21	0.44	0.22	-0.76%	0.63%	-1.21
Australia only	0.00	1.00	0.00	0.00	0.00	0.89%	1.17%	0.77
Japan only	0.00	0.00	1.00	0.00	0.00	-0.63%	1.12%	-0.56
Singapore only	0.00	0.00	0.00	1.00	0.00	-1.46%	0.76%	-1.93
Hong Kong only	0.00	0.00	0.00	0.00	1.00	0.13%	1.04%	0.12

In the CSTCRASH period (Panel C), the associated diversification benefits were not carried forward. The portfolio return enhancement of rebalancing towards Asian REITs has completely disappeared. Nevertheless, the portfolio return and Sharpe ratio are higher with full investment in US REITs. Specifically, the expected return of a portfolio that is fully invested in US REITs is 0.91 percent, while the expected return of reallocating 20 percent to Asian REITs is only 0.37 percent due to the poor performance of Asian REITs that are more affected by the Chinese stock market crash than the US REITs. During this crisis, risk can still be reduced by investing in Asian REITs with lower risk reduction and lower Sharpe ratios. For instance, a mixed-asset portfolio strategy (with minimum 70 percent in US REITs and 10 percent in Asian REITs) would have reduced volatility from 1.15 percent to 0.89 percent with a Sharpe ratio that is reduced from 0.79 to 0.42. For Asian investors who do not have a diversified portfolio, they could invest in one that is fully invested in AREITs, which would provide them with a 0.89 percent return and a 0.77 Sharpe ratio, but with a marginal increase of 0.02 percent volatility relative to a 100 percent US REIT portfolio.

Second, we apply the variance and covariance estimated from the preceding results to examine portfolio diversification and risk management in stock and REIT markets. In using the conditional volatility estimates from the VECH-MGARCH model to construct hedge ratios (Kroner and Sultan, 1993) and optimum portfolio weights (Kroner and Ng, 1998), we consider each country portfolio to compose of stocks and REITs as we wish to minimize the portfolio risk without lowering the expected returns. Given that a long position in stocks

(s) can be hedged with a short position in REITs (r), the risk minimizing hedge ratio (HR) between stocks and REITs at time t is:

$$HR_{rs,t} = COV_{rs,t} / CV_{r,t}$$

where $COV_{rs,t}$ is the estimated conditional covariance of stocks and REITs at time t, and $CV_{r,t}$ the conditional variance of REITs at time t. Then the optimal portfolio weights of stocks ($w_{s,t}$) at time t are calculated by using: $w_{s,t} = \frac{CV_{s,t} - COV_{rs,t}}{CV_{r,t} + CV_{s,t} - 2 * COV_{rs,t}}$; where $w_{s,t}$ is the weight of the stock index in a one dollar two-asset portfolio at time t. The optimal weight of the REIT index is equal to (1-$w_{s,t}$), under the condition that (a) $w_s = 0$ if $w_s < 0$, (b) $w_s = w_s$ if $0 <= w_s <= 1$, and (c) $w_s = 1$ if $w_s > 1$.

Table 12 reports the estimates of the optimum weights and hedge ratios over the three crisis periods. During the GFC, the average optimum weight for the five REITs is about 0.66 cents (1-0.3437), and ranges from 20.71 cents (HK REITs) to 99.86 cents (US REITs), thus implying that the optimum allocation for HK REITs in a one-dollar stock and REIT market portfolio is 20.71 cents, with the remaining 79.29 cents invested in the HK stock index. During the EDC, the average optimum allocation weight of REITs is 52.64 cents (1-0.4736) and between 23.63 cents (SREITs) and 94.97 cents (US REITs). In contrast, the optimum allocation for the US REITs is 61.98 cents during the CSTCRASH. Thus, the investment weight of REITs is the highest during the GFC but levelled off during the CSTCRASH. There is an exception, as Panel B indicates that the mean test statistics are significantly rejected at the 1 percent level, thus implying that the optimum portfolio weight of REITs during the GFC is significantly higher than that during the EDC and CSTCRASH.

Table 12 Stock-REIT: Portfolio Management and Hedging in the Three Crisis Periods

Panel A: Hedge Ratios and Optimum Portfolio Weights for Five Stock-REIT Pairs

	GFC		EDC		CSTCRASH	
	Hedge ratio	Weight (stock)	Hedge ratio	Weight (stock)	Hedge ratio	Weight (stock)
USREITs	0.4131	0.0014	0.5577	0.0503	0.6239	0.3802
AREITs	0.4265	0.1053	0.5824	0.3700	0.7270	0.4823
JREITs	0.5315	0.4410	0.4457	0.5998	0.5481	0.7655
SREITs	0.6785	0.3777	0.8409	0.7637	0.8714	0.7823
HKREITs	0.6392	0.7929	0.4316	0.5841	0.6166	0.7086
Average	0.5378	0.3437	0.5716	0.4736	0.6774	0.6238

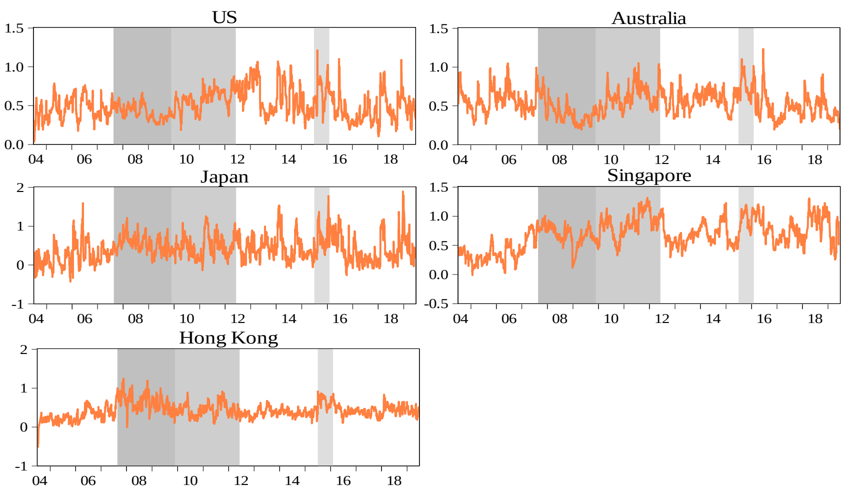
Panel B: Mean Test of Optimum Portfolio Weight

	GFC vs EDC	GFC vs CSTCRASH	EDC vs CSTCRASH
USREITs	-11.612***	-21.340***	-18.105***
AREITs	-25.538***	-15.592***	-4.595***
JREITs	-10.056***	-19.140***	-10.351***
SREITs	-28.440***	-20.457***	-0.956
HKREITs	-22.552***	5.062***	-7.408***

Notes. We consider a portfolio composed of the stock and REIT market index whereby we wish to minimize the risk without lowering the expected returns. We further assume a long position in stocks can be hedged with a short position in REITs, thereby allowing the risk minimizing hedge ratios and optimum portfolio weight (stock) to be derived from the variance-covariance estimated from the VECH-MGARCH model. *** indicates two-tail statistical significance at the 1 percent level.

The average optimum hedging ratios for the five countries are 0.5378 (GFC), 0.5716 (EDC) and 0.6774 (CSTCRASH), which means one dollar that is long in the GFC period should be short sold by 53.78 cents in the REIT market. This average hedging ratio is higher in the EDC and CSTCRASH, thus reflecting that short hedgers are more pessimistic about the market conditions during the GFC. Finally, Figure 7 shows the time-varying optimum hedging ratios across the five REIT markets, with the minimum-maximum values estimated as (0.413-0.679), (0.432-0.841) and (0.548-0.871) for the GFC, EDC and CSTCRASH, respectively.

Figure 7 Stock-REIT: Time-Varying Hedging Ratios



Note: The analysis assumes a long position in stocks can be hedged with a short position in REIT. The three shaded columns (from the left) denote the GFC, EDC and CSTCRASH (x-axis: month; y-axis: country hedge ratio}.

6. Conclusion

Our research paper extends the existing literature in two main ways: (a) capturing the market integration of the four Asian and the US REIT markets and between the stock and REIT markets of the five countries using the 3Cs, and (b) elucidating the REIT allocation strategies and hedging in stocks and REITs during the three crisis times. Given the focus of the various approaches and associated indicators, the picture that emerges from the empirical results might not be complete. Nevertheless, the indications of the main results and the major economic implications are evident from this research. Notably, this study has produced the following findings.

First, the five major REIT markets show less integration than their corresponding stock markets, which implies that there is still potential for international diversification. In contrast, greater market integration may inadvertently face contagion in the event of financial and economic crises, such as the GFC and CSTCRASH.

Second, the within-Asia REIT markets appear to be more risk-connected than the US/Asia REIT markets. Moreover, the REIT markets have experienced some significant shifts in their net directional risk connectedness indexes over the three crises. While the JREITs are relatively more influential in the REIT market integration during the GFC, AREITs and SREITs contribute most to the market integration of REITs during the EDC and CSTCRASH.

Third, investors and policymakers may benefit from the findings on the various causal relationships in the net total directional risk connectedness index to predict the future performance of market integration in the cross-listed REIT and stock-REIT markets, and better strategize their investment and asset allocations. They are reminded that any modelling of the REIT markets and cause and effect dependence of the stock and REIT markets should be implemented with linear regression equations and nonlinear VaR systems to examine risk spillover and connectedness for comprehensive (i.e. linear and nonlinear) results.

Finally, future research can investigate the appropriate levels of market integration of regional and global REITs with key determinants, whereby the benefits of integration could be realized with little risk of contagion.

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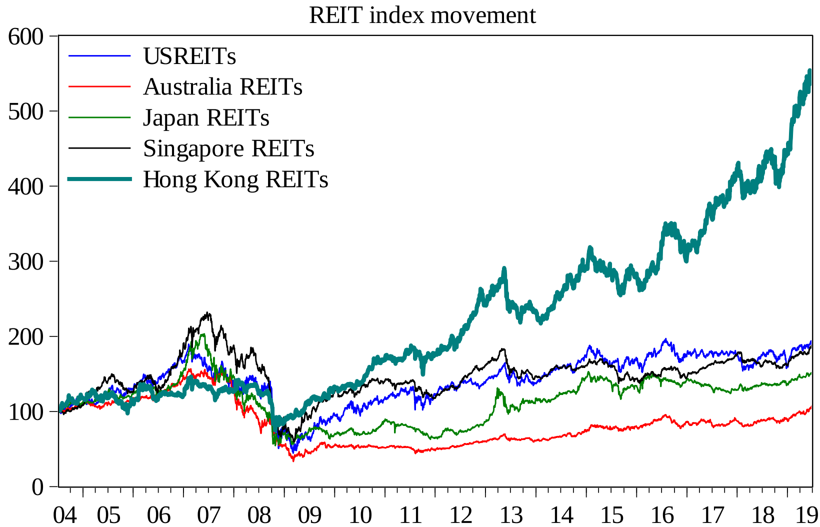
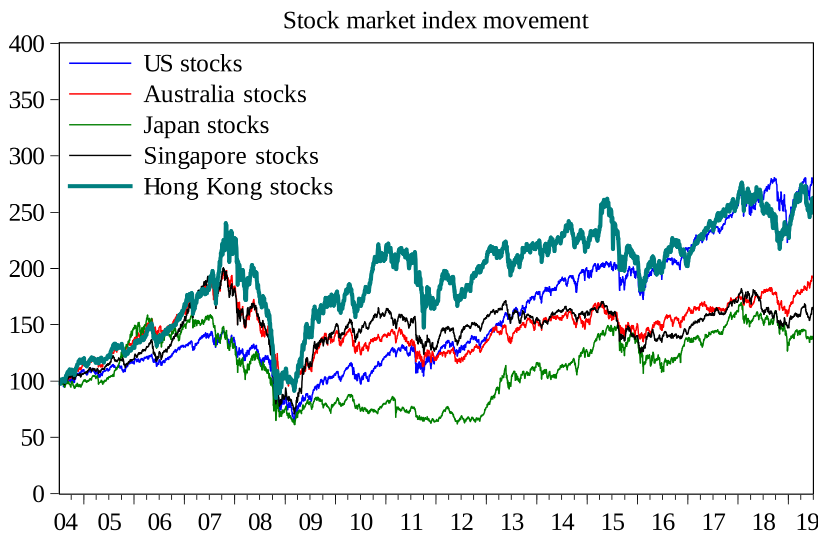
Appendices

Appendix A-1 Sample REIT and Stock Market Index Movements (Rebased)



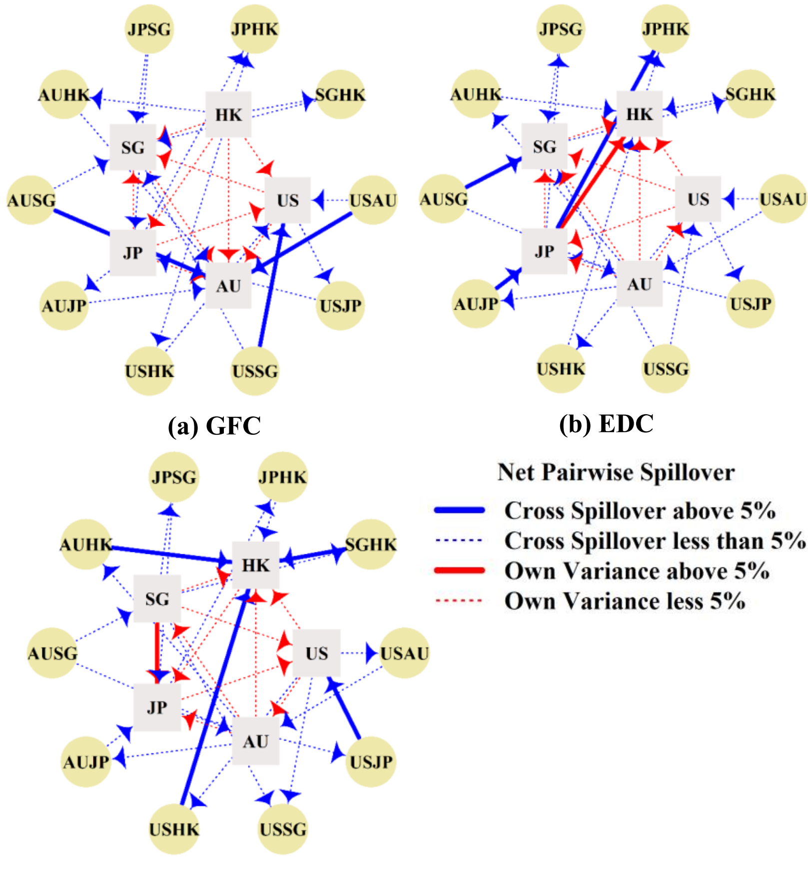


Appendix B-1 Estimated Coefficients for Variance–Covariance Equation in REITs for the Full Period

	USR(1)	AUSR(2)	JPR(3)	SGR(4)	HKR(5)
Constant estimates					
USR(1)	1.52E-08	4.39E-08**	8.81E-09	2.40E-08**	1.97E-07**
AUSR(2)		1.26E-07***	2.54E-08	6.90E-08***	5.66E-07***
JPR(3)			5.09E-09	1.39E-08	1.14E-07
SGR(4)				3.77E-08***	3.09E-07***
HKR(5)					2.54E-06***
ARCH estimates					
USR(1)	0.0246***	0.0039**	0.0432***	0.0216***	0.0301***
AUSR(2)		0.00062	0.0069**	0.0034**	0.0048**
JPR(3)			0.0759***	0.0381***	0.0528***
SGR(4)				0.0191***	0.0265***
HKR(5)					0.0368***
Asymmetry/leverage estimates					
USR(1)	0.0239***	0.0344***	0.0241***	0.0159***	0.0049*
AUSR(2)		0.0496***	0.0347***	0.0229***	0.0070*
JPR(3)			0.0243***	0.0161***	0.0049*
SGR(4)				0.0106***	0.0032*
HKR(5)					0.00099
GARCH estimates					
USR(1)	0.968***	0.971***	0.947***	0.972***	0.954***
AUSR(2)		0.974***	0.950***	0.975***	0.957***
JPR(3)			0.926***	0.951***	0.933***
SGR(4)				0.976***	0.958***
HKR(5)					0.940***

Notes: The estimates are derived by using a five-market (REIT) VAR-VECH-MGARCH that restricts A (ARCH), B (GARCH) and D (leverage) as diagonals. All regressions follow the GARCH (1, 1) model and are estimated with maximum likelihood by using the Berndt-Hall-Hall-Hausman (BHHH) maximization algorithm. ***, **, * denote two-tailed significance at the 1, 5 and 10 percent levels respectively.

Appendix C-1 Network Diagram of Risk Spillovers in the Three Crisis Periods



(a) GFC **(b) EDC** **(c) CSTCRASH**

Notes: This graph shows 10 pairs of networks among the five REIT markets ("Own variance spillover") and 20 pairs between variance and covariance ("Cross spillover") in the three crisis periods (GFC, EDC, and CSTCRASH) which use the average net-pairwise directional spillover and connectedness indexes extracted from rolling variance decomposition with 300-day window span. The arrow on each edge is running from the risk transmitter to risk receiver. The edge between the variance and covariance only considers the interaction of the variance with the covariance which contains the corresponding variance. For example, for "USAU", which is the covariance between US and AU, is only interlinked with US and AU. The width of the edge is divided into two types with a criteria of 5%. There are two edge colors for "Own variance spillover" and "Cross spillover" to enhance the spillover effect in the network graph, which are red and blue respectively. That is, the red solid line/red dotted line indicates more than 5% (less than 5%) of the net-pairwise spillovers for "Own variance spillovers" and the blue solid line/blue dotted line indicates net pairwise spillovers more than 5% (less than 5%) for "Cross spillover".

Appendix D-1 Factor Framework: Linear and Nonlinear Causal Relationships on Total and Net Total Directional Spillover-Connectedness

Panel A: Static Test

Causality direction	GFC			EDC			CSTCRASH		
		Linear	Nonlinear		Linear	Nonlinear		Linear	Nonlinear
	Lag	F -stat	T-stat	Lag	F-stat	T-stat	Lag	F-stat	T-stat
TS_{US} => TS_{Asian}	9	**21.09******	**1.927*****	3	**37.06******	**3.77******	3	**236.01******	**1.76*****
TS_{Asian} => TS_{US}	9	**9.35******	**2.36******	3	0.145	**1.33***	3	**2.65*****	0.04
$NTOTALS_{ST}$ => $NTOTALS_{REIT}$	5	**78.61******	**2.94******	2	**15.32******	**2.33******	5	**8.52******	1.24
$NTOTALs_{REIT}$ => NTOTALS	5	**18.50******	**1.84*****	2	**4.052******	**1.48***	5	0.44	**2.13*****

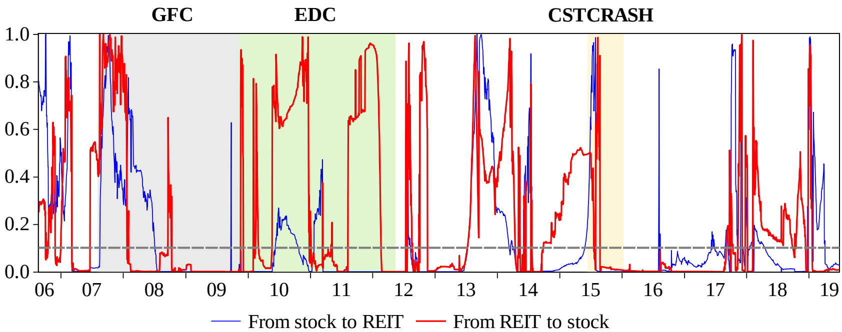
Panel B: Rolling Test

Causality direction		GFC		EDC		CSTCRASH	
		Linear # (%)	Nonlinear # (%)	Linear # (%)	Nonlinear # (%)	Linear # (%)	Nonlinear # (%)
TS_{Asian} <=> TS_{US}	Unilateral	143 (24%)	138 (23%)	258 (39%)	246 (38%)	26 (17%)	94 (63%)
	Bilateral	333 (56%)	369 (63%)	298 (45%)	343 (52%)	98 (65%)	40 (27%)
$NTOTALS_{ST}$ <=> NTOTALS	Unilateral	66 (11%)	131 (22%)	105 (16%)	426 (65%)	17 (11%)	59 (39%)
	Bilateral	419 (71%)	261 (44%)	264 (40%)	200 (31%)	114 (76%)	65 (43%)

Notes: This table presents the results of bivariate linear and nonlinear causal relationships on time-varying total directional spillover and net total directional spillover series of the US and Asian factor in the three crisis periods (GFC, EDC, and CSTCRASH). The Asian factor is defined as the first dominant factor derived from implementing a "factor analysis" by using SPSS from a set of four-country REIT returns (AU, JP, SG and HK). Bivariate nonlinear tests are performed by referring to Diks and Panchenko test (DP test; 2006). VAR residuals are used to test the null hypothesis of nonlinear causality. For each causality test, the lag order is determined by using Schwarz information criteria (SIC). Two pairs of linear and nonlinear bivariate causality tests are implemented. Panel A shows the results of static tests with the three crisis periods. F-statistics and T-statistics are shown for the linear and nonlinear versions, respectively. ***, ** and * indicate statistical significance at the 1, 5 and 10 percent (one-tail) levels, respectively. Panel B presents the results of rolling window tests that use a one-year (252-day) rolling window. The number and corresponding percentage of significant causalities at the 10% level or each crisis period are presented. The total number of observations for the GFC, EDC, and CSTCRASH, are 590, 655, and 150, respectively. "TS" indicates the total spillover transmission of the "Asian" factor and the US. "NTOTALS" indicates the net total directional spillovers for the "stock market factor (ST)" and "REIT factor (REIT)" respectively.

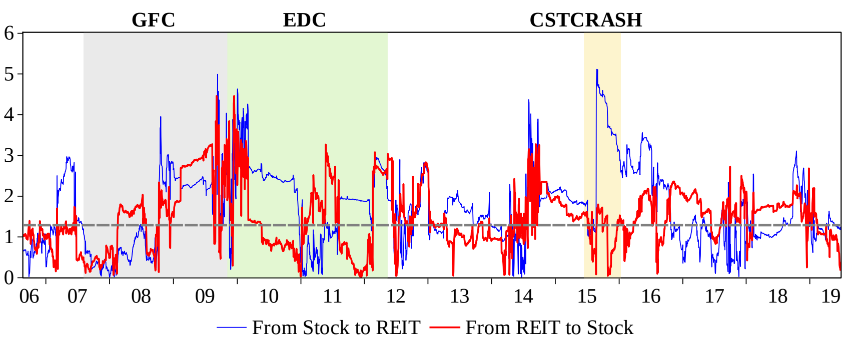
Appendix E-1 Rolling Bivariate Linear (*p*-Values) and Nonlinear Granger Causality (*t*-Statistics)

Panel 1A: Linear: Between Stock-REIT Factor



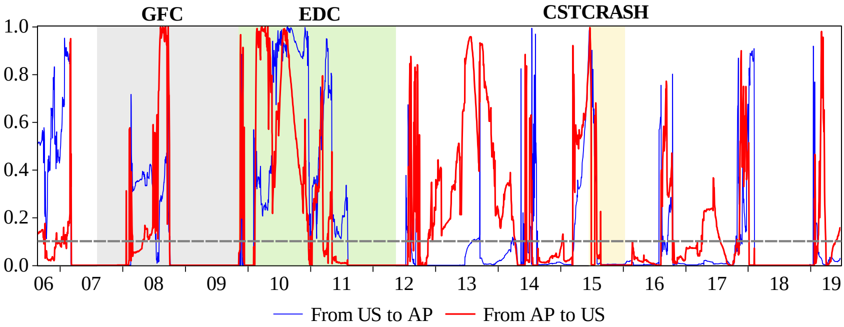
Notes: This plot shows the time-varying bivariate linear Granger causality p-values based net total directional risk (variance and covariance) spillovers of principal components of stocks that varies with time, and net total directional risk (variance and covariance) spillovers of the principal components of REITs with a one-year (252-trading) rolling window. The value indicates the changes in the p-values on bivariate linear causal relationships. The dashed line indicates p-value of 0.1 (10% significance level). The three shaded areas (from the left) indicate GFC, EDC, and CSTCRASH, respectively.

Panel 1B: Nonlinear: Between Stock-REIT Factor



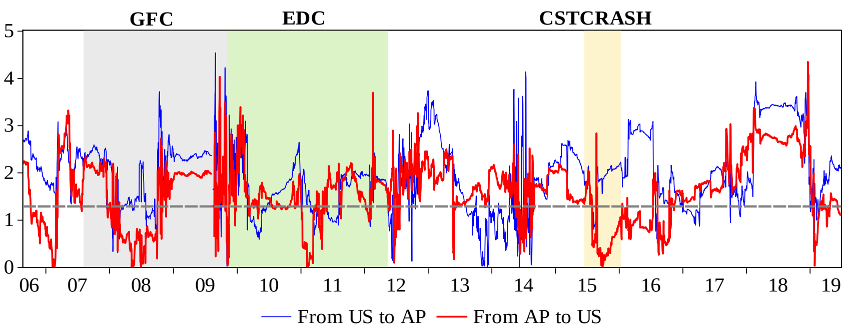
Notes: This plot shows the nonlinear bivariate causality test statistics with time per Diks and Panchenko (2006) based on net total directional risk (variance and covariance) spillovers of the principal components of stocks that varies with time, and net total directional risk (variance and covariance) spillovers of the principal components of REITs with a 1 year (252-trading) rolling window. The value indicates the changes in test-statistics on nonlinear bivariate causal relationships. The dashed line indicates 10% significance. The three shaded areas (from the left) indicate GFC, EDC, and CSTCRASH, respectively.

Panel 2A: Linear: Between the US REITs and Asian REIT Factor



Notes: This figure shows the p-value of the bivariate linear Granger causality that varies with time by using net total directional risk spillovers of the USREITs that vary with time, and net total directional risk spillovers of the first principal components of the four Asian REITs (AP) with a one-year (252-trading) rolling window. The value indicates the changes in the p-value on bivariate causal relationships. The dashed line indicates p-value of 0.1 (10% significance level). The shaded areas indicate GFC, EDC, and CSTCRASH, respectively.

Panel 2B: Nonlinear: Between the US REITs and Asian REIT Factor



Notes: This figure shows the bivariate nonlinear causality test statistics that vary with time per Diks and Panchenko (2006) by using the net total directional risk spillovers of the USREITs that vary with time and net total directional risk spillovers of the first principal components of the four Asian REITs (AP) with a 1 year (252-trading) rolling window. The value indicates the changes of the test-statistics on bivariate nonlinear causal relationships. The dashed line indicates a 10% significance level. The shaded areas indicate GFC, EDC, and CSTCRASH, respectively.