Is there really any Contagion among Major Equity and Securitized Real Estate Markets? Analysis from a New Perspective

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Abstract

This study examines contagion across general equity and securitized real estate markets of China, Hong Kong and the Us during the Chinese financial crisis.This is the first study to combine the case-resampling bootstrap method with the coskewness and cokurtosis test. Thus, the new method works well on data with a non-normal distribution or nonconstant variance. Additional channels of contagion may also be detected to reflect a more precise pattern of contagion. In contrast to Hatemi-J and Hacker, Applied Financial Economics Letters, 1(6),343-347(2005)'s result, we find thatthe case-resampling bootstrap method diminishes the overall effect of contagion. In particular, no additional channels of contagion can be found when the case-resampling bootstrap method is applied on the coskewnesstest, but when the case-resampling bootstrap method is applied on the cokurtosis test, additional channels of contagion are detected. Furthermore, the overall effect of contagion is greater on the general equity markets than on the securitized real estate markets. This study has useful implications to investors, regulators and policy makers.

Keywords Contagion. Coskewness test. Cokurtosis test. Case-resampling bootstrap method

Introduction

Since Deng Xiao-ping implemented the open-door policy in 1978, starting a major economic reform in China, China began to transform from a planned economy to a market economy, and its economy has kept growing at a relatively high rate of 8 % or above. In 2010, China even surpassed Japan and became the second largest economy in the world just behind the US. However, China's economic growth has slowed down recently. Its economic growth rate has dropped to a 6-year low of 6.9 % in 2015. Furthermore, a stock market crash broke out in China in mid-June 2015, triggering the Chinese financial crisis. Although the Chinese government intervened the financial markets through various channels, the stock prices kept on falling. The Shanghai Composite Index fell from a 7-year high of 5166.35 on 12 June 2015 to a trough of 2927.29 on 26 August 2015, which was a plunge of over 40 %. The Chinese financial crisis caused stock markets in Hong Kong and other Asian countries to drop sharply, too. Stock markets in Europe and the US also experienced a significant fall in August.

It is suspected that there is a contagious effect among the international stock markets during the Chinese financial crisis. We would also like to investigate the contagious effect between international real estate markets during this crisis, which is unknown, too. The real estate market is becoming more and more important in recent years. According to Hudson-Wilson et al. (2003), real estate can give high absolute returns, lower overall portfolio risk and hedge against unexpected inflation or deflation. These motivate investors to include real estate in their portfolio. Moreover, the recent internationalization and globalization of real estate markets lead to stronger integration, so we expect more co-movements among global property prices (Hatemi-J and Roca 2010). However, real estate can serve as both a type of consumption goods and an investment tool (Hui and Zheng 2012). Therefore, real estate markets may have a different pattern of contagion. Furthermore, previous studies on contagion among real estate markets resulted in mixed results (see Literature Review Section). By investigating contagion across international equity and real estate markets during the Chinese financial crisis, not only we can add knowledge to the currently limited literature on contagion among international real estate markets, but also we can see how the Chinese financial crisis, emerged from China, is different from previous financial crises which are mostly originated in countries with free markets, in terms of contagion patterns. Compared with the Asian financial crisis in 1997, which was originated in Thailand, and the global financial crisis in 2008, which was originated in the US, we expect China to be the source of contagion in the Chinese financial crisis, while other economies are recipients. However, since the Chinese financial crisis is less severe than the Asian financial crisis and the global financial crisis, the effect of contagion may not be so significant. Furthermore, China′s financial market is not totally free and is expected to be manipulated, which introduces asymmetric information and a lack of rational expectations. Therefore, the contagion pattern during the Chinese financial crisis may be different. This can help investors reallocate their portfolio during financial crises in order to reduce their risks. Regulators and policy makers can also monitor the financial markets more effectively to mitigate the impact of financial crises. In this study, we combine Hatemi-J and Hacker (2005)′s case-resampling bootstrap method with Fry et al. (2010)′s coskewness test and Hui and Chan (2012)′s cokurtosis test, thereby extending the case-resampling bootstrap method to higher ordered moments. This study is the first one to combine the coskewness/cokurtosis test with the caseresampling bootstrap method to form a new test, highlighting the originality and academic contribution of this study. Our new combined method not only can detect additional channels of contagion and cope with data with a non-normal distribution or non-constant variance, but also can detect additional channels of contagion when compared with Hatemi-J and Hacker (2005)′s case-resampling bootstrap method applied on the linear regression model. We apply our method to test contagion among the equity and securitized real estate markets of three economies: China, Hong Kong and the US, during the period January 2, 2012 – January 23, 2016. We use securitized real estate indices because the frequency of most housing price indices is either weekly or monthly, so there would be too few data for contagion analysis. Daily securitized real estate indices offer sufficient data for contagion analysis and are compatible to the daily equity indices used in this study, too.

The paper proceeds as follows. Literature Review Section reviews previous works on contagion across real estate markets. Contagion Tests Section describes the contagion tests. In Data Section, we select the crisis periods and the equity and securitized real estate indices. Results Section displays the results of the tests. We draw up conclusions in Conclusion Section.

Literature Review

There are a number of previous studies on contagion, cointegration or comovements among real estate markets (or between real estate and equity markets). Various methods are used. One common method is to derive contagion test based on correlation. Forbes and Rigobon (2002) derived the adjusted correlation coefficient from the ordinary correlation coefficient, and hence constructed the Forbes-Rigobon test (a 2nd ordered moment test). They found a high level of interdependence, but virtually no contagion, during the 1987 US market crash, 1994 Mexican devaluation and 1997 Asian crisis. Fry et al. (2010) increased the order of moments to 3, developing the coskewness test and applied it to examine contagion across global real estate markets during the Asian and US subprime crises. Although the coskewness test detected additional channels of contagion, only little evidence of contagion during the US subprime crisis is shown. Hui and Chan (2012) extending Fry et al. (2010)'s framework to fourth ordered moments and hence derived the cokurtosis test. They applied the test to investigate contagion between the real estate markets of US, UK, China and Hong Kong during the recent global financial crisis. The results showed significance evidence of contagion between those countries. The same test was applied by Hui and Chan (2014) to examine contagion across real estate and equity markets of Hong Kong, US and UK during the global financial crisis. The cokurtosis test showed a highly significant evidence of contagion between the equity and real estate markets in both directions. Furthermore, they found that that US is the centre of shock of the global financial crisis.

Cointegration test is another commonly used method to study interaction between securitized real estate markets. Yunus (2009) applied the recursive cointegration model to investigate the degree of interdependence among the securitized property markets of six major countries and the US from January 1990 to August 2007. She found that the US and Japan markets led five cointegrated markets to a long run equilibrium, whereas only Netherlands and France provided some diversifications to US investors. Ryan (2011) implemented a specific class of Vector Autoregression (VAR) models to examine the level of integration between international listed property markets during the Asian crisis and the current global credit crisis. He showed that due to cointegration between the markets, the benefits of diversification disappeared during the crises in both hedged and un-hedged cases. Yunus (2012) examined dynamic interactions among securitized property markets, equity markets and key macroeconomic factors for ten developed counties. She found that each property market was cointegrated with its respective equity market and key macroeconomic factors in the long run, and was also affected by the overall economy in the short run. Some studies used the fractional approach. Serrano and Hoesli (2012) applied the Fractionally Integrated Error Correction Model (FIECM) to investigate long-run relationship between securitized real estate returns and three sets of variables representing factors driving securitized real estate returns. The results showed strong evidence of fractional cointegration, mainly characterized by short memory, between securitized real estate and the three sets of variables. On the contrary, Liow and Yang (2005), who applied the Fractionally Integrated Vector Error Correction Model (FIVECM) to examine cointegration between real estate markets of four Asian economies, found long memory characteristics in the cointegration of securitized real estate market, stock market and major macroeconomic factors.

Simulation methods can also be used to test contagion. Hatemi-J and Hacker (2005) proposed a case-resampling bootstrap method which performs accurately when the assumption of normality and constant variance is not fulfilled. They applied this method to test for contagion from Thai to Indonesian equity markets during the Asian financial crisis and found significant evidence of contagion. Hatemi-J and Roca (2010) applied the same approach to test contagion across real estate markets of different countries during the US subprime crisis. The results showed no significant evidence of contagion. The same method was also applied by Hatemi-J et al. (2014) to investigate integration of five internationalized real estate markets with the world market. Except for United Arab Emirates (UAE), all other four markets were found to be integrated with the world market. Hui and Chan (2013) extended the case-resampling bootstrap method to test the parameters in the Forbes-Rigobon multivariate (FRM) test, and applied the method to investigate contagion across equity and real estate markets of four countries during the European sovereign debt crisis. They found that the effect of contagion was generally not significant.

There are also other methods to test contagion across property markets. For example, Bond et al. (2006) used the latent factor model to examine contagion across real estate markets during the Asian crisis in 1997–98. They found existence of contagion among the markets. Wilson et al. (2007) applied the method of structural time series to measure spillover effects across Asian property markets during the Asian crisis, and found a broad level of interdependence. Liow (2008) used a combination of Johansen linear cointegration, Bierens nonlinear cointegration, Granger causality tests, variance decomposition analysis and volatility spillover methodology to examine the changes in both long- and short-run relations among the US, UK and eight Asian securitized real estate markets around the Asian crisis and in the most recent period. The results showed a stronger interdependence among Asian markets in both long- and short-run. Moreover, this interdependence appeared to grow even stronger recently. Case et al. (2012) applied the Dynamic Conditional Correlation model with Generalized Autoregressive Conditional Heteroskedasticity (DCC-GARCH) to examine dynamics in the correlation between publicly traded REITs and non-REIT equity returns. They found three distinct periods of REIT-stock correlations. Hui and Chen (2012) applied the multivariate cumulative sum (CUSUM) test and the renormalized partial directed coherence (PDC) method to investigate the structural causality change of securitized real estate indices of five Asian countries and regions. They found the emergence of regional influence of the Chinese securitized real estate market on the causality structure of the five markets. Hui and Ng (2012) tested the short- and long-run interrelationships between Hong Kong′s residential property and stock markets during the period 1990–2006 using Granger causality test, variance decomposition and CUSUM test. The results showed that the correlation between residential property price and stock index had become weaker over time. Anderson et al. (2015) use a newly-developed time-varying rangebased volatility model to capture the dynamics of securitized real estate volatility, and investigated the impact of extreme events on the volatility dependence in a broad set of 13 developed countries during the period 1990–2012. They found that information transmission through the volatility channel can exhibit either bi- or uni-directional causality. In addition, financial contagion following the subprime crisis is found between the US and Australia. Hoesli and Reka (2015) tested three financial mechanisms potentially driving contagion, and examined a behavioral dimension in the crisis propagation by considering investor sentiment and panic risk. They found that contagion prevailed between REITs and stocks and that phenomenon was driven by behavioral and liquidity mechanisms.

The above summarizes previous studies on contagion/cointegration/comovements across real estate markets. Mixed results are shown: some found significant evidence of contagion, but some did not. The majority of them found the existence of contagion/cointegration/interdependence/co-movement among global property markets. For example, Liow (2008) found that this interdependence appeared to be on a rising trend recently. This coincides with Hatemi-J and Roca (2010) that internationalization and globalization of real estate markets caused stronger integration, leading to more comovements among global property prices (see Introduction Section). However, only a few of them studied China (e.g. Hui and Chen 2012). As China is an emerging economy, it is important to study the contagion pattern during the Chinese financial crisis, which may be different from the contagion pattern in previous financial crises because China′s market is not totally free. This can help us understand how China′s market affects other economies′ markets.

Furthermore, most of the previous studies use contagion tests based on correlation or cointegration tests. However, those standard contagion tests based on correlation do not work well on data which do not satisfy the conditions of normality and constant variance. This leads to the development of the case-resampling bootstrap which can deal with data of non-normal distributionornon-constant variance (Hatemi-J and Roca2010). Hatemi-J and Hacker (2005), Hatemi-J and Roca (2010) and Hatemi-J et al. (2014) applied the case-resampling bootstrap method on a single bivariate regression model, while Hui and Chan (2013) extended Hatemi-J and Roca (2010)'s bivariate model to a multivariate framework, thereby using the case-resampling bootstrap method to test the parameters in the Forbes-Rigobon multivariate (FRM) test. However, both the bivariate regression model and the FRM test are analogues to the Forbes-Rigobon test which is a 2nd ordered moment test. However, according to Fry et al. (2010) and Hui and Chan (2014), sometimes correlation cannot reveal the whole contagion pattern. Some investors would like to know the higher ordered moments of asset returns, too. For example, risk adverse investors prefer positive skewness and lower kurtosis. Therefore, it is worth considering the higher ordered moments. Different contagion patterns may be observed. This leads to the development of the coskewness and cokurtosis tests. In this study, we combine the case-resampling bootstrap method with the coskewness and cokurtosis tests to form a newmethod, and apply thecase-resamplingbootstrap methodto estimate the coskewness statistics and cokurtosis statistics (this is the innovation in our methodology). Thus our new method has the advantage over Hui and Chan (2014)'s method (and also other standard methods) that it performs accurately when the assumption of normality and constant variance is not fulfilled. Our method is also superior to the method of Hatemi-J and Hacker (2005), Hatemi-J and Roca (2010) and Hatemi-J et al. (2014) that a more precise pattern of contagion can be obtained by extending the case-resampling bootstrap method to higher ordered moments. We expect that our new method can detect additional channels of contagion when compared with Hatemi-J and Hacker (2005)'s caseresampling bootstrap method applied on the linear regression model.

Contagion Tests

The Forbes-Rigobon Test

The Forbes-Rigobon test was invented by Forbes and Rigobon (2002), who first developed the adjusted (unconditional) correlation coefficient for testing contagion from market i to market j (Forbes and Rigobon 2002; Dungey et al. 2005; Hui and Chan 2012, 2013):

$$v_{y|x_i} = \frac{\rho_y}{\sqrt{1 + \left(\frac{\sigma^2_{y,i}}{\sigma^2_{x,i}} - 1\right)\left(1 - \rho_y^2\right)}} \qquad (1)$$

where $\sigma_{x,i}$ and $\sigma_{y,i}$ represent the standard deviation of the asset return of market i in the pre-crisis period and the crisis period respectively, and ρ_y is the correlation between asset returns of markets i and j during the crisis period.

The Forbes-Rigobon test has various forms. For example, the refinement form of the Forbes-Rigobon Statistics is (Dungey et al. 2007; Hui and Chan 2012, 2014):

$$FR_1(i \to j) = \frac{\frac{1}{2}\ln\left(\frac{1+\hat{v}_{y|x_i}}{1-\hat{v}_{y|x_i}}\right) - \frac{1}{2}\ln\left(\frac{1+\hat{\rho}_x}{1-\hat{\rho}_x}\right)}{\sqrt{\frac{1}{T_y-3}+\frac{1}{T_x-3}}} \tag{2}$$

where ρ_x denotes the correlation between asset returns of markets i and j during the precrisis period, ^ denotes the sample estimator, and T_x, T_y are the sample sizes of the precrisis period and the crisis period respectively. $FR_1(i \to j)$ follows a standard normal distribution under the null hypothesis of no contagion. A one-sided z-test is applied to $FR_1(i \to j)$ for testing contagion.

The Coskewness Test

The coskewness test considers the interaction between the first and second ordered moments of return. The coskewness statistics for testing the null hypothesis of no contagion from market i to market j are (Fry et al. 2010; Hui and Chan 2012, 2014):

$$CS_1\left(i \to j; r_i^1, r_j^2\right) = \left(\frac{\hat{\psi}_y\left(r_i^1, r_j^2\right) - \hat{\psi}_x\left(r_i^1, r_j^2\right)}{\sqrt{\frac{4\hat{v}_{y|x_i}^2+2}{T_y} + \frac{4\hat{\rho}_x^2+2}{T_x}}} \right)^2$$

$$CS_1(i \to j; r_i^2, r_j^1) = \left(\frac{\hat{\psi}_y(r_i^2, r_j^1) - \hat{\psi}_x(r_i^2, r_j^1)}{\sqrt{\frac{4\hat{\nu}_{y|x_i}^2 + 2}{T_y} + \frac{4\hat{\rho}_x^2 + 2}{T_x}}} \right)^2$$

where

$$\hat{\psi}_y(r_i^m, r_j^n) = \frac{1}{T_y} \sum_{t=1}^{T_y} \left(\frac{y_{i,t} - \hat{\mu}_{y,i}}{\hat{\sigma}_{y,i}} \right)^m \left(\frac{y_{j,t} - \hat{\mu}_{y,j}}{\hat{\sigma}_{y,j}} \right)^n, \quad (5)$$

$$\hat{\psi}_x(r_i^m, r_j^n) = \frac{1}{T_x} \sum_{t=1}^{T_x} \left(\frac{x_{i,t} - \hat{\mu}_{x,i}}{\hat{\sigma}_{x,i}} \right)^m \left(\frac{x_{j,t} - \hat{\mu}_{x,j}}{\hat{\sigma}_{x,j}} \right)^n, \quad (6)$$

where $x_{i,t}$ and $y_{i,t}$ denote the continuously compounded daily return of market i on day t during the pre-crisis period and crisis period respectively, while $\hat{\mu}_{x,i} = \frac{1}{T_x} \sum_{t=1}^{T_x} x_{i,t}$ and $\hat{\mu}_{y,i} = \frac{1}{T_y} \sum_{t=1}^{T_y} y_{i,t}$.

Under the null hypothesis of no contagion, $CS_1(i \to j; r_i^1, r_j^2)$ and $CS_1(i \to j; r_i^2, r_j^1)$ are asymptotically distributed as χ_1^2.

The Cokurtosis Test

The cokurtosis test considers the interaction between the first and third ordered moments of return. Compared with the coskewness test, the order or moments is further increased by one. The cokurtosis statistics for testing the null hypothesis of no contagion from market i to market j are (Hui and Chan 2012, 2014):

$$CK_1\left(i \to j; r_i^1, r_j^3\right) = \left(\frac{\hat{\psi}_y\left(r_i^1, r_j^3\right) - \hat{\psi}_x\left(r_i^1, r_j^3\right)}{\sqrt{\frac{-7 + 13\hat{v}^2_{y|x_i} - 8\hat{v}^4_{y|x_i}}{T_y} + \frac{-7 + 13\hat{\rho}^2_x - 8\hat{\rho}^4_x}{T_x}}} \right)^2 \qquad (7)$$

$$CK_1\left(i \to j; r_i^3, r_j^1\right) = \left(\frac{\hat{\psi}_y\left(r_i^3, r_j^1\right) - \hat{\psi}_x\left(r_i^3, r_j^1\right)}{\sqrt{\frac{-7 + 13\hat{v}^2_{y|x_i} - 8\hat{v}^4_{y|x_i}}{T_y} + \frac{-7 + 13\hat{\rho}^2_x - 8\hat{\rho}^4_x}{T_x}}} \right)^2 \qquad (8)$$

where $\hat{\psi}_y\left(r_i^m, r_j^n\right)$ and $\hat{\psi}_x\left(r_i^m, r_j^n\right)$ are defined by (5) and (6) respectively. Under the null hypothesis of no contagion, $CK_1\left(i \to j; r_i^1, r_j^2\right)$ and $CK_1\left(i \to j; r_i^2, r_j^1\right)$ are asymptotically distributed as χ^2_1.

Note that for both coskewness and cokurtosis tests, we follow Forbes and Rigobon (2002)'s assumption of no endogeneity between markets.

The Case-Resampling Bootstrap Method

Standard methods of contagion tests, like those described in Sub-sections The ForbesRigobon Test –The Cokurtosis Test, have a disadvantage that if the data set is not normally distributed, or its variance is not constant, then the result may not be accurate. To cope with this problem, Hatemi-J and Hacker (2005) developed an alternative test of contagion using the case-resampling bootstrap method. One advantage of this method is that it performs accurately when the assumption of normality andconstantvarianceisnotfulfilled (Hatemi-J and Roca 2010).

The details of the case-resampling bootstrap method are as follows (Hatemi-J and Hacker 2005):

To test contagion from market i to market j, the following regression model is set up:

$$r_{j,t} = \alpha_1 + \alpha_2 d_t + \beta_1 r_{i,t} + \beta_2 d_t r_{i,t} + \varepsilon_t; \qquad (9)$$

where $r_{i,t}$ and $r_{j,t}$ denote the continuously compounded daily return of markets i and j respectively ($t = 1, 2, \ldots, T$, $T = T_x + T_y$), and d_t is a dummy variable which gives a value of 1 if day t belongs to the crisis period, and 0 otherwise.

The null hypothesis of no contagion is:

$$H_0 : \beta_2 = 0 \qquad (10)$$

Normally, we conduct a two-tailed t-test to $\frac{\hat{\beta}_2}{\hat{\sigma}}$ ($\hat{\sigma}$ is the standard error of OLS estimator $\hat{\beta}_2$) to test the null hypothesis (10). However, for the case-resampling bootstrap method, the procedure is carried out as follows:

(i) For the T given observations of $\{r_{i,t}, r_{j,t}, d_t\}$ in (9), select T of them randomly with replacement.

(ii) For these T random observations selected in Step 1, compute the OLS estimator $\hat{\beta}_2$ of the coefficient β_2.

(iii) Repeat steps (i) and (ii) N times so that we obtain N estimations $\hat{\beta}^1_2; \hat{\beta}^2_2; \ldots; \hat{\beta}^N_2$.

(iv) The bootstrap estimator $\hat{\beta}^*_2$ of the coefficient β_2 is given by the median of all N estimations $\hat{\beta}^1_2; \hat{\beta}^2_2; \ldots; \hat{\beta}^N_2$, while its p-value is determined as follows:

(a) If $\hat{\beta}^*_2 \geq 0$, then p-value = (number of $\hat{\beta}^k_2 < 0$ + number of $\hat{\beta}^k_2 > 2\hat{\beta}^*_2$)/$N$.

(b) If $\hat{\beta}_2^* < 0$, then p-value = (number of $\hat{\beta}^k_2 > 0$ + number of $\hat{\beta}^k_2 < 2\hat{\beta}^*_2$)/N.

In this study, we use 1000 estimations to calculate the bootstrap estimator, i.e. N = 1 , 000.

Hatemi-J and Hacker (2005), Hatemi-J and Roca (2010) follow Forbes and Rigobon (2002)'s assumption of no endogeneity between markets, and assume a single source of contagion.

Our New Method

Hatemi-J and Hacker (2005), Hatemi-J and Roca (2010), Hatemi-J et al. (2014) all applied the case-resampling bootstrap method to the linear regression model (9), which is equivalent to the Chow test in Dungey et al. (2005). According to Dungey et al. (2005), the Chow test is an alternative formation of the ForbesRigobon test, which is a 2nd ordered moment test based on correlation. However, according to Fry et al. (2010) and Hui and Chan (2014), correlation is sometimes insufficient to reflect the whole pattern of contagion. If we increase the order of moments of the contagion test, additional channels of contagion may be detected. In this study, we apply the coskewness test and cokurtosis test. However, since these two tests do not work well on data which are not normally distributed or their variance is not constant, instead of calculating the test statistics (3), (4), (7) and (8) directly, we estimate the test statistics by the case-resampling bootstrap method. Thus we can obtain a more precise pattern of contagion as well as deal with data with a non-normal distribution or varying volatility.

Since the test statistics (3), (4), (7) and (8) are non-negative, before conducting the case-resampling bootstrap method, we define the following test statistics first:

¼ ψ^y r1i ;r2j −ψ^x r1i ;r2j ð Þ

csIi→j;r1i s

;r2jffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiff

iffi4v^y x2j i þ þ 4 2 þ 11

2 ρ^x 2

Ty Tx

¼ ψ^y r2i ;r1j −ψ^x r2i ;r1j ð Þ

cs1 s

i→j;ri2;r1jffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiff
iffiffiffiffi4v^y x2j i þ þ 2 þ 12

2 4ρ^x 2

Ty Tx

ψ^y ri1;r3j −ψ^x r1i;r3j

ck i→j;r ;r ¼ −8v^ 2 7 ð13Þ

1 1i 3j

t Ty Tx

ψ^y 3i ;r1j −ψ^x 3i ;r1j

uuvffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffif
fiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffif
fiffi2 7 þ 13v^2yxjiyx4ji þ þ 13ρ^x2−8ρ^x4ffi

u
t Ty þ Tx

We have the following relationships:

$$CS_1 i \rightarrow j; r^1_i ; r^2_j = cs_1 i \rightarrow j; r^1_i ; r^2_j{}^2 \quad (15)$$

$$CS_1 i \rightarrow j; r^2_i ; r^1_j = cs_1 i \rightarrow j; r^2_i ; r^1_j{}^2 \quad (16)$$

$$CK_1\left(i \to j; r^1_i; r^2_j\right) = ck_1\left(i \to j; r^1_i; r^2_j\right)^2 \quad (17)$$

$$CK_1\left(i \to j; r^2_i; r^1_j\right) = ck_1\left(i \to j; r^2_i; r^1_j\right)^2 \quad (18)$$

ck1i→j;r3i;r1j ¼

uvffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffi

ffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffiffi

ffi2 7 þ 13v^2y xj i −8v^4y xj i 2 7 þ 13ρ^2x−8ρ^4xffi ð14Þ

For each of the test statistics (11) – (14), we conduct the case-resampling bootstrap procedures (i) – (iv) in The Case-Resampling Bootstrap Method Sub-section. We repeat steps (i) and (ii) 1000 times (N = 1 , 000) to obtain the bootstrap estimators $cs^*_1(i \to j; r^1_i; r^2_j)$, $cs^*_1(i \to j; r^2_i; r^1_j)$, $ck^*_1(i \to j; r^1_i; r^2_j)$ and $ck^*_1(i \to j; r^2_i; r^1_j)$. Note that for each time we calculate the statistics (11) – (14) in step (ii), we have to adjust the sample size of the crisis period T_y (and hence $T_x = T - T_y$) so that $T_y = \sum_{t=1}^{T} d_t$. From Eqs. (15) – (18), the bootstrap estimators of the coskewness and cokurtosis statistics are:

$$CS_1(i \to j; r_i^1, r_j^2) = cs_1(i \to j; r_i^1, r_j^2)^2 \quad (19)$$

$$CS_1(i \to j; r_i^2, r_j^1) = cs_1(i \to j; r_i^2, r_j^1)^2 \quad (20)$$

$$CK_1(i \to j; r_i^1, r_j^2) = ck_1(i \to j; r_i^1, r_j^2)^2 \quad (21)$$

$$CK_1(i \to j; r_i^2, r_j^1) = ck_1(i \to j; r_i^2, r_j^1)^2 \quad (22)$$

As in the coskewness and cokurtosis tests, we follow Forbes and Rigobon (2002)'s assumption of no endogeneity between markets.

Data

We choose three economies. For each of the three economies, we select one general equity index and one securitized real estate index, making up a total of six equity indices. China, the expected source of contagion in the Chinese financial crisis, is first chosen. Hong Kong, being a Special Administrative Region (SAR) of China, has a close economic tie with China, and Hong Kong Stock Exchange is the 3rd largest stock exchange in the world in terms of market cap, so Hong Kong is chosen, too. Finally, we choose the US, which is the largest economy in the world, and its New York Stock Exchange is the largest stock exchange in the world in terms of market cap. Since the US makes up about one-third of the world's total market cap, it can reflect the global financial market to some extent. By examining the degree of significance of contagion from China to the US, we can see whether the contagion has spread worldwide during the Chinese financial crisis. Table 1 shows the indices selected from Bloomberg:

Note that the code in the bracket next to the index indicates the Bloomberg code of that index. The three general equity indices consist of the most frequently traded securities in the corresponding economies, and are widely accepted as benchmarks of performance of equity markets of the corresponding economies. The three securitized real estate indices are comprised of equities of the largest listed real estate companies of the corresponding economies, and hence are representative. Therefore, they can truly reflect the performance of the overall real estate markets of the corresponding economies. All indices are converted to US dollar to make them compatible.

The whole period of observation is January 2, 2012 – January 23, 2016, a total of 1060 observations. We divide the timeline into pre-crisis and crisis periods. Usually, the presence of a speculative attack associated with stock market turmoil is chosen as the criterion to determine the crisis period. The Shanghai Composite Index recorded a historical high of 5166.35 on June 12, 2015. On the following day, which was a nontrading Saturday, the China Securities Regulatory Commission launched a series of measures to curb the overheated stock market, triggering a sharp fall of the A-shares on

Table 1 The equity indices we choose

	General equity index	Securitized real estate index
China	Shnaghai Stock Exchange Composite Index (SHCOMP)	Shanghai Stock Exchange Property Index (SHPROP)
Hong Kong	Hang Seng Index (HSI)	Hang Seng Property Index (HSP)
US	S&P 500 Index (SPX)	S&P 500 Real Estate Industry Group Index GICS Level 2 (S5REAL)

the next trading day (June 15, 2015). Hence the pre-crisis and crisis periods are set as follows:

Pre-crisis period: January 2, 2012 – June 12, 2015 (900 observations). Crisis period: June 15, 2015 – January 23, 2016 (160 observations).

Results

Descriptive Statistics

We obtain the data of the six equity indices over the period of observation. The trends of the six indices are shown in the following figures (Figs.1,2 and 3).

From the above figures, the six indices are on a rising trend during the pre-crisis period. During the crisis period, the indices SHCOMP, SHPROP, HSI and HSP fall sharply by about 40 %. However, during the same period, SPX Index drops just mildly, while S5REAL Index just fluctuates up and down without a clear trend. Hence we suspect that there is contagion from SHCOMP to the indices SHPROP, HSI and HSP, but not to the indices SPX and S5REAL.

The mean and standard deviation of the continuously compounded daily returns of the indices during the pre-crisis and crisis periods are shown in the following table:

From Table 2, the average returns of all the six indices are lower in the crisis period than in the pre-crisis period. The standard deviations of the daily returns of all six indices also increase during the crisis period, i.e., the indices become more volatile.

To test whether the standard deviations of the daily returns of all six indices are significantly higher in the crisis period than in the pre-crisis period, we compute the

95 % confidence intervals for the sample variance of the daily returns in the pre-crisis and crisis periods of the six indices by Wessa (2016) as follows:

From Table 3, there is no overlapping between the 95 % confidence intervals for the sample variance of the daily returns in the pre-crisis and crisis periods for all six indices, so at 5 % significance level, the variance (and hence standard deviation) is

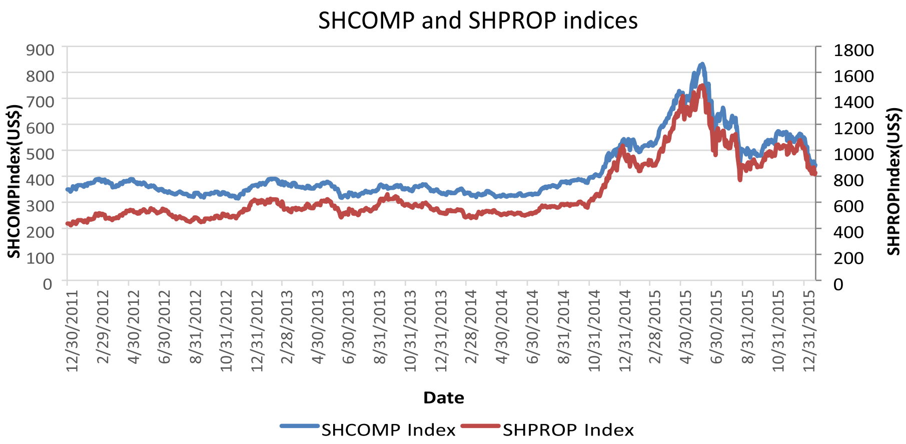

Fig. 1 SHCOMP and SHPROP indices

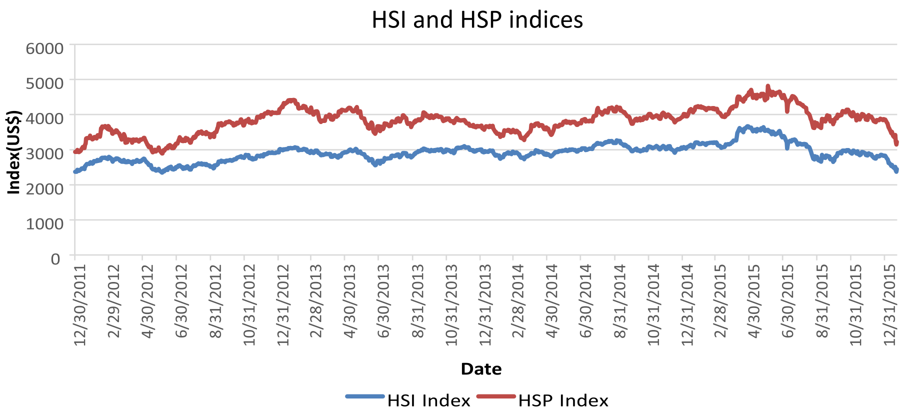

Fig. 2 HSI and HSP indices

significantly higher in the crisis period than in the pre-crisis period. This justifies the division of the whole period into pre-crisis and crisis periods.

Next, we use the software Minitab 17 to perform the Anderson-Darling test to test for normality of the data. The result of the normality test is shown in the following table:

Table 4 shows that for all the six indices, the p-values of the normality test are smaller than 0.005 (i.e. the Anderson-Darling test is significant at 0.5 % level), showing that the null hypothesis of normality is strongly rejected. Hence the standard tests for contagion may not work well in our case.

Results and Analysis

Here we test contagion among the six indices during the period January 2, 2012 – January 23, 2016. The following six methods are applied:

1) OLS regression (see The Case-Resampling Bootstrap Method Sub-section)

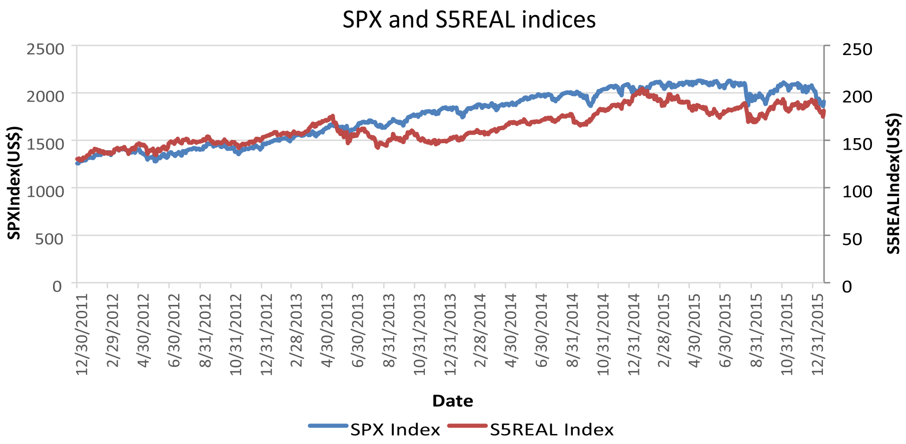

Fig. 3 SPX and S5REAL indices

Table 2 Descriptive statistics of the indices

Index	SHCOMP	HSI	SPX	SHPROP	HSP	S5REAL
Mean (pre-crisis period)	0.0965 %	0.0437 %	0.0567 %	0.1371 %	0.0511 %	0.0352 %
Standard deviation (pre-crisis period)	0.0122	0.0095	0.0073	0.0183	0.0118	0.0086
Mean (crisis period)	-0.3937 %	-0.2266 %	-0.0585 %	-0.3710 %	-0.2293 %	0.0085 %
Standard deviation (crisis period)	0.0282	0.0152	0.0113	0.0353	0.0159	0.0115

2) Coskewness test (see The Cokurtosis Test Sub-section)
3) Cokurtosis test (see The Cokurtosis Test Sub-section)
4) Case-resampling bootstrap method (based on OLS regression) (see The CaseResampling Bootstrap Method Sub-section)
5) Case-resampling bootstrap method (based on coskewness test) (see Our New Method Sub-section)
6) Case-resampling bootstrap method (based on cokurtosis test) (see Our New Method Sub-section).

Since we follow Forbes and Rigobon (2002)'s assumption of no endogeneity between markets, we have to identify the source of contagion first. The Chinese financial crisis began in June 2015 when China's stock market started to fall sharply. The crisis then spread to Hong Kong and other parts of the world later. Therefore, the source of contagion is China's equity market. Hence we determine Shanghai Composite Index (SHCOMP) to be the unique source, while the other five indices are identified as recipients.

We apply the six tests described above on the continuously compounded daily returns of the indices on each day during the period of observation. For the caseresampling bootstrap methods, we generate 1000 simulations by Minitab 17 to calculate the bootstrap estimators. The results are shown in the following tables:

The p-values in Tables 5 and 6 indicate the significance of the corresponding test statistics (or bootstrap estimators). If a particular p-value is smaller than a certain threshold level (usually 0.05, which is adopted in this study), this indicates that there is significant evidence of contagion from SHCOMP to the corresponding recipient at that threshold level. A smaller p-value indicates that the corresponding test statistic or bootstrap estimator is more significant. From Tables 4 and 5, the standard methods and the case-resampling bootstrap methods give similar values of the estimators of the

Table 3 95 % confidence intervals for the sample variance of the daily returns in the pre-crisis and crisis periods of the six indices

	SHCOMP	HSI	SPX	SHPROP	HSP	S5REAL

Table 4 Results of the Anderson-Darling test

Index	SHCOMP	HSI	SPX	SHPROP	HSP	S5REAL
p-value	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Pre-crisis period	(0.000135, 0.000163)	(0.000083, 0.000100)	(0.000049, 0.000058)	(0.000305, 0.000367)	(0.000128, 0.000154)	(0.000068, 0.000082)
Crisis period	(0.000648, 0.001007)	(0.000189, 0.000293)	(0.000105, 0.000163)	(0.001021, 0.001587)	(0.000207, 0.000321)	(0.000108, 0.000167)

coefficients/statistics. However, the standard methods show more significant evidence of contagion than the case-resampling bootstrap methods do. Using the OLS regression method, at 5 % significance level, there is significant evidence of contagion from SHCOMP to HSI and SPX, but insignificant evidence of contagion for the other three recipients. The coskewness test shows significant evidence of contagion at 5 % significance level in half of the cases. The cokurtosis test can detect even more additional channels of contagion, showing significant evidence of contagion at 5 % level in 8 of the total of 10 cases. In particular, the $CK_1 i \rightarrow j; r^1_i ; r^2_j$ statistic shows that there is significant evidence of contagion from SHCOMP to all the five recipients at even 0.1 % level.

However, the case-resampling bootstrap methods show less significant evidence of contagion. For the case-resampling bootstrap method based on OLS regression, at 5 % significance level, significant evidence of contagion is found from SHCOMP to and SPX only. Using our new method of combining the case-resampling bootstrap method with the coskewness test, the evidence of contagion is even insignificance at 5 % level for all cases. Additional channels of contagion are detected when the case-resampling bootstrap method is applied on the cokurtosis test, with the bootstrap estimator CK^*_1

$i \rightarrow j; r^1_i ; r^2_j$ showing significant evidence of contagion from SHCOMP to both HSI

Table 5 Results using the standard methods

Recipient	HSI	SPX	SHPROP	HSP	S5REAL
β_2	-2.5202	3.1164	-0.0638	-1.3747	0.2732
p-value	0.0119	0.0019	0.9491	0.1695	0.7847
$cs_1(i \rightarrow j; r_i^1, r_j^2)$	-1.9901	-2.7065	-1.2886	-0.8637	-3.1459
$CS_1(i \rightarrow j; r_i^1, r_j^2)$	3.9603	7.3249	1.6605	0.7459	9.8967

p-value	0.0466	0.0068	0.1975	0.3878	0.0017
$cs_1(i \rightarrow j; r_i^2, r_j^1)$	-1.6116	-2.4455	-1.5049	-1.3053	-3.5530
$CS_1(i \rightarrow j; r_i^2, r_j^1)$	2.5972	5.9807	2.2646	1.7037	12.6236
p-value	0.1071	0.0145	0.1324	0.1918	0.0004
$ck_1(i \rightarrow j; r_i^1, r_j^3)$	5.1822	3.3340	-3.9251	7.0101	4.1042
$CK_1(i \rightarrow j; r_i^1, r_j^3)$	26.8552	11.1155	15.4062	49.1414	16.8447
p-value	2.19×10^{-7}	0.0009	8.67×10^{-5}	2.38×10^{-12}	4.06×10^{-5}
$ck_1(i \rightarrow j; r_i^3, r_j^1)$	-0.5268	3.1537	-6.0184	0.8445	3.2625
$CK_1(i \rightarrow j; r_i^3, r_j^1)$	0.2775	9.9459	36.2215	0.7132	10.6441
p-value	0.5984	0.0016	1.76×10^{-9}	0.3984	0.0011

Table 6 Results using the case-resampling bootstrap methods

Recipient	HSI	SPX	SHPROP	HSP	S5REAL
β^*_2	-2.1938	3.0633	-0.0106	-1.1249	0.2792
p-value	0.133	0.019	0.994	0.358	0.848
$cs_1^*(i \rightarrow j; r_{i1}, r_{j2})$	-1.6408	-2.5495	-1.3103	-0.5972	-2.6116
$CS_1^*(i \rightarrow j; r_{i1}, r_{j2})$	2.6924	6.5000	1.7169	0.3567	6.8206
p-value	0.373	0.128	0.435	0.769	0.283
$cs_1^*(i \rightarrow j; r_{i2}, r_{j1})$	-1.3973	-2.3466	-1.5722	-0.9774	-3.2078
$CS_1^*(i \rightarrow j; r_{i2}, r_{j1})$	1.9525	5.5067	2.4719	0.9553	10.2899
p-value	0.431	0.138	0.407	0.559	0.085
$ck_1^*(i \rightarrow j; r_{i1}, r_{j3})$	4.1982	3.0827	-3.7031	5.7592	3.4985
$CK_1^*(i \rightarrow j; r_{i1}, r_{j3})$	17.6248	9.5030	13.7131	33.1678	12.2398
p-value	0.007	0.082	0.141	0.000	0.351
$ck_1^*(i \rightarrow j; r_{i3}, r_{j1})$	-0.7381	2.9765	-5.5877	0.4837	2.8560
$CK_1^*(i \rightarrow j; r_{i3}, r_{j1})$	0.5447	8.8594	31.2225	0.2340	8.1565
p-value	0.707	0.032	0.114	0.759	0.101

and HSP at 5 % level, while $CK^*_1 i \rightarrow j; r^2_i; r^1_j$ shows significant evidence of contagion from SHCOMP to SPX at the same level, yet the overall degree of significance of contagion is still lower than that using the standard cokurtosis test.

Comparing the results using the standard methods and the case-resampling bootstrap methods, we can see that the case-resampling bootstrap methods show larger p-values and hence less significant evidence of contagion than the standard methods do. This is contrary to Hatemi-J and Hacker (2005)'s result that the case-resampling bootstrap method shows much more significant evidence of contagion than OLS regression does. On the other hand, Hatemi-J and Roca (2010) showed no significantevidence of contagion from the US to UK, Japan and Australia during the sub-prime crisis (Hatemi-J and Roca (2010) applied the caseresampling bootstrap method only, but did not use OLS regression). The main reason for the discrepancies between the results is that the observations are selected randomly from the given sample in the case-resampling bootstrap method (Hui and Chan 2013). This study showsthattheresultthatstandardmethodsshowingsignificantevidenceofcontagionat5% level for most cases is, in fact, an illusion due to non-normally distributed data. The caseresampling bootstrap method gives a more accurate result.

In particular, from our results, the case-resampling bootstrap method reduces the effect of contagion by an even larger extent when applied on the coskewness and cokurtosis tests. However, when the case-resampling bootstrap method is applied on the cokurtosis test, additional channels of contagion can still be found when compared with the case-resampling bootstrap method applied on OLS or the coskewness test. This shows the advantage of the cokurtosis test. Hui and Chan (2014) found that the cokurtosis test can detect additional channels of contagion, thereby reflect a more precise pattern of contagion. This study shows that the case-resampling bootstrap method based on the cokurtosis test can preserve this advantage of the cokurtosis test. In this study, the case-resampling bootstrap methods applied on OLS and the coskewness test show insignificant evidence of contagion from China′s general equity market to Hong Kong's general equity and securitized real estate market at 5 % level. However, the same channels of contagion are found to be highly significant at 5 % level when the case-resampling bootstrap method is applied on the cokurtosis test. This result is closer to the real situation that Hong Kong's stock market has fallen together with the Chinese stock market since mid-2015. This may be a result of the Shanghai-Hong Kong Stock Connect which was launched on November 17, 2014, allowing Mainland investors to trade certain stocks listed in Hong Kong (mainly large cap and mid cap stocks). Hong Kong investors can also trade certain stocks listed on the Shanghai Stcok Exchange (SSE). Thus Hong Kong and Shanghai's stock markets have become more interrelated since then.

For both standard and case-resampling bootstrap methods, the overall effect of contagion is greater on the general equity markets than on the securitized real estate markets. This can be explained by two reasons. Firstly, real estate can serve as both consumption goods and an investment tool. The consumption feature of real estate moderates the contagion effect. Therefore, it is more difficult for shocks to transmit within equity markets than within real estate markets (Hui and Chan 2014). Secondly, the three general equity indices are the most representative stock indices of the corresponding three economies. They have larger turnovers and there are a lot of funds (especially ETFs) tracking their performances. On the other hand, there are fewer funds tracking the performances of the three securitized real estate indices and the turnover is relatively smaller. Hence the effect of contagion is smaller within the securitized real estate markets.

Conclusion

In this study, we incorporate the case-resampling bootstrap method with the coskewness and cokurtosis tests to investigate contagion across general equity and securitized real estate markets of China, Hong Kong and the US during the Chinese financial crisis. The main results are shown as follows:

1) The case-resampling bootstrap methods show less significant evidence of contagion than the standard methods do, reflecting a more precise pattern of contagion under non-normally distributed data.
2) No additional channels of contagion can be found when the case-resampling bootstrap method is applied on the coskewness test, but when the caseresampling bootstrap method is applied on the cokurtosis test, additional channels of contagion are detected (compared with the case-resampling bootstrap method applied on the linear regression model). In particular, there is highly significant evidence of contagion from China's general equity market to Hong Kong's general equity and securitized real estate market at 5 % level.
3) For both standard and case-resampling bootstrap methods, the overall effect of contagion is greater on the general equity markets than on the securitized real estate markets.

Previous studies like Hatemi-J and Hacker (2005), Hatemi-J and Roca (2010) and Hatemi-J et al. (2014) also applied the case-resampling bootstrap method to test contagion, but all of them applied the method on the OLS regression model only. This study is the first to combine the case-resampling bootstrap method with the coskewness and cokurtosis tests. The aim of constructing this method is to detect additional channels of contagion (compared with the case-resampling bootstrap method applied on the linear regression model) as well as cope with data which are not normally distributed or their variance is not constant. However, in reality, the case-resampling bootstrap method applied on the coskewness test fails to detect any additional channels of contagion, but additional channels of contagion are detected when the caseresampling bootstrap method is applied on the cokurtosis test (compared with the case-resampling bootstrap method applied on the linear regression model). This reflects the advantage of the cokurtosis test that when using the case-resampling bootstrap method to estimate the statistics of the cokurtosis test, additional channels of contagion can be found when compared with the case-resampling bootstrap method applied on contagion tests of lower ordered moments. Therefore, our new method can reflect a more precise pattern of contagion under non-normally distributed data.

Although the case-resampling bootstrap methods show less significant evidence of contagion than the standard methods do, this may be a result that China's stock market is not totally free. Subject to government manipulation, China's financial market exhibits asymmetric information and lack of rational expectations. Hence it is not a complete market. This may distort the contagion pattern. According to the World Bank's restrictive definition, contagion is the transmission of shocks to other countries or the cross-country correlation, beyond any fundamental link among the countries and beyond common shocks. This definition is rather restrictive. Although contagion is insignificant, there may still be comovement or cointegration between the markets. The downward movement of China and Hong Kong's general equity and securitized real estate indices during the crisis period may better be explained by comovement or cointegration. Therefore, it is wrong to deduce from our results that invest in Chinese stocks due to potential diversification. In fact, the case-resampling bootstrap method based on the cokurtosis test shows significant evidence of contagion from China's general equity market to Hong Kong's general equity and securitized real estate markets (for the estimator $CK^{*}{}_{1}i \rightarrow j; r^{1}{}_{i}; r^{2}{}_{j}$) as well as the US's general equity market

(for the estimator $CK^{*}{}_{1}i \rightarrow j; r^{2}{}_{i}; r^{1}{}_{j}$), so contagion really exists between the markets.

One major implication of our results is that investors should reallocate their portfolio appropriately during financial crises in order to reduce their risks. For example, our results show that the overall effect of contagion is greater on the general equity markets than on the securitized real estate markets (see Results Section), so it is advisable for investors to include real estate in their portfolio in order to reduce risk. On the other hand, holding Mainland and Hong Kong stocks together may not result in effective diversification due to increasing interrelation between the two markets. Another implication is that regulators and policy makers should monitor the financial markets more effectively to mitigate the impact of financial crises. For example, from our results, the case-resampling bootstrap method based on the cokurtosis test shows significant evidence of contagion from China's general equity market to Hong Kong's general equity and securitized real estate markets (see Results Section). The Hong Kong Government should be aware that the Chinese financial crisis may affect Hong Kong's economy and take appropriate measures. Hong Kong's year-to-year economic growth rate has slowed down to 0.8 % in 2016 Q1, the lowest growth rate since 2012 Q1, reflecting that the Chinese financial crisis has weakened Hong Kong's economy. In order to cope with the further slowdown of the economy, Financial Secretary John Tsang Chun-wah announced a series of relief measures in the 2016–17 Budget. The most representative real estate index in Hong Kong, the CCL Index has also fell from the historical high of 146.45 in late September 2015 to 127.46 in late March 2016, which is a 13 % decrease. This indicates that the financial crisis has spread to the real estate market. In order to prevent the housing prices from falling too much, the government should review its measures to curb speculation on the housing market such as Buyer Stamp Duty (BSD) and Special Stamp Duty (SSD).

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