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Are international securitized property markets converging or diverging?

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a b s t r a c t

This study establishes a new framework which combines the recursive model with the Fractionally Integrated Vector Error Correction Model (FIVECM) to investigate the cointegration relationship among 9 securitized real estate indices, which are divided into three groups: Asian, European and North American groups. Our new combined framework has the advantage of reflecting the changes in cointegration dynamics over a period of time instead of a single result for the whole period. The results show that the three groups of markets follow a similar cointegration trend: the cointegration relationship gradually increases before the global financial crisis, reaches a peak during the crisis, and dies down gradually after the crisis. However, cointegration among Asian and European countries occurs at a much later time than cointegration among North American countries does, showing that North America is the source of cointegration, while Asia and Europe are the recipients. This study has important implications to investors and related authorities that investors can adjust their portfolio according to the test results to reduce their risk, while related authorities can take appropriate measures to stabilize the economy and mitigate the effects of financial crises.

Keywords:
Recursive approach
Fractional cointegration
Securitized real estate markets
Financial crisis

1. Introduction

For long, the real estate market has not only been the mainstay of whole economy [1], but also been an essential component of worldwide institutional investors' portfolios, because of its low correlation with other asset classes across national boundaries. As a major investment asset, real estate has a strong wealth effect on economic development [2]. Direct real estate investment (by purchasing actual physical property) was used to be the only choice for investors to engage in real estate investment. Nowadays, in the long run, the real estate markets of several major economies are increasingly correlated due to high liquidity of capital and financing. Such phenomenon induces negative effects on investors' portfolio returns. In contrast, the short run co-movements among various real estate markets are still insignificant [3]. In other words, diversified strategy is beneficial to direct real estate investment in the short-run. However, high costs of acquisition and management of property, together with illiquidity and stringent policies in different countries, make overseas direct investment difficult or even impossible for small investors.

Since 1960s, the emergence of Real Estate Investment Trusts (REITs) in the US provides an alternative investment tool for investors. It provides global investors an easy access to real estate markets. Since the securities are widely recognized among US investors, during the last two decades, over 20 countries in the world have established REIT regimes, while other countries have introduced REIT-like structures. The development of REITs has enlightened increasing investments in global real estate securities. Securitized property has been widely accepted as a class which deserves permanent allocation in multiclass portfolio [4] due to its dramatic growth and risk adjustment. However, investments and developments in real estate markets are very long-term in nature and possess two important characteristics, namely leverage and illiquidity. These two characteristics make most investors under-diversified, along with constraints of high transaction costs, holding constraints, or specific investment objectives [5].

Due to the growing importance of securitized property markets, vast studies have been conducted on this field. In particular, two methods are adopted by some previous studies. The first is the recursive model developed by Hansen and Johansen [6], and then applied by Rangvid [7] and Yunus [8] to investigate the cointegration relationship of stock markets and securitized property markets respectively. The second is the Fractionally Integrated Vector Error Correction Model (FIVECM) adopted by Liow and Yang [9]. This method is an extension of the Fractionally Integrated Error Correction Model (FIECM) (adopted by Serrano and Hoesli [10]) to multiple dimensions. FIECM and FIVECM have the advantage over Error Correction Model (ECM) and Vector Error Correction Model (VECM) in the way that FIECM and FIVECM incorporate a long history of past cointegration residuals, so they can incorporate long memory (long-range dependence) and short memory (shortrange dependence) [9,10]. However, previous studies never applied both methods together. This study fills in this gap and contributes to the existing literature by establishing a new framework which combines recursive cointegration with FIVECM. Under our new combined framework, we estimate the fractional cointegration ranks and conduct the cointegration trace test based on a gradually enlarging of the length of the window. This technique can reflect the changes in cointegration dynamics during a period of time instead of a single result for the whole period. Therefore, we can depict the time-varying dynamics of the cointegration

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trace test and the estimated parameter of fractional cointegration. This can show how the cointegration pattern varies over time. We apply this new framework to investigate cointegration among 9 securitized real estate markets during the period 2000–2011. We divide the markets into three groups according to the continent each market belongs to: Asian, European and North American groups. By comparing the trends in the cointegration patterns of the three groups of markets over the period of time, we can see which group of markets is the source of cointegration, and which groups are the recipients.

The paper proceeds as follows: Section 2 review previous studies on related topics. Section 3 describes our methodology. Section 4 describes the data chosen. Section 5 displays the empirical results. Finally, we draw a conclusion in Section 6.

2. Literature review

Dynamics of property stocks in terms of return and volatility have evoked the scholars' interests recently. Bond et al. [11] 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. [12] 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. Yunus and Swanson [13] examined long-run relationships and short-run causal linkages among the public property markets of the Asia-Pacific region and the US from January 2000 to March 2006. Long-term results indicated that the markets of Hong Kong and Japan provide the greater diversification benefits from the perspective of US investor, while short-run causality tests showed no significant lead–lag relationships between the property markets of the US and the Asia-Pacific region. Liow [14] examined 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 during the most recent period. He found a stronger interdependence among Asian markets in both long- and short-run. Furthermore, this interdependence seemed to be on a rising trend recently. Gallo and Zhang [15] believed that global property markets are inter-regionally independent but intra-regionally cointegrated. In addition, they found that North America and Asia-Pacific regions still have some signs of diversification for some time in the future. Hui and Chen [16] applied the multivariate cumulative sum (CUSUM) test and the renormalized partial directed coherence (PDC) method to examine the structural causality change of securitized real estate indices of five Asian countries and regions. The result showed emergence of regional influence of the Chinese securitized real estate market on the causality structure of the five markets. Fry et al. [17] applied the coskewness test to examine contagion across global real estate markets during the Asian and US subprime crises. They found only little evidence of contagion during the US subprime crisis. Hui and Chan [18] applied the cokurtosis test to investigate contagion across equity and securitized real estate markets of Hong Kong, US and UK during the global financial crisis. They found that the cokurtosis test showed a highly significant evidence of contagion between the equity and real estate markets in both directions. In particular, the contagion between US's equity and real estate markets was the most significant.

Cointegration test is one of the most commonly used methods to study securitized property markets. This method was first developed by Johansen and Juselius [19]. Osterwald-Lenum [20] provided a detailed distribution of the statistic through simulation. Hansen and Johansen [6] developed several recursive estimation models for testing cointegration, which were later applied by Rangvid [7] and Yunus [8]. Rangvid [7] analyzed the degree of convergence among three major European stock markets within the framework of a recursive common stochastic trends analysis. He found that the degree of convergence among European stock markets had been increasing during the recent two decades. Yunus [8] examined the degree of interdependence among the securitized property markets of six major countries and the US during the period January 1990–August 2007. He concluded 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 [21] 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 found that due to co-integration between the markets, the benefits of diversification disappeared during the crises in both hedged and un-hedged cases. Yunus [22] tested dynamic interactions among securitized property markets, equity markets and key macroeconomic factors for ten developed counties. He found that each property market was co-integrated with its respective equity market and with key macroeconomic factors in the long run, and was also influenced by the overall economy in the short run. Meanwhile, the fractional approach has been broadly used to approximate the security market [23,24]. This approach has also been applied to the research on securitized real estate market. Okunev and Wilson [25] investigated the existence of co-integration between the REIT and the S&P 500 indices. The results showed that the equity and real estate markets were fractionally integrated. Serrano and Hoesli [10] applied the FIECM to examine the existence of long-run relationship between securitized real estate returns and three sets of variables representing factors driving securitized real estate returns. They found 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 [9], who applied the FIVECM to test cointegration between real estate markets of four Asian economies, suggested that there are long memory characteristics in the cointegration of securitized real estate market, stock market and major macro-economic factors.

The above summarizes previous studies on contagion/cointegration between real estate markets. Some like Yunus [8] adopted the recursive model, while some like Serrano and Hoesli [10] and Liow and Yang [9] applied the FIECM/FIVECM. However, none of the previous studies applied both methods at the same time. In order to fill in this gap, we combine the recursive model with the FIVECM. Hence instead of a single result of the cointegration trace test and the estimated parameter of fractional cointegration, we obtain these two parameters as variables varying with time, so we can see how the cointegration pattern changes over time.

3. Methodology

The primary purpose of this paper is to investigate the dynamic convergence of the interlinkage among the global securitized property markets. The basic method to fulfill the objective is the cointegration test. However, instead of using the ordinary multivariate cointegration test, we utilize the more general fractional cointegration test. With the advantage of relaxing the linearity assumption, the fractional cointegration test allows nonlinear equilibrium relationships between different markets. Hence more details can be provided by the more general degree of cointegration, namely $I(d)$, This method is firstly associated with recursive estimate technique. We estimate the degree of cointegration recursively as the sample size is gradually upgraded by a constant increment over time. The fractional cointegration d is estimated recursively by our tests.

If a non-stationary time series can be transformed into stationary one by dth order differencing, it is said to be integrated of order d and denoted by $I(d)$, where d belongs to the integer domain. If a linear combination of several non-stationary series comes to be stationary, the series are said to be cointegrated and expressed by the cointegration equation [26]. Such equation reveals the long-run equilibrium relationship among series, which would render implications for diversified strategy in portfolio choice of real estate investment. Firstly, the traditional cointegration regression is established in the following equation:

$$\sum_{i=1}^{p} \beta_i \ln M_{i,t} = z_t, \tag{1}$$

where M_i refers to the index of ith market in different category group so that it is the entry of $\boldsymbol{M}_t$. For the sake of convenience, we denote $m_i = \ln(M_i)$ and thus compose the $\boldsymbol{m}_t$. β_i refers to the corresponding cointegration parameter, where $i = 1, 2, 3 \ldots p$, and p depends on the specific number of sample market. z_t is the residual series. In this case, $\boldsymbol{m}_t$ is a set of $I(1)$ series to be cointegrated and innovation term z_t is $I(0)$. Consequence, for the sake of vector error correction model (VECM), we consider the preliminary model for the global securitized markets of real estate:

$$\Delta m_t = \alpha\beta' m_t + \sum_{l=1}^{G} \phi_l \Delta m_{t-l} + \varphi_0 + \varepsilon_t,$$

where $\Delta \boldsymbol{m}_t$ is the log-difference of the securitized property markets indices vector of order p, $\Delta \boldsymbol{m}_{t-l}$ is the log-difference of lagged set of the vector. α and β are the $p \times r$ matrices with rank r, denoting the weighted coefficient of cointegration equations and the cointegration coefficient respectively.

Refer back to the univariate process, Hosking [27] discussed the fractional differencing on the integration of series such that the process is $I(d)$ with $d < 1$. The fractional parameter $d < 1/2$ indicates the nonlinearity of integration. Following Hosking [27], the interpretation of the degree is shown as follows: When $-1/2 < d < 1/2$, the process is both stationary and invertible. In particular, when $0 < d < 1/2$, the process has long-run memory and when $-1/2 < d < 0$, the process has short-run memory. The dependent range of process can be characterized by the auto-correlation function (ACF) and partial auto-correlation function (PACF). Precisely speaking, ACF and PACF are negative with hyperbolic decay near zero in the case of short memory, and are positive with hyperbolic decay in the case of long memory. In addition, the process shows no long-run effect when $1/2 < d < 1$ and drifts away from equilibrium permanently when $d > 1$.

Furthermore, in the multivariate process, fractional cointegration inhibits a more detailed feature of long-run equilibrium between variables than traditional cointegration. It considers that the cointegrated process is $I(d)$, while z_t is integrated of $I(d-b)$ with $b > 0$. This relaxes the restriction of error term being $I(0)$ in ordinary cointegration. Therefore, such fractional cointegrated process can be performed in the following term:

$$\Delta^{d-b} \beta m_t \sim I(0),$$

where $\Delta = 1 - L$, and L is the lag operator.

The fractional differencing operator is defined by

$$\Delta^d = (1-L)^d = \frac{1}{\Gamma(-d)} \sum_{j=0}^{\infty} \frac{\Gamma(j-d) L^j}{\Gamma(j+1)},$$

where Γ denotes the gamma function. When $d = b = 1$, the cointegrated process reduces to a traditional cointegration.

To estimate the fractional cointegration parameter d, preliminary steps have to be done. Initially, the order of integration for each series have to be verified through a test of stationarity since all the series' order should be the same to perform cointegration analysis.

To address the issue, applying Augmented Dickey–Fuller (ADF) method, the unit root tests are employed to identify the integration order (d) for each time series.

Furthermore, following the estimation method developed by Geweke and Porter-Hudak [28], we perform a spectral regression:

$$\ln\left(I_u\left(\omega_j\right)\right) = a + (1-d)\ln\left(4\sin^2\left(\frac{\omega_j}{2}\right)\right) + \varepsilon_t, \qquad j = 1, 2, \ldots, n$$

where $I_u\left(\omega_j\right) = \frac{1}{2\pi T}\left|\sum_{t=1}^{T} \mathrm{e}^{\mathrm{i}t\omega}\left(z_t - \bar{z}\right)\right|^2$, and $\varepsilon_t = \ln\left(\frac{I_u(\omega_j)}{f_u(\omega_j)}\right)$.

$I_u(\omega_j)$ expresses the periodogram of z_t at frequency ω_j. ε_t is assumed to be i.i.d. with asymptotic zero mean and $\pi^2/6$ variance respectively, T is the number of observations and $n = T^{\mu}$ for $0 < \mu < 1$ is the number of low frequency ordinates used in the regression. = Geweke and Porter-Hudak [28] suggested to use μ = 0.55, 0.575 or 0.6. In this paper, we use μ = 0.575 (as suggested by Serrano and Hoesli [10]) in our estimation.

Finally, in contrast to the Fractionally Integrated Error Correction Model (FIECM) of single dimension in Ref. [10], we consider the advanced cointegration equation in the form of Fractionally Integrated Vector Error Correction Model (FIVECM). Following Lasak's framework [29], our new FIVECM can be shown as:

$$1m_t = \alpha\beta'\left(\Delta^{d} - \Delta\right)m_t + \sum_{l=1}^{G}\varphi_i 1m_{t-l} + \varphi_0 + \varepsilon_t, \tag{2}$$

where $\alpha\beta'\left(\Delta^{d} - \Delta\right)M_t$ is the fractional error correction (FEC) term and d is the fractional cointegration rank. Based on the FEC term, we can re-establish the Johansen test for Eq. (2) and report the trace test result. Furthermore, in order to investigate the dynamics of the cointegration, we can employ the recursive cointegration technique [6] suggested by Rangvid [7]. That is to say, we estimate the fractional cointegration ranks and conduct the cointegration trace test based on a gradually enlarging of the length of the window. The initial window consists of the first 300 data of the sample. After that, we add 2 or 3 data (depends on the sample group) to the window for each iteration step, make the estimation and test recursively, until the window is expanded to the whole sample. According to Rangvid [7], this technique can reflect the cointegration dynamics in a period of time instead of a single result for the whole period. Therefore, this approach is advanced of depicting the timevarying dynamics of parameter set and consistency of fractional cointegration in the recursive estimation. Furthermore, we also use this technique on the fractional cointegration parameter estimation to explore the dynamic length of dependent lag over the study period.

4. Data

We collect the data of 9 securitized real estate indices from Bloomberg over 2000–2011. We use weekly data as Yunus [8] did because in using daily data, subsequent (cointegration) test results may be a function of the worldwide response of shocks to major news/business events during the period of study [8]. However, if we use monthly or quarterly data, the sample size would be too small for a cointegration analysis and hence would affect the accuracy of our result. Therefore,

Table 1
Classification of the indices.

Group	HK	UK	US	CAN	FRA	GER	JP	NLD	SGP
Asian	Ď						Ď		Ď
European		Ď			Ď	Ď		Ď	
North American			Ď	Ď					

Note: The data are from Bloomberg base on FTSE Index.

Table 2
Descriptive statistics of the logarithm of the indices.

	HK	UK	US	CAN	FRA	GER	JP	NLD	SGP
Mean	2.146	3.379	3.211	3.141	3.342	2.918	1.196	3.213	2.725
Median	2.112	3.273	3.200	3.152	3.420	2.900	1.185	3.229	2.689
Maximum	2.516	3.801	3.499	3.441	3.774	3.281	1.573	3.533	3.127
Minimum	1.712	2.930	2.868	2.785	2.925	2.473	0.834	2.920	2.327
Std. Dev.	0.188	0.201	0.136	0.182	0.268	0.164	0.179	0.180	0.210
Skewness	−0.027	0.500	0.156	−0.114	−0.201	0.255	0.113	−0.107	0.184
Kurtosis	2.082	2.008	1.980	1.626	1.557	2.657	2.137	1.745	1.923

Jarque–Bera	21.154	48.819	28.349	47.998	55.412	9.412	19.951	40.220	32.139
Probability	0.000	0.000	0.000	0.000	0.000	0.009	0.000	0.000	0.000
Observations	1103	1103	1103	581	581	581	581	581	581

weekly data is more suitable. The exact period of observation is 7 January 2000–18 February 2011. We convert the indices into US dollars to make them compatible. All indices belong to the FTSE EPRA/NAREIT Real Estate Index Series, which incorporates REITs and stocks of real estate holding and development companies. They consist of the most heavily traded real estate securities in the corresponding economies, and can reflect the performances of listed real estate companies in those economies.

The 9 indices in Table 1 are categorized into three groups: Asian, European and North American groups.

5. Result

We first look at a glance of the descriptive statistics of the indices chosen in Section 4:

Table 2 shows the descriptive statistics of the logarithm (base 10) of the indices. From the table, Hong Kong, Canada, France and the Netherlands' indices are negatively skewed. The remaining five indices are positively skewed. The Jarque–Bera test for all indices are highly significant (significant at 1% level), indicating that the logarithms of all indices match the normal distribution very well.

Prior to the cointegration analysis, all the data are tested for stationarity. We take logarithm of the indices. For all series, the hypothesis of existence of unit root after Augmented Dickey–Fuller (ADF) tests cannot be rejected. Thus they are nonstationary. Instead, ADF tests indicate that all the returns (the first order difference) of the series are stationary, which is to say that, all the time series are $I(1)$ process. The results echo with some previous studies like Wilson and Zurbruegg [30] and Gerlach et al. [31].

To fully understand the dynamics of the global securitized property markets, we carry out recursive fractional cointegration tests on the three groups. For each group, in the recursive estimation, the width of the initial window is set to be 300 and the increment level is set to be 3 such that three data will be updated into the regression window of iteration. Our result is divided into two parts. In the first part, we plot the time path of the cointegration trace test over the period of observation. For each line $r = n$, where $n = 0, 1, 2, \ldots$, if the line rises above 1, this means that the null hypothesis of no cointegration of rank $n + 1$ is rejected. Otherwise the null hypothesis remains true. In the second part, we display the curve of the estimated parameter of fractional cointegration. According to Liow and Yang [9], the fractional parameter d indicates different characteristics of the process: if $-0.5 < d < 0$, the process is regarded as short memory; if $0 < d < 0.5$, the process shows a long memory pattern; if $0.5 < d < 1$, it is a mean reverting process; and if $d > 1$, the process will be inconsistent and a swift shock to the process will make it drift away from its long-run equilibrium permanently. The following shows the results of the cointegration test on the three groups.

5.1. Asian group

Figs. 1 and 2 demonstrate the statistics of trace test and fractional parameter of the Asian group respectively:

Fig. 1 shows a rising pattern of the lines before the global financial crisis, indicating increasing cointegration relationship among Asian countries. However, only the line representing $r = 0$ rises above the critical level of 1 during a very short period of time in early 2009, showing significant evidence of cointegration of rank 1. After that, the statistic drops, indicating that the cointegration relationship decreases after the financial crisis. Fig. 2 shows a decreasing trend in the fractional cointegration parameter followed by a sudden increase in 2009 Q4. This implies that long-run memory characteristic is in charge before

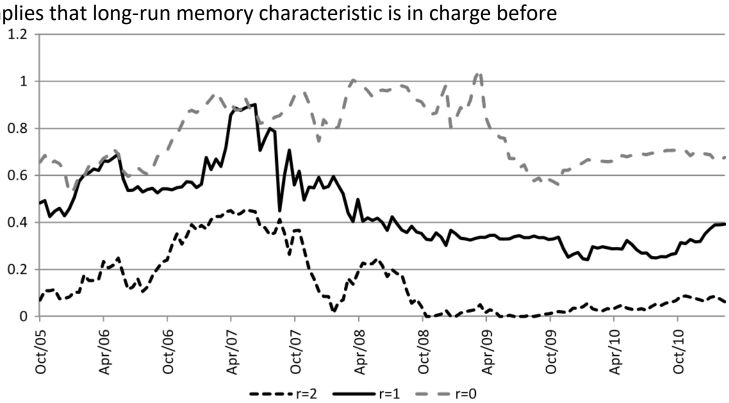

Fig. 1. Trace test for Asian group. *Note*: for the ease of interpretation, the test statistics in Fig. 1 have been scaled by the critical value of 90% level of significance. The part in the figure above 1 indicates that the cointegration relationship is significant at 90% level of significance.

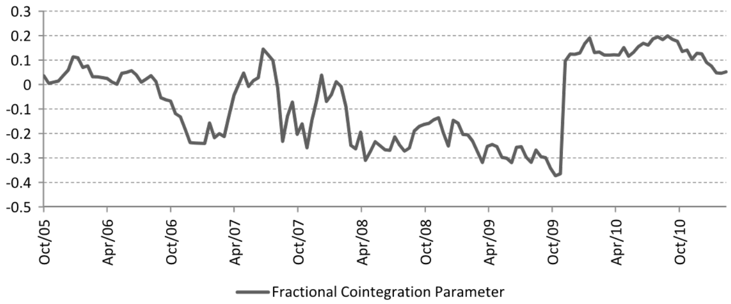

Fig. 2. Estimated parameter of fractional cointegration of Asian group.

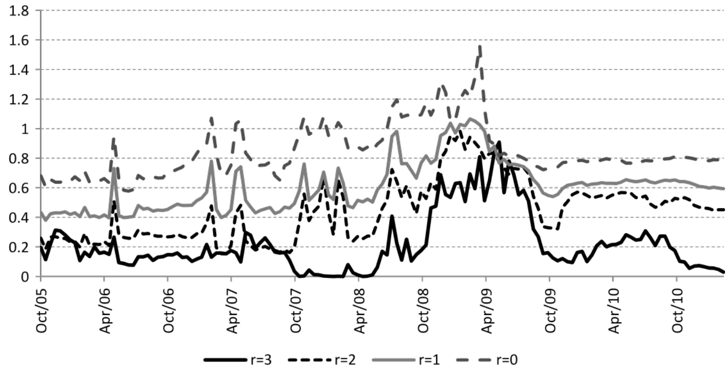

Fig. 3. Trace test for European group. *Note*: for the ease of interpretation, the test statistics in Fig. 1 have been scaled by the critical value of 90% level of significance. The part in the figure above 1 indicates that the cointegration relationship is significant at 90% level of significance.

2006 Q4. After that, short-run memory dominates until 2009 Q4 (long-run memory restores for a short time in mid-2007), when long-run memory returns.

5.2. European group

Figs. 3 and 4 show the time paths of trace test and fractional parameter of the European group respectively:

From Fig. 3, all the four lines are on a rising trend from late 2005 to early 2009, showing increasing cointegration relationship among European countries before and during the global financial crisis. In particular, the line representing $r = 0$ rises above the critical level of 1 in mid-2008 and then further surges sharply to a peak of about 1.6 in early 2009, indicating significant evidence of cointegration of rank 1, and the cointegration relationship is the strongest in early 2009. Note that the line representing $r = 0$ maintains above the critical level of 1 for nearly two years (mid-2008–early 2009), which is the longest among the three groups. Furthermore, the line representing $r = 1$ also surges above 1 during late 2008–early 2009, indicating significant evidence of cointegration of rank 2. Since 2009 Q2, the lines have fallen gradually, meaning that the cointegration relationship weakens after the crisis. From Fig. 4, the European group displays a typical

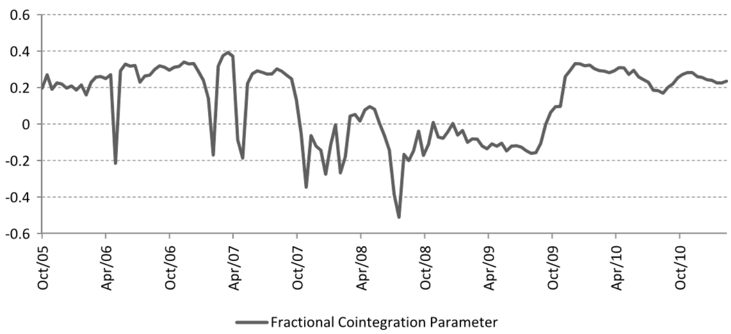

Fig. 4. Estimated parameter of fractional cointegration of European group.

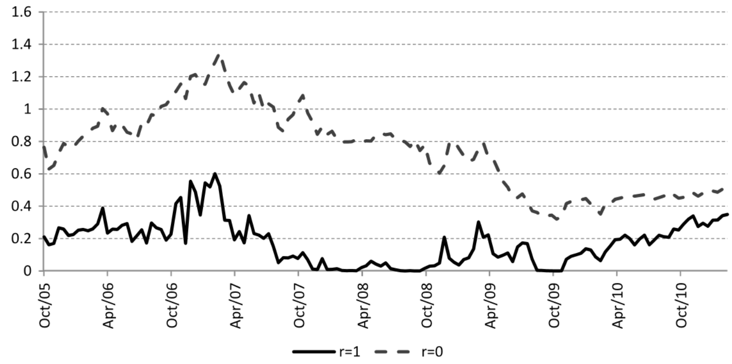

Fig. 5. Trace test for North American group. *Note*: for the ease of interpretation, the test statistics in Fig. 1 have been scaled by the critical value of 90% level of significance. The part in the figure above 1 indicates that the cointegration relationship is significant at 90% level of significance.

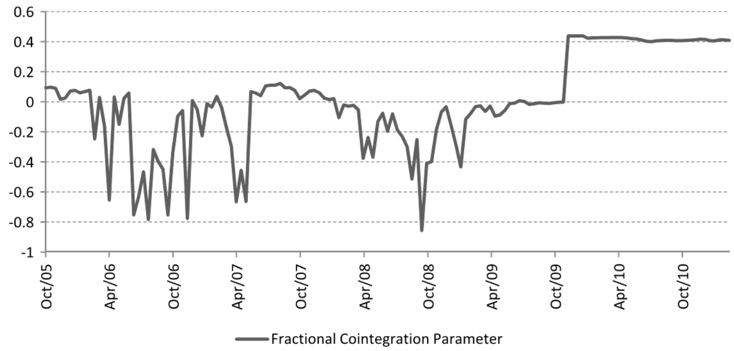

Fig. 6. Estimated parameter of fractional cointegration of north American group.

pattern which is substantially influenced by the global financial crisis in 2008: long-run memory dominates before 2007 Q4. The process switches to short-run characteristic thereafter, followed by a transition to long-run memory in late 2009.

5.3. North American group

Figs. 5 and 6 display the time paths of trace test and fractional parameter of the North American group respectively:

Similar to Figs. 1 and 3, Fig. 5 also depicts an increasing trend of the lines initially, suggesting that the two North American markets become increasingly convergent. However, the line representing $r = 0$ rises above the critical level of 1 during late 2006–mid-2007, and peaks at about 1.3 around early 2007. Both times are much earlier than those of the Asian and European groups. Since 2007 Q2, the lines decrease gradually and reach a trough in late 2009, indicating decreasing convergence between the two markets. After that, the lines rebound slightly. The time path of the fractional cointegration parameter in Fig. 6 indicates that the cointegration process is long-run memory initially. In early 2006, the process switches to short-run memory, which persists until 2009 Q4, after that long-run memory returns.

From the above figures, we can see that the three groups of markets exhibit similar results. From the time paths of trace test (Figs. 1, 3 and 5), the three groups of markets follow a similar cointegration trend: the cointegration relationship gradually increases before the global financial crisis, reaches a peak during the crisis, and dies down gradually after the crisis. The line representing $r = 0$ remains above the threshold level of 1 for a rather long period of time during the crisis except for the Asian Group, of which the line representing $r = 0$ rises above 1 in early 2009, but quickly falls below 1 afterwards. This shows that the Asian countries are the regions least affected by the global financial crisis. This result is expected as the global financial crisis was originated in the US, where the subprime crisis already emerged in 2007. The shock spread to Europe in early 2008, and then spread further to other parts of the world in September 2008, when Lehman Brothers went bankruptcy. Meanwhile, from the time paths of the estimated parameter of fractional cointegration (Figs. 2, 4 and 6), we can see that the fractional parameters of the Asian, European and North American groups follow a similar trend: the fractional parameters remain negative from mid-2008 to late 2009, and have rebounded to a positive level since October 2009. This suggests that short-run memory dominates the cointegration process during the global financial crisis, but long-run memory has restored since the recovery. We can see that when the economic condition is normal, the cointegration process consists mainly of long-run memory. However, when a financial crisis breaks out, the process would turn into short-run memory. Financial crises have the effect of shortening the length of cointegration dependence.

However, there are differences between the results. From the time paths of trace test, the line representing $r = 0$ peaks at different times for the three groups. For the North American group, the line representing $r = 0$ peaks in early 2007, which is much earlier than the peaking time of the line representing $r = 0$ for the Asian and Europeans groups, which is early 2009. This shows that the financial crisis affects different parts of the world at different times. The US is the center of shock of the financial crisis. The subprime crisis in the US, which is a preceding of the global financial crisis, already emerged in late 2006–early 2007. This explains why the line representing $r = 0$ rises above 1 around that time, showing significant evidence of cointegration between the two North American countries. North America is the source of cointegration. The shock spread to Europe and Asia in 2008. That is why the line representing $r = 0$ peaks at a much later time for the European and Asian groups. Europe and Asia are the recipients of cointegration. The time paths of the estimated parameter of fractional cointegration also show this difference. The fractional parameter of the North American group already falls below zero in early 2006, and drops further to nearly −0.8 in mid-2006, indicating short-run memory, which is a sign of cointegration. Meanwhile, for the Asian and European groups, the fractional parameter falls below zero in late 2007 and maintains negative thereafter until late 2009. This shows that cointegration among the Asian and European countries occurred at a much later time than cointegration among the North American countries does.

6. Discussion

The main results of this study are summarized as follows:

(1) The three groups of markets follow a similar cointegration trend: the cointegration relationship gradually increases before the global financial crisis, reaches a peak during the crisis, and dies down gradually after the crisis.
(2) The Asian countries are the regions least affected by the global financial crisis.
(3) For most groups, short-run memory dominates the cointegration process during the global financial crisis, but long-run memory has restored since the recovery.
(4) Cointegration among Asian and European countries occurs at a much later time than cointegration among North American countries does. Hence North America is the source of cointegration, while Asia and Europe are the recipients.

Our results show that the patterns of cointegration of the three groups of markets are somewhat similar. Firstly, from the trace test, for all three groups, the markets become more and more cointegrated during the pre-crisis period. The cointegration relationship is most significant during the global financial crisis, but fades out gradually after the crisis. Secondly, from the time paths of the fractional parameter, we can see that short-term memory persists during the global financial crisis. The crisis has the effect of shortening the length of cointegration dependence. However, long-run memory is restored after the crisis. This shows that the impact of the global financial crisis is worldwide. Almost all markets are affected. However, the degree of impact varies among markets. European and North American countries, which are centers of shocks of the crisis, are more severely affected. On the other hand, Asian countries are less affected by the crisis, as shown by the result of the trace test that the line representing $r = 0$ rises above 1 for only a very short period of time. Therefore, our results can show how a financial crisis affects different markets in the world. The time that the global financial crisis affects different regions of the world is also different. The trace test shows that the line representing $r = 0$ peaks at a much earlier time for the North American group than for the Asian and European groups. The fractional parameter of the North American group also falls negative earlier than that of the Asian and European groups. Both results coincide with the fact that US is the origin of the global financial crisis and the shock spread to other parts of the world in 2008.

The results highlight the advantage of our methodology over those of others like Liow and Yang [9] and Serrano and Hoesli [10]. They applied the FIVECM and FIECM respectively, but did not adopted the recursive model, so only a single result of the fractional parameter (called ‘‘fractional cointegration coefficient’’ in Refs. [9,10]) was obtained. Serrano and Hoesli [10] found that the fractional parameter is negative, indicating that short-run memory governed the cointegration process, while Liow and Yang [9] just showed the opposite result. However, both of them only produced a single result for the whole period. In reality, the fundamentals of a market are always changing, so we expect the cointegration pattern to vary over time, too. To cope with this, our new framework combines recursive cointegration with FIVECM, so we can see how the trace test and fractional parameter very over the whole period of observation. Thus how the cointegration pattern among different countries changes over the time period can be observed. Instead of a single fixed fractional parameter found by Liow and Yang [9] and Serrano and Hoesli [10], we find that the fractional parameter varies over time: it stays positive initially, falls negative during the global financial crisis, and returns positive after the crisis, indicating that shortrun memory dominates the cointegration process during the global financial crisis, but long-run memory is in charge before and after the crisis.

Yunus [8] also applied the recursive model to test cointegration among the securitized property markets of six major countries and the US. However, he did not adopted the FIECM or FIVECM. Therefore, only the time path of the trace test was obtained, but there was no statistics of the fractional parameter. Furthermore, Yunus [8] conducted the trace test for a single group of countries only. In contrast, we divide the nine countries into three groups of countries in this study. By comparing the time paths of trace test and fractional parameter of different groups of countries over the same period of time, we can see how the cointegration pattern varies among different groups of countries over the time period. For instance, if one group shows significant evidence of cointegration at an earlier time than other groups do, then that group of countries can be regarded as the source of cointegration (see the explanation in Section 5). In our study, the time paths of both the trace test and fractional parameter show that cointegration among Asian and European countries occurs at a much later time than cointegration among North American countries does. This reflects that North America is the source of cointegration in the global financial crisis, while Asia and Europe are the recipients. Yunus [8], Liow and Yang [9] and Serrano and Hoesli [10] cannot show the sources and recipients of cointegration.

This study has important implications to investors and related authorities. Making use of the time paths of trace test and fractional parameter, investors can adjust their portfolio accordingly to reduce their risk, while related authorities can take appropriate measures to stabilize the economy and mitigate the effects of financial crises. For example, in the trace test, if the line representing $r = 0$ (or 1, 2,...) rises sharply, this implies that the cointegration relationship between the markets is becoming stronger. Bubbles may be forming and hence a financial crisis may occur later. If the macroeconomic factors also indicate evidence of bubbles forming, e.g. a sharp rise in the inflation rate, then there is a higher probability that a financial crisis occurs. In this case, investors should sell their assets and hold more cash to avoid losses, while the government should maintain sufficient reserve to prevent huge deficit in case a financial crisis occurs. In particular, if the line representing $r = 0$ rises above the threshold level of 1, indicating significant evidence of cointegration, investors and related authorities should pay more attention to the market movements and be aware of outbreak of a financial crisis.

7. Conclusion

In this study, we construct a new framework which combines recursive cointegration with FIVECM to investigate the cointegration relationship among three groups of securitized property markets: Asian, European and North American groups. Our new combined framework has the advantage of reflecting the changes in cointegration dynamics in over a period of time instead of a single result for the whole period. The results show that the three groups of markets follow a similar cointegration trend, with the cointegration relationship reaching a peak during the global financial crisis. This study is useful for investors and related authorities that investors can adjust their portfolio according to the test results to reduce their risk, while related authorities can take appropriate measures to stabilize the economy and mitigate the effects of financial crises.

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