Non-linear Short-run Adjustments between REITs and Stock Markets in the USA and Australia

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ABSTRACT

This study, following the model proposed by Gregory and Hansen (1996), utilises the residual-based test for co-integration with structural breaks in order to examine whether non-linear co-integration exists between real estate investment trusts (REITs) and corresponding stock markets in the United States and Australia. Moreover, we employ the smooth-transition, vector-error correction model (STVECM) including the generalized autoregressive conditional heteroskedasticity (GARCH) model, in order to separately explore the adjustment efficiencies of the short-run REIT and corresponding stock return dynamics as well as respective REIT return dynamics while there is the long-run disequilibrium between the REITs and corresponding stock markets and between the respective REIT markets in the two countries.

Our empirical results demonstrate that there is a non-linear co-integration with structural breaks between the equity and mortgage REITs and stock markets in the US, between the REITs and stock markets in the Australia and between the REIT markets in both the US and Australia. When large positive and negative deviations of STVECM exist, the speed of equilibrium adjustment of the S&P 500 index is greater than that of the Mortgage REIT index. However, when large positive (negative) deviations of STVECM exist, the speed of equilibrium adjustment of the Australian REIT (stock) index is greater, and that of the Australian REIT (US REIT) index for reversion is greater. Then, the results of a non-linear Granger causality test proposed by Hiemstra and Jones (1994) find that there are credit price effects between the US for each type of REIT and stock markets regardless of whether there are large positive or negative deviation (or return) regimes in STVECM (or STVAR). However, there is a feedback effect between the REITs and the stock markets in Australia. In addition, the price leadership of the US REIT market is relative to the Australian REIT market.

Keywords: REITs; STVECM; structural break co-integration; nonlinear Granger causality; GARCH.

JEL Classification: C22; G11; L85; D53; C58; G14

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1. Introduction

As of December 2010, the global market capitalization of REITs has surpassed US$ 800 billion, with nearly 500 fund management units. Thus, REITs have become another favourite choice among investors besides the stock market. Since real estate properties can preserve value while REITs increase liquidity and financial transparency, investors who previously invested only in highly liquid and profitable stocks are now including an increasing number of real-estate related securities into their portfolios to diversify their investment risk. Considering that the effect to diversify risk by investing in the real estate market of different countries may not be inferior to the effect of investing in the stock and real estate markets, this study also examines the real estate price movements of two different countries and the impact they may have on the investment strategy of investors.

Most literatures have confirmed the co-integration between the real estate and stock markets (Tuluca et al., 2000; Liow and Yang, 2005; and Hui and Yue, 2006). If nonlinear characteristics significantly exist in the time series, the testing power of a traditional linear model may abruptly drop. Considering that the REIT index and corresponding stock index may change over time in a long-term time series, this study uses the residual-based test for co-integration with structural breaks proposed by Gregory and Hansen (1996) to analyse the time-series co-integration between the REIT indices and corresponding stock indices. Wilson and Okunev (1997) found that a non-linear relationship exists between the real estate and stock markets. However, the extent of their mean reversion was quite slow and deviations between the two markets could be prolonged. Subsequently, Wilson and Okunev (1999) used fractional co-integration to find no co-memories between the stock and property markets in the United States and United Kingdom, but they found some evidence of long co-memories in Australia on either side of the 1987 in spite of no co-memory during the entire period. By using the non-parametric rank test, Su (2011) examined whether a non-linear long-run equilibrium exists between the real estate and stock markets in western European countries and his result demonstrated strong evidence for non-linear adjustments when there was deviation from a long-run equilibrium. In addition, by utilising the threshold auto-regressive (TAR) model, Su et al. (2011) tested whether a long-run relationship between the real estate and stock markets in European countries existed, and they found that the dynamics reverting to a long-run equilibrium did follow non-linear adjustments with a specific threshold value.

Considering that structural break may lead to a non-linear relationship between the real estate and stock markets, this study adopts the non-linear model to analyse the respective

behaviours of short-term mean reversion for the two markets when they deviate from the long-run equilibrium relationship. The phenomenon of non-linear mean reversion between each real estate market and stock market does not necessarily follow the results of long memory. However, the theory of interaction between noise and arbitrage traders have proposed that arbitrageurs must be aware of the potential for noise traders in order to drive returns further away from equilibrium before correction. To be more specific, the dynamics governing small return deviations from the equilibrium differs at least from the dynamics governing large return deviations. In this case, the smooth transition vector error-correction model (STVECM) should be able to capture the real estate and stock market dynamics with large and small returns and allow the gradual movement between the different regimes In addition, the high-frequency financial asset prices may fluctuate in clusters. Therefore, after confirming the co-integration relationship (with structural breaks) between the REIT and corresponding stock price indices, this study further explores whether the STVECM with the GARCH model can accurately describe the dynamic adjustments in reverting to long-run equilibrium between the REIT and corresponding stock price indices.

Past literatures have not reached a consistent conclusion on the lead-lag relationship of the stock and real estate markets, which included ‘wealth effect’ and ‘credit price effect’. In regard to the wealth effect, Chau et al. (2000) pointed out that the rise of the S&P 500 index would result in the decline of Jones Lang LaSalle JLW real-estate price indices in the following season. The results of Oppenheimer and Grissom (1998), Larson (2005) and Chen (2007) showed that stock indices could serve as a leading indicator for the REIT prices and a rapid reversal of the stock market would lead to the same reaction from the REIT markets. The non-linear causality test used by Okunev et al (2002) found that Australian stock markets had a significant one-way impact on its real estate markets. In regard to credit price effect, Hui and Yue (2006) found that the prices of used houses in Beijing and Shanghai would affect stock indices in Shanghai but the stock indices did not affect the corresponding housing prices. Moreover, some empirical literatures found that there were two-way relationships between stock and real-estate prices or the causal relationships between the two markets only showed in some areas. The empirical study by Green (2002) showed that causality relationships between stock and housing prices did exist in high-priced housing areas but was not significant in areas with low housing prices.

The traditional vector auto-regression (VAR) model includes linear predictive ability while disregarding the non-linear effects. Based on the concept of nonparametric statistics and correlation integral, this study adopts the nonparametric non-linear Granger causality test

proposed by Hiemstra and Jones (1994) to analyse whether there is either a wealth effect or a credit price effect between the stock and REIT prices in the US and Australia, respectively. Meanwhile, we are also interested in finding out whether the REIT indices in the US or Australia would serve as a leading indicator for price movements.

Real estate securitization originated in the US, whose REIT markets include the longest history and a market capitalization ranks first in the world. Australia developed its REITs in 1971, and its market capitalization ranks second in the world. Due to such rankings, investors will simultaneously allocate their investment in both the stock and real estate securitization markets in the US and Australia in order to diversify risk. Therefore, when interest rates becomes lower and inflation becomes rampant, those who simultaneously invest in real estate securitization and stock markets in the US and Australia (or those who make investments in the US and Australian real estate securitization markets) will be eager to know what the lead-lag relationship is between the REIT and stock markets in these areas (or the REIT markets in these two countries). They will also want to know if co-integration with structural breaks exists between the REIT and stock markets in these countries (or the REIT markets in these two countries). When the REIT indices and stock indices (or the REIT indices in these two countries) deviate from their long-run equilibrium respectively, how efficiently can the two indices adjust themselves dynamically and revert to equilibrium? This study further analyses whether co-integration with structural breaks exists between the respective three REIT (i.e., equity, mortgage and hybrid) and stock markets. When the respective REIT indices and stock indices deviate from the long-run equilibrium, how efficiently can the two indices adjust themselves dynamically and revert to equilibrium? Hence, the study will examine the correlation between the stock and real estate securitization markets in the US and Australia in terms of the overall and classified REIT indices. In this case, this study can serve as a good reference for the investors investing in these two regions.

The remainder of this paper is organised as follows. Section 2 describes the data and statistical analysis used in this study and Section 3 introduces the methodology. Section 4 analyses the empirical results and Section 5 presents the conclusions.

2. Data and Descriptive Analysis

2.1 Data Range

The data range of this study consists of the REIT indices and corresponding stock indices in the US and Australia. The REIT indices in the US include the daily REIT indices

for all and the equity, mortgage and hybrid types. The corresponding stock price index in the US is the daily S&P 500 index. The data employed for Australia includes the daily All REIT index and the All Ordinaries index. Since the beginning of the REIT indices in the US and Australia are different, this study utilises the beginning of the REIT index of each country as the beginning of the REIT index and of the stock price index for each country. Thus, the data for the REIT index and the stock price index in the US extend from 1 January 1999 to 2 February 2011 and those for Australia are from 3 March 2000 to 28 February 2011. In addition, the data for the REIT indices in the US and Australia extend from 3 March 2000 to 28 February 2011. The data source for the REIT indices as well as the stock price indices employed in this study is from the Datastream database.

2.2 Descriptive Statistical Analysis of the REIT and Stock Indices

The results in Table 1 show that the REIT index return average for equity REITs in the US is significantly higher than that of the other four REITs. However, the results of the standard deviation in Table 1 show that the fluctuations in the Hybrid REIT index return in the US are significantly higher than those in the other four REIT index returns. In addition, the average for S&P 500 index returns in the US is significantly higher than that for ASX index returns in Australia, which indicates that the average stock index return in the US is significantly higher than that in Australia. The standard deviation in the same table shows that the fluctuations in S&P 500 index returns in the US is higher than those in ASX index returns in Australia, indicating that the risk of S&P 500 stock index return in the US is higher. Combing the standard deviations in Tables 1, we find that there are significantly greater fluctuations regardless of the REIT index returns or stock index returns in the US, which shows that there is a close relationship between the fluctuations in the REIT index and those in the stock index in the US.

3. Methodology

3.1 Nonlinear Unit Root Test

In order to reinforce the power of the unit root test for the non-linear dynamic adjustments of the REIT and stock indices in the US and Australia, respectively, this study utilises the non-linear KSS stationarity test by Kapetanios et al. (2003). The goal of the KSS test is to detect the presence of non-stationarity against a non-linear but stationary exponential smooth transition autoregressive (ESTAR) process. Given that γ cannot be identified in the null hypothesis, Luukkonen et al. (1988) and Kapetanios et al. (2003) used the first-order

Taylor series to approximately estimate $\left\{1-\exp\left(-\theta Y_{t-1}^2\right)\right\}$. The model is expressed as:

$$\Delta Y_t = \gamma Y_{t-1}\left\{1-\exp\left(-\theta Y_{t-1}^2\right)\right\} + \varepsilon_t \quad (1)$$

For the null hypothesis $\theta = 0$, equation (1) can be re-written as:

$$\Delta Y_t = \zeta + \delta Y_{t-1}^3 + \sum_{i=1}^{k} \rho_i \Delta Y_{t-i} + \varepsilon_t, t = 1, 2, ..., T \quad (2)$$

If the estimate does not reject the hypothesis $H_0 : \delta = 0$, the sequence is a unit root; otherwise the sequence is a non-linear constant ESTAR.

The results of the KSS non-linear stationarity test show that all of the REIT indices and corresponding stock price indices in the US as well as the REIT index and stock price index in Australia are all linear unit roots whose first-order differences are stationary. This confirms that the respective REIT indices and stock price indices are I (1) sequences in such areas.

3.2 Structure break co-integration test

Considering the tendency that stock price and house price indices most likely change over time, we use the co-integration test proposed by Gregory and Hansen (1996). This test can be used to analyse non-linear co-integration relationships with structural breaks in time series. First, the traditional co-integration model of housing prices P_{ht} and stock prices P_{st} is assumed as (3):

$$P_{st} = \mu_1 + \alpha_1 P_{ht} + e_t, \quad t = 1, \cdots, n, \quad (3)$$

Nevertheless, it is found that a co-integration relationship may remain for some time and then turn into a new long-term equilibrium relationship. It is therefore required that assumptions of co-integration with structural breaks be changed into an unknown. Furthermore, we consider that structural breaks may occur in both the intercept and the slope. In this case, the dummy variables are established as:

$$D_{t\tau} = \begin{cases} 0 & if \quad t \le [n\tau] \\ 1 & if \quad t > [n\tau] \end{cases} \quad (4)$$

Among them, $\tau \in (0, 1)$ is the unknown structural break point in the time series. In addition, the structural co-integration model can appear in the following three forms:

1. Structural breaks occur in the intercept (C)

$$P_{ht} = \mu_1 + \mu_2 D_{t\tau} + \alpha_1 P_{st} + e_t \quad (5)$$

2. Structural breaks occur in both the intercept and time trends (C/T)：

$$P_{ht} = \mu_1 + \mu_2 D_{t\tau} + \beta_t t + \alpha_1 P_{st} + e_t \quad (6)$$

$P_{ht}=u_1+u_2D_{t\tau}+\beta_t+\alpha_1P_{st}+e_t$,

3. Structural breaks occur in both the intercept and the slope (C/S)：

$$P_{ht} = \mu_1 + \mu_2 D_{t\tau} + \alpha_1 P_{st} + \alpha_2 P_{st} D_{t\tau} + e_t \quad (7)$$

Under the assumption of $\tau \in T$, Gregory and Hansen (1996) utilised the above three models in order to make an ordinary least squares (OLS) estimation for each τ and to obtain the residuals $\hat{e}_{t\gamma}$. The augmented Dickey-Fuller (ADF) statistics can be used to regress $\Delta\hat{e}_{t\tau}$ on $\hat{e}_{t-1\tau}$ and κ backward differential ($\Delta\hat{e}_{t-1\tau},\cdots,\Delta\hat{e}_{t-1\kappa\tau}$) by OLS estimation, in order to obtain the regression coefficients for $\hat{e}_{t-1\tau}$. The t statistics are ADF (τ) =t and stat ($\hat{e}_{t-1\tau}$). Its test statistics ADF * are not the traditional ADF statistics but the minimum statistics that correspond to specific structural break points, defined as:

$$\text{ADF}^{*}=\inf \text{ADF}(\tau) \quad (8)$$

The critical value of the test statistic is simulated by Gregory and Hansen (1996) using the response surface function. The simulation is also used in our empirical results to obtain the asymptotically distributed critical value.

3.3 Non-linearity Test and Estimations of the STVECM (STVAR)-GARCH

In order to review the different return dynamics for both the small and large deviations from the co-movements between the stock and REIT prices in the US and Australia separately, this study applies the STVECM to allow for a smooth transition for return dynamics in different regimes. Meanwhile, we let the residuals in this model follow a GARCH process in order to capture the heterogeneity of the residuals. However, if a co-integration does not exist between the stock and REIT prices in any such location, the study uses the STVAR to smoothly transform the return dynamics in different regimes to capture the different dynamics of the stock and REIT price returns in the lower and higher return regimes. In addition, we let the residuals in the STVAR follow a GARCH process. Thus, the STVECM-GARCH and STVAR-GARCH can be expressed as follows:

$$\begin{aligned}
\Delta P_t^h &= (\alpha_0^h + \alpha_1^h Z_{t-1} + \sum_{i=1}^{q} \alpha_{i+1}^h \Delta P_{t-i}^s + \sum_{i=1}^{q} \alpha_{i+1+q}^h \Delta P_{t-i}^h) + (\beta_0^h + \beta_1^h Z_{t-1} + \sum_{i=1}^{q} \beta_{i+1}^h \Delta P_{t-i}^s \\
&+ \sum_{i=1}^{q} \beta_{i+1+q}^h \Delta P_{t-i}^h) F(Z_{t-d}:\gamma,\tau) + \varepsilon_t^h \\
\Delta P_t^s &= (\alpha_0^s + \alpha_1^s Z_{t-1} + \sum_{i=1}^{q} \alpha_{i+1}^s \Delta P_{t-i}^s + \sum_{i=1}^{q} \alpha_{i+1+q}^s \Delta P_{t-i}^h) + (\beta_0^s + \beta_1^s Z_{t-1} + \sum_{i=1}^{q} \beta_{i+1}^s \Delta P_{t-i}^s \\
&+ \sum_{i=1}^{q} \beta_{i+1+q}^s \Delta P_{t-i}^h) F(Z_{t-d}:\gamma,\tau) + \varepsilon_t^s
\end{aligned} \quad (9)$$

$$h_{h,t} = \phi_0 + \phi_1 \varepsilon_{h,t-1}^2 + \phi_2 h_{h,t-1}$$
$$h_{s,t} = \delta_0 + \delta_1 \varepsilon_{s,t-1}^2 + \delta_2 h_{s,t-1}$$
$$h_{hs,t} = \rho \sqrt{h_{h,t} h_{s,t}}$$

where $\alpha_1^h + \beta_1^h$ ($\alpha_1^s + \beta_1^s$) represents the speed of adjustment of reverting to the equilibrium after the REIT price (stock price) deviates from the equilibrium in the higher regime of transition function while α_1^h (α_1^s) represents that in the lower regime of the transition function. If $\left|\alpha_1^s + \beta_1^s\right|$ is less than $\left|\alpha_1^h + \beta_1^h\right|$ ($\left|\alpha_1^s\right|$ is less than $\left|\alpha_1^h\right|$), the stock price has a faster mean reversion to the equilibrium compared to REIT price, which means that the stock price has a greater influence on price discovery than the REIT price (following Sun, Tong and Yan, 2009). Hence, the STVECM or STVAR is more appropriate to describe the investment behaviours of gradual changes in the different market compositions. The STVECM (STVAR) is governed by the continuous smooth transition function $F(Z_{t-d}:\gamma,\tau)$ ($F(\Delta r_{t-d}:\gamma,\tau)$). In addition, this study also utilises the STVECM-GARCH model in order to analyse the adjustment speed of reversion to the equilibrium after the respective REIT price in the US and Australia deviates from the long-run equilibrium so as to consider the viewpoint of the investors in both of the REIT markets. According to Terasvirta (1994), two types of the transition function in equation (9) are considered as follows:

$$F\left(Z_{t-d}:\gamma,\tau\right) = \left\{1+\exp\left[-\gamma\left(Z_{t-d}-\tau\right)/\sigma_{Z_{t-d}}\right]\right\}^{-1}, \gamma > 0 \qquad (10)$$

$$F\left(Z_{t-d}:\gamma,\tau\right) = 1-\exp\left[-\gamma\left(Z_{t-d}-\tau\right)^2/\sigma_{Z_{t-d}}\right], \gamma > 0 \qquad (11)$$

Let us take the STVECM between the stock and REIT prices for example. Equation (9) with transition function (10) is called the logistic STVECM (or LSTVECM), and the LSTVECM represents the different dynamics for the two return regimes with a smooth transition function $F\left(Z_{t-d}:\gamma,\tau\right)$ =0~1 as $Z_{t-d} = -\infty \sim +\infty$. When $\gamma \to +\infty$, $F\left(Z_{t-d}:\gamma,\tau\right) \to 0$ represents the regime of large negative deviations if the stock prices are significantly lower than the REIT prices for $Z_{t-d} << \tau$ and $F\left(Z_{t-d}:\gamma,\tau\right) \to 1$ represents the regime of large positive deviations if the stock prices are significantly higher than the REIT prices for $Z_{t-d} >> \tau$. Equation (9) with transition function (11) is called the exponential STVECM (or ESTVECM). The ESTVECM means that there are different dynamics in the transition regime, but similar dynamics in the extreme regimes since $F\left(Z_{t-d}:\gamma,\tau\right) \to 1$ as $\left|Z_{t-d}\right| \to +\infty$.

The non-linear STVECM is only identified under the alternative hypothesis of non-linearity $H_0:\gamma>0$ rather than the null hypothesis of linearity $H_0:\gamma=0$. In addition, Luukkonen et al. (1998) proposed that it is feasible to replace $F\left(Z_{t-d}:\gamma,\tau\right)$ with its third-order Taylor approximation of $\gamma=0$. In order to directly examine whether the parameters of the third-order Taylor series in equation (12) are 0, this study utilises the Wald test as follows:[18]

$$\begin{aligned}\Delta P_t^h &= \pi_{10}+\pi_{11}^{'}W_t+\kappa_{11}^{'}W_t\left(Z_{t-d}\right)+\kappa_{12}^{'}W_t\left(Z_{t-d}\right)^2+\kappa_{13}^{'}W_t\left(Z_{t-d}\right)^3+\eta_{1t}\\ \Delta P_t^s &= \pi_{20}+\pi_{21}^{'}W_t+\kappa_{21}^{'}W_t\left(Z_{t-d}\right)+\kappa_{22}^{'}W_t\left(Z_{t-d}\right)^2+\kappa_{23}^{'}W_t\left(Z_{t-d}\right)^3+\eta_{2t}\end{aligned} \tag{12}$$

where $W_t=\left(Z_{t-1},\Delta P_{t-1}^s...,\Delta P_{t-q}^s,\Delta P_{t-1}^h...,\Delta P_{t-q}^h\right)$. Before estimating the non-linear STVECM, it is necessary to test for linearity using $F\left(Z_{t-d}:\gamma,\tau\right)=0$ for the delay parameter *d* with the smallest *p*-value. After the delay parameter *d* is determined, the linearity test is equivalent to the test of the hypothesis：

$$H_0:\kappa_{11}^{'}=\kappa_{12}^{'}=\kappa_{13}^{'}=\kappa_{21}^{'}=\kappa_{22}^{'}=\kappa_{23}^{'}=0 \tag{13}$$

We use the auxiliary regression (14) as follows.[19]

$$\begin{aligned}\hat{\varepsilon}_t^h &= \pi_{10}+\pi_{11}^{'}W_t+\kappa_{11}^{'}W_t\left(Z_{t-d}\right)+\kappa_{12}^{'}W_t\left(Z_{t-d}\right)^2+\kappa_{13}^{'}W_t\left(Z_{t-d}\right)^3+\nu_{1t}\\ \hat{\varepsilon}_t^s &= \pi_{20}+\pi_{21}^{'}W_t+\kappa_{21}^{'}W_t\left(Z_{t-d}\right)+\kappa_{22}^{'}W_t\left(Z_{t-d}\right)^2+\kappa_{23}^{'}W_t\left(Z_{t-d}\right)^3+\nu_{2t}\end{aligned} \tag{14}$$

where $\hat{\varepsilon}_t^h\left(\hat{\varepsilon}_t^s\right)$ is the residual under the null hypothesis of linearity VECM or VAR. Then, we use the Wald test statistic in order to examine the linear versus non-linear STVECM or STVAR. Moreover, this study utilises a sequence of tests in equation (15) in order to identify whether the LSTVECM or ESTVECM is the suitable model. The null hypothesis for identifying the type of transition is as follows:

$$\begin{aligned}&H_{04}:\kappa_{13}^{'}=\kappa_{23}^{'}=0\\ &H_{03}:\kappa_{12}^{'}=\kappa_{22}^{'}=0\left|\kappa_{13}^{'}=\kappa_{23}^{'}=0\right.\\ &H_{02}:\kappa_{11}^{'}=\kappa_{21}^{'}=0\left|\kappa_{12}^{'}=\kappa_{22}^{'}=\kappa_{13}^{'}=\kappa_{23}^{'}=0\right.\end{aligned} \tag{15}$$

If H_{04} is rejected, then the LSTVECM is fitted. If H_{03} is rejected, then the ESTVECM is

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[16] If the STVAR is confirmed, we use the Wald test as shown in the following equation, where $W_t=\left(\Delta P_{t-1}^s...,\Delta P_{t-q}^s,\Delta P_{t-1}^h...,\Delta P_{t-q}^h\right)$. $\begin{aligned}\Delta P_t^h &= \pi_{10}+\pi_{11}^{'}W_t+\kappa_{11}^{'}W_t\left(\Delta r_{t-d}\right)+\kappa_{12}^{'}W_t\left(\Delta r_{t-d}\right)^2+\kappa_{13}^{'}W_t\left(\Delta r_{t-d}\right)^3+\eta_{1t}\\ \Delta P_t^s &= \pi_{20}+\pi_{21}^{'}W_t+\kappa_{21}^{'}W_t\left(\Delta r_{t-d}\right)+\kappa_{22}^{'}W_t\left(\Delta r_{t-d}\right)^2+\kappa_{23}^{'}W_t\left(\Delta r_{t-d}\right)^3+\eta_{2t}\end{aligned}$

[17] If the STVAR is confirmed, we use the following auxiliary regression: $\begin{aligned}\hat{\varepsilon}_t^h &= \pi_{10}+\pi_{11}^{'}W_t+\kappa_{11}^{'}W_t\left(\Delta r_{t-d}\right)+\kappa_{12}^{'}W_t\left(\Delta r_{t-d}\right)^2+\kappa_{13}^{'}W_t\left(\Delta r_{t-d}\right)^3+\nu_{1t}\\ \hat{\varepsilon}_t^s &= \pi_{20}+\pi_{21}^{'}W_t+\kappa_{21}^{'}W_t\left(\Delta r_{t-d}\right)+\kappa_{22}^{'}W_t\left(\Delta r_{t-d}\right)^2+\kappa_{23}^{'}W_t\left(\Delta r_{t-d}\right)^3+\nu_{2t}\end{aligned}$

fitted. If both H_{04} and H_{03} is accepted but H_{02} is rejected, then the LSTVECM should be selected.

4. The empirical results

4.1 Results of the co-integration test

As seen in Table 2, Panel A shows that when structural breaks are considered, there is a non-linear co-integration relationship in at least one model test between US Equity REIT or Mortgage REIT indices and the S&P 500 indices, respectively. Meanwhile, there is a non-linear co-integration relationship in at least one model test between Australian all REIT indices and its ASX stock indices. There is a non-linear co-integration relationship in at least one model test between US all REIT indices and Australian all REIT indices. Moreover, the structural break points of the co-integration between the US various-type REIT indices and the S&P 500 indices fall during the first half of 1999 while the structural break points of the co-integration between Australian all REIT indices and its stock indices fall in 2002. Furthermore, the structural break points of the co-integration between US all REIT indices and Australian all REIT indices fall in 2007. However, there is no non-linear co-integration relationship between Hybrid REIT and the S&P 500 stock indices. Thus, this study utilises the nonlinear co-integrated equilibrium, which does not contain error correction terms that establish the short-run dynamic adjustment model between Hybrid REIT and stock prices.

4.2 Results of the Non-linear Test and the STVECM (or STVAR)

The results of linearity against the non-linear test in Tables 3 show significant evidence of non-linearity between the REIT and corresponding stock prices in the US and Australia and between the two REIT prices. In order to determine *d*, we estimate a range of d values ($1 \le d \le 6$), where the *F* statistics with the minimum *p*-value or the maximum *F* statistics identify the optimal d value. The results in Table 4 show that H_{04} is rejected for *d*=1 between Equity REIT and the S&P 500 indices and between the US and Australian REIT indices as well as for d=5 between the RETI and stock indices in Australia. These results indicate that the LSTVECM is a more appropriate model. However, H_{03} is rejected for *d*=1 between Hybrid REIT and the S&P 500 indices and for d=3 between Mortgage REIT and the S&P 500 indices, which indicates that the ESTVAR and ESTVECM are more appropriate models.

Tables 5-1 to 5-2 show respectively the short-run dynamic STVECM-GARCH (or

STVAR-GARCH) estimation results for various types of US REIT and stock index returns, Australian REIT and stock index returns and US and Australian REIT index returns. The estimated parameters, ψ_2, δ_2 or ρ of STVECM-GARCH (STVAR-GARCH), show that the previous messages from every type of US REIT and stock indices, Australian REIT and stock indices and US and Australian REIT indices all have significant impact on index volatility either individually or collectively. The results of the STVECM (or STVAR) in Tables 5-1 to 5-2 consistently show positive γ smooth parameters and most of them are significantly large, meaning that there is a quick transition from one regime to another. The estimated results of the smooth transition functions in the dynamics between the REIT and corresponding stock indices in the US and Australia as well as between the two REIT indices are listed in equations (17) to (21) below. These results further confirm that the smooth transition functions between Hybrid REIT and stock indices and between Mortgage REIT and stock indices follow the exponential transition type, while those between Equity REIT and stock indices, between REIT and stock indices in the Australia and between the REIT indices in the US and Australia follow the logistic transition type. The transition function between Equity REIT and the S&P500 indices in equation (17) is estimated as follows:

$$F\left(Z_{t-1}|\gamma,\tau\right)=\left\{1+\exp[-39.655\left(Z_{t-1}-0.151\right)]\right\}^{-1}$$

$$F\left(Z_{t-1}|\gamma,\tau\right)=\left\{1+\exp[-3.662\left(Z_{t-1}-0.058\right)]\right\}^{-1} \quad (17)$$

The transition function between Mortgage REIT and the S&P500 indices in equation (18) is estimated as follows:

$$F\left(\Delta r_{t-1}|\gamma,\tau\right)=\left\{1-\exp[-392.258\left(\Delta r_{t-1}-0.070\right)^2]\right\}$$
$$F\left(\Delta r_{t-1}|\gamma,\tau\right)=\left\{1-\exp[-31.536\left(\Delta r_{t-1}-0.035\right)^2]\right\} \quad (18)$$

The transition function between Hybird REIT and the S&P500 indices in equation (19) is estimated as follows:

$$F\left(Z_{t-3}|\gamma,\tau\right)=\left\{1-\exp[-1.258\left(Z_{t-3}-0.199\right)^2]\right\}$$
$$F\left(Z_{t-3}|\gamma,\tau\right)=\left\{1-\exp[-6.583\left(Z_{t-3}-0.254\right)^2]\right\} \quad (19)$$

The transition function between Australian REIT and the ASX stock indices in equation (20) is estimated as follows:

$$F\left(Z_{t-5}|\gamma,\tau\right)=\left\{1+\exp[-844.465\left(Z_{t-5}+0.040\right)]\right\}^{-1}$$
$$F\left(Z_{t-5}|\gamma,\tau\right)=\left\{1+\exp[-34.092\left(Z_{t-5}+0.062\right)]\right\}^{-1} \quad (20)$$

The transition function between US REIT and Australian REIT indices in equation (21) is estimated as follows:

$$F\left(Z_{t-1}|\gamma,\tau\right)=\left\{1+\exp[-15.435\left(Z_{t-1}+0.159\right)]\right\}^{-1}$$
$$F\left(Z_{t-1}|\gamma,\tau\right)=\left\{1+\exp[-8.129\left(Z_{t-1}-0.072\right)]\right\}^{-1} \quad (21)$$

The Z_{t-1} coefficients of Mortgage REIT (S&P 500 stock) indices in the US with large negative and positive deviations are all -1.470 (-0.331). The Z_{t-1} coefficients of Equity REIT (S&P 500 stock) indices in the US with large negative and positive deviations are -1.109 (1.724) and -0.009 (0.036), respectively. The Z_{t-1} coefficients of the REIT (ASX stock) indices in Australia with large negative and positive deviations are 0.126 (-0.076) and 0.125 (-0.456), respectively. The Z_{t-1} coefficients of the US REIT (Australian REIT) indices with large negative and positive deviations are -0.051 (20.039) and 3.211 (-0.744), respectively. These results indicate that there are consistently quick and evident mean reversions to the equilibrium for large negative and positive deviations between each-type of REIT and stock indices in the US, between REIT and stock indices in the Australia and between the US and Australian REIT indices. More specifically, regardless of whether large positive deviations (i.e. when the S&P 500 indices are significantly higher than Mortgage REIT indices), or large negative deviations exist (when the S&P 500 indices are significantly lower than Mortgage REIT indices), the adjustment speed of the US S&P 500 indices reversion to equilibrium is greater than that of the Mortgage REIT indices. This may be the reason why investors who simultaneously invest in US Mortgage REITs and S&P 500 stocks prefer to purchase stocks that offer higher returns, so they purchase stocks more frequently than REITs, pushing the corresponding stock prices back to equilibrium at a faster speed than REIT prices. Moreover, when the S&P 500 indices are significantly higher than Equity REIT indices (i.e. when there are large positive deviations), the informed traders tend to buy the relatively cheaper Equity REITs. In this case, the incentive to purchase Equity REITs will increase, thus accelerating the adjustment speed of Equity REITs indices reverting to equilibrium. However, when the S&P 500 indices are significantly lower than Equity REITs indices (i.e. when there are large negative deviations), investors tend to purchase Equity REITs that may offer lower risks and more stable returns, thus pushing the adjustment speed of Equity REITs indices reverting to equilibrium faster than that of their corresponding stock indices. In addition, when Australian common stock indices are significantly higher (lower) than its REIT indices (i.e. when there are large positive (negative) deviations), informed traders tend to buy the relatively cheaper REITs (stocks), thus pushing the adjustment speed of REIT (stock) indices reverting to equilibrium faster than that of their corresponding stock (REIT) indices. When U.S. REITs indices are significantly higher (lower) than Australian REIT indices (i.e. when there are large

positive (negative) deviations), the informed traders tend to buy relatively cheaper Australian REITs (US REITs), thus pushing the adjustment speed of Australian REIT (U.S. REIT) indices reverting to equilibrium faster than that of U.S. REIT (Australian REIT) indices.

Moreover, the adjustment speeds of U.S. Mortgage REIT and the S&P 500 indices reverting to equilibrium from large positive or negative deviations are equal, and this may be the reason why the nature of the Mortgage REITs is very similar to that of bonds. Since investments in the Mortgage REITs and S&P 500 stocks are made to diversify the risk of changes in interest rates, investors of both Mortgage REITs and S&P 500 stocks have developed very rigid investment habits. Thus, regardless of whether there is a large positive deviation (i.e. stock indices are significantly higher than REIT indices) or a large negative deviation (i.e. stock indices are significantly lower than REIT indices), investors of Mortgage REITs and S&P 500 stocks basically do not have the incentive to change their investment behaviour, resulting in the equal adjustment speeds of Mortgage REIT and S&P 500 indices when reverting to equilibrium. However, the speeds of adjustment in reverting to equilibrium of the large positive and negative deviations between US Equity REIT and S&P 500 indices, between Australian REIT and ASX stock indices, or between US REIT and Australia REIT indices are unequal, and this may be the reason why the nature of Equity REITs is relatively similar to that of stocks, resulting in the possibility that investors' incentives to invest in these REITs and stocks are easy to change.

According to the theoretical models of the interaction between arbitrageurs and noise traders, noise traders further drove prices to show their persistency when there were small deviations. On the contrary, when there are large deviations, the arbitrageurs will be more confident in driving the market in the appropriate direction and price movements will quickly revert to equilibrium. Moreover, this study demonstrates that the ESTVECM is fitted for describing the short-run return dynamics of the deviations from the co-movement equilibrium between Mortgage REIT and S&P 500 stock prices in the US, while the LSTVECM is more suitable for describing those between Equity REIT and S&P 500 stock prices in the US, between the REIT and ASX stock prices in the Australia and between the US and Australian REIT prices. That is, the adjustment speeds between Mortgage REIT and S&P 500 stock prices in the US reverting to equilibrium for the large positive and negative deviations are all equal, while those between Equity REIT and S&P 500 stock prices in the US, between the REIT and ASX stock prices in the Australia and between the two REIT prices in the US and Australia are unequal.

The REIT prices significantly influence the stock prices, regardless of whether there are large positive or negative deviations (or returns) in STVECM (or STVAR) between US REITs and stock indices. This may be due to the possibility that REIT markets in the US have the largest market capitalization in the world and more mature investment environments for investors compared to those in other countries. Thus, when the US REIT prices rise, the value of REITs held by American companies will also increase, which pushes up the market capitalization of US enterprises as well as stock prices. Meanwhile, by putting their REITs on mortgages, American investors can borrow more money to invest and stimulate the stock market, thus raising stock prices. Hence, it is confirmed that the 'credit price effect' can commonly exist in the US. In other words, in terms of price discovery, the US REIT markets are more important than the stock markets. Nevertheless, both 'credit price effect' (in which REIT prices clearly influence stock prices) and 'wealth effect' (in which stock prices influence REIT prices) are found in Australia. This may be due to the possibility that Australian REITs and stock markets have equal powers that influence one another. Similarly, US REIT indices significantly influence Australian REIT indices, which show that price discovery is more important in the US REIT market than the Australian REIT market.

5. Conclusion

This study utilised the co-integration test with structural breaks proposed by Gregory and Hansen (1996) in order to test whether non-linear co-integration relationships exist between US REITs and stock indices, between Australian REIT and stock indices and between US REITs and Australian REIT indices. Moreover, we used a GARCH-included STVECM to separately explore the adjustment efficiencies of the US and Australian REIT and corresponding stock prices as well as the two countries' REIT prices when there are deviations in long-run equilibrium between the US and Australian REIT indices. Furthermore, this study used the non-linear Granger causality test mentioned by Hiemstra and Jones (1994) to analyse whether 'wealth effect' (in which stock prices influence REIT prices) or 'credit price effect' (in which REIT prices influence stock prices) exists in the US and Australian markets. We also attempted to discover where a price discovery function existed in the US or Australian REIT markets. Our results showed that there are non-linear structural break co-integration relationships between the US Equity and Mortgage REIT indices and corresponding stock indices, between Australian REIT and stock indices and between the US

and Australian REIT indices, respectively. Moreover, the results of a non-linear Granger causality test found that there is a credit price effect in which the various types of US REIT indices influence stock indices regardless of whether large positive or negative deviations (or returns) in STVECM (or STVAR) occur. Nevertheless, the so-called credit price effect and the wealth effect simultaneously exist in Australian REIT and stock markets. In addition, the price discovery function is more important in the US REIT market than the Australian REIT market.

In sum, the return dynamics governing the small deviations were obviously different from those governing the large deviations. Furthermore, our results showed that in order to diversify the risk of changes in interest rates, investors included rigid habits in investing toward bond-type US Mortgage REITs and S&P 500 stocks. As a result, their adjustment speeds when reverting to equilibrium had a tendency to be equal when there were large positive or negative deviations. However, the REITs investments in US Equity REIT and stock indices, Australian REIT and stock indices and the US and Australian REIT indices were mainly stock-type Equity REITs of which the investors were more likely to change their investing incentives. Therefore, the short-run adjustment speeds when reverting to equilibrium for the large negative and positive deviations were unequal. Specifically speaking, when large positive and negative deviations from the equilibrium between US Mortgage REIT and S&P 500 stock indices exist, the adjustment speed of stock indices reverting to equilibrium was greater than that of REIT indices. Meanwhile, the adjustment speed of US Equity REIT and S&P 500 indices when reverting to equilibrium for large negative and positive deviations was different, but the adjustment speed of Equity REIT indices when reverting to equilibrium was greater than that of stock indices. However, when there was a large positive deviation in the Australian REIT and stock indices, the adjustment speed of the REIT indices when reverting to equilibrium was faster than that of corresponding stock indices. In this case, when there was a large negative deviation, this conclusion is reversed.

Contributions toward this paper include the following. We use a model that allowed the time-series variables to exist in the structural breaks and the self-decided structure break point to examine whether the non-linear co-integration with structural breaks exists between the US and Australia REIT indices and corresponding stock indices as well as between the respective REIT indices. Moreover, we confirm that STVECM with GARCH can be applied to analyse the efficiency of short-run dynamic adjustment in mean reversion when there are deviations from the equilibrium between the US, Australian REIT and corresponding stock indices and

between the US and Australian REIT indices, respectively. On the one hand, the STVECM used by this study confirms that the US S&P 500 index plays a driver role when reverting to equilibrium between Mortgage REIT and corresponding stock indices while US Equity REIT index plays a driver role when reverting to equilibrium between Equity REIT and corresponding stock indices. Meanwhile, the remaining indices in the STVECM include different adjustment speeds when reverting to equilibrium when large positive and negative deviations from the equilibrium occur. On the other hand, we also confirm that credit price effects exist in each type of US REIT and the stock market regardless of whether large positive or negative deviations (or returns) occur in STVECM (or STVAR). However, there is a feedback effect between Australian REIT and stock markets as well as a price discovery between the US REIT market and the Australian REIT market. Based on the above results and analysis, this paper can serve as an informative reference for investors planning to invest in either the US or Australia.

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Table 1 Descriptive Statistics of REIT Index Returns in the US and Australia

Items	US all REITs	US EQUITY REITs	US MORTGAGE REITs	US HYBRID REITs	Aus all REITs	S&P 500	Aus ASX
Mean	0.000147	0.000183	-0.000263	-0.000261	-0.00012	2.42E-05	0.000162
Median	0.000000	0.000000	0.000000	0.000000	0.000226	0.000146	0.000486
Maximum	0.162366	0.168755	0.219701	0.16378	0.080593	0.109572	0.053601
Minimum	-0.205429	-0.215324	-0.192739	-0.232155	-0.121282	-0.094695	-0.085536
Std. Dev.	0.019626	0.020305	0.019555	0.02253	0.013959	0.013294	0.010138
Skewness	-0.181449	-0.195064	-0.027507	-0.569542	-0.90442	-0.114767	-0.672606
Kurtosis	21.08004	21.46572	26.39837	19.77375	13.72932	10.73365	10.33056
Jarque-Bera	43207.44	45072.46	72336.7	37345.93	13669.13	7909.275	6413.337
	[0.000000]	[0.000000]	[0.000000]	[0.000000]	[0.000000]	[0.000000]	[0.000000]
LB Q (4)	111.16***	112.76***	30.485***	29.836***	25.702***	34.022***	12.054**
LB Q (8)	128.63***	128.73***	50.530***	40.639***	80.236***	43.190***	21.990***

Note: 1. Numbers in [ ] indicate the p-value of the Jarque-Bera statistics.

2. ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively.

Table 2 Structural Break Co-integration Tests for the REIT and Stock Indices

Panel A: US Various-type REIT and Stock Indices

Index Name	Model Design	Statistics	Structural Break Point	Co-integration
S&P 500 EQUITY REITS	C	-4.159	1999/3/8	No
	C/T	-4.563	1999/3/12	No
	C/S	-4.538	1999/3/19	Yes
S&P 500 HYBRID REITS	C	-4.082	1999/3/8	No
	C/T	-4.543	1999/3/12	No
	C/S	-4.539	1999/3/23	No
S&P 500 MORTGAGE REITS	C	-4.314	1999/3/8	No
	C/T	-5.171	1999/3/9	Yes
	C/S	-4.745	1999/3/19	Yes

Panel B: Australian REIT and ASX Stock Indices

Index Name	Model Design	Statistics	Structural Break Point	Co-integration
ASX Stock Index REIT Index	C	-4.005	2008/7/21	No
	C/T	-5.057	2002/6/26	Yes
	C/S	-3.745	2008/11/17	No

Panel C: US and Australian REIT Indices

Index Name	Model Design	Statistics	Structural Break Point	Co-integration
US All REIT Index Australian REIT Index	C	-4.731	2007/5/16	Yes
	C/T	-3.864	2008/1/4	No
	C/S	-4.373	2007/5/18	No

Note: Statistics indicate the ADF^* statistics defined in equation (8).

Table 3 Nonlinear Test

Panel A: US REIT and S&P 500 Stock Indices						
EQUITY REITs and S&P 500						
d	1	2	3	4	5	6
H_0 F Stat	63.0314	54.2710	58.9111	57.3745	53.3201	43.9632
p-value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001
HYBRID REITs and S&P 500						
d	1	2	3	4	5	6
H_0 F Stat	53.6428	31.2420	62.1970	51.9303	28.4243	90.2303
p-value	0.0000	0.0018	0.0000	0.0000	0.0048	0.0000
MORTGAGE REITs and S&P 500						
d	1	2	3	4	5	6
H_0 F Stat	33.3900	38.2819	42.5467	37.0605	32.8731	30.3021
p-value	0.0041	0.0008	0.0002	0.0012	0.0049	0.0109
Panel B: AUS REIT and Stock Indices						
d	1	2	3	4	5	6
H_0 F Stat	30.4290	28.6041	29.6201	34.8241	35.5418	34.5093
p-value	0.0105	0.0181	0.0134	0.0026	0.0021	0.0029
Panel C: US REIT and S&P 500 Stock Indices						
d	1	2	3	4	5	6
H_0 F Stat	82.9228	111.0763	89.4587	89.4591	93.2141	55.2317
p-value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Note: 1.The specification and null hypothesis of the nonlinear STVECM (or STVAR) are given in equations (14) and (13), respectively.

2. d is the optimal lag length of the transition variable Z_{t-d} .

3. The testing statistics are adopted in the Wald test, and the specification of the testing statistics is listed in equation (15).

Table 4 Model Specifications for the LSTVECM vs. ESTVECM

Panel A: US REIT and Stock

EQUITY REITs and S&P 500

d	Ho4 F Stat	p-value	Ho3 F Stat	p-value	Ho2 F Stat	p-value
1	15.2744	0.0093	12.6248	0.0272	35.0319	0.0000
2	10.8782	0.0538	14.5147	0.0127	28.7953	0.0000
3	14.5798	0.0123	20.8810	0.0009	23.2635	0.0003
4	16.1054	0.0065	13.1231	0.0223	28.0279	0.0000
5	12.0443	0.0342	7.5312	0.1840	33.6915	0.0000
6	7.6428	0.1771	7.0586	0.2163	29.2438	0.0000

HYBRID REITs and S&P 500

d	Ho4 F Stat	p-value	Ho3 F Stat	p-value	Ho2 F Stat	p-value
1	2.2000	0.6991	16.0930	0.0029	35.3051	0.0000
2	1.0201	0.9067	9.5120	0.0500	20.7075	0.0004
3	23.9905	0.0001	16.9458	0.0020	21.1017	0.0003
4	30.3724	0.0000	8.7520	0.0676	12.7093	0.0128
5	9.0083	0.0609	8.9606	0.0621	10.4322	0.0337
6	29.4803	0.0000	42.0122	0.0000	18.3910	0.0010

MORTGAGE REITs and S&P 500

d	Ho4 F Stat	p-value	Ho3 F Stat	p-value	Ho2 F Stat	p-value
1	1.8769	0.8659	17.8870	0.0031	13.6217	0.0182
2	2.2706	0.8106	30.3425	0.0000	4.7924	0.4417
3	3.4165	0.6361	34.3194	0.0000	4.7924	0.4417
4	5.2118	0.3906	25.6019	0.0001	6.2242	0.2850
5	6.4103	0.2683	18.9551	0.0020	7.4856	0.1870
6	6.6775	0.2457	18.2100	0.0027	5.3921	0.3699

Panel B: Australian REIT and Stock Indices

d	Ho4 F Stat	p-value	Ho3 F Stat	p-value	Ho2 F Stat	p-value
1	8.8987	0.1132	12.2584	0.0314	9.2428	0.0998
2	7.2378	0.2036	11.3245	0.0453	10.0185	0.0747
3	7.3265	0.1975	12.5237	0.0283	9.7419	0.0829
4	12.7768	0.0256	12.0983	0.0335	9.8982	0.0782
5	12.4598	0.0290	11.9163	0.0360	11.1160	0.0491
6	10.1613	0.0708	13.3223	0.0205	10.9776	0.518

Panel C: US and Australian REIT Indices

d	Ho4 F Stat	p-value	Ho3 F Stat	p-value	Ho2 F Stat	p-value
1	44.2362	0.0000	19.9909	0.0028	18.2500	0.0056
2	33.3460	0.0000	43.8039	0.0000	33.0793	0.0000
3	28.8012	0.0001	38.1381	0.0000	21.9706	0.0012
4	17.7946	0.0068	41.2468	0.0000	29.7229	0.0000
5	14.1071	0.0285	49.0795	0.0000	29.4949	0.0000
6	17.1959	0.0086	24.9869	0.0003	12.8696	0.0452

Note: 1. Null hypothesis of the nonlinear model specification for the LSTVECM versus the ESTVECM is given in equation (16).
2. d is the optimal lag length of the transition variable Z_{t-d} .
3. The testing statistics are adopted in the Wald test, and the specification of the testing statistics is given in equation (15).

Table 5-1 Estimated Results of Models in US REIT and US Stock Indices

Items		Equity REIT and Stock Indices		Hybrid REIT and Stock indices		Mortgage REIT and Stock Indices	
Models		LSTVECM-GARCH		ESTVAR-GARCH		ESTVECM -GARCH	
Mean Equations		Δp_t^h	Δp_t^s	Δp_t^h	Δp_t^s	Δp_t^h	Δp_t^s
Constant	α_0	-0.545 (-1.810**)	0.228 (0.225)	0.058 (3.732***)	0.037 (2.382*)	0.101 (3.982***)	0.053(2.168***)
z_{t-1}	α_1	-1.109 (-1.927**)	1.724(0.675)			-0.012(-0.207)	0.079 (1.000)
Δp_{t-1}^h	α_2	0.239 (4.357***)	-0.357 (-0.318)	0.035 (1.861*)	0.006(0.660)	0.140 (-0.207)	0.005 (0.402)
Δp_{t-1}^s	α_3	0.019(0.672)	2.447 (0.474)	-0.017(-1.334)	-0.045 (-4.377***)	-0.017 (-0.737)	-0.051 (-2.126**)
Constant	β_0	0.640 (2.111***)	-0.192 (-0.186)	-4.971(-0.003)	2.684(0.001)	-1.202 (-2.533**)	-0.134 (-0.960)
z_{t-1}	β_1	1.100 (1.768*)	-1.688 (-0.643)			-1.458 (-2.456**)	-0.410 (-2.751***)
Δp_{t-1}^h	β_2	-0.237(-3.944***)	0.368 (0.326)	-0.323(-0.005)	0.537(0.006)	-1.637 (-3.037***)	-0.066(-1.505)
Δp_{t-1}^s	β_3	-0.057(-1.605)	-2.544 (-0.492)	-1.937(-0.015)	0.688(0.002)	0.010 (0.033)	0.011(0.180)
Transition Speed	γ	39.655 (1.344)	3.662 (1.109)	392.258(0.122)	31.536(0.105)	1.258 (3.858***)	6.583 (1.655*)
Threshold Parameter	τ	0.151(1.559)	0.058 (2.383**)	0.070(0.030)	0.035(0.053)	0.199 (3.038***)	0.254 (1.715*)
Variance and Covariance Equations		$h_{h,t}$	$h_{s,t}$	$h_{h,t}$	$h_{s,t}$	$h_{h,t}$	$h_{s,t}$
Constant	ϕ_0, δ_0	0.028 (6.961***)	0.0106 (4.481***)	0.028 (64.243***)	0.010 (73.310***)	0.066 (13.627***)	0.009 (13.826***)
$\varepsilon_{h,t-1}^2, \varepsilon_{s,t-1}^2$	ϕ_1, δ_1	0.126 (12.138***)	0.065 (10.335***)	0.121 (13.632***)	0.064 (88.386***)	0.170 (19.448***)	0.065 (39.312***)
$h_{h,t-1}, h_{s,t-1}$	ϕ_2, δ_2	0.856 (70.041***)	0.928 (79.782***)	0.860 (114.558***)	0.929 (504.577***)	0.818 (101.352***)	0.930 (602.021***)
$h_{h.s,t}$	ρ	0.620 (61.112***)		0.498 (36.971***)		0.485 (47.410***)	

Notes：1. The specifications of the STVECM and VECM are given in equations (9)

2. The numbers in ( ) indicate the t-statistics.

3. ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively.

Table 5-2 Estimated Results of Models of Australian REIT and Stock Indices and US REIT and Australian REIT Indices

Items		Australian REIT and Stock Indices		US REIT and Australian REIT Indices	
Models		LSTVECM-GARCH		LSTVECM-GARCH	
Mean Equations		Δp_t^h	Δp_t^s	Δp_t^{h1}	Δp_t^{h2}
Constant	α_0	0.122 (10.620***)	0.024 (2.211**)	0.092 (4.210***)	11.733(0.847)
z_{t-1}	α_1	0.126 (2.623***)	-0.076 (-1.799*)	-0.051 (-0.293)	20.039(0.867)
Δp_{t-1}^h	α_2	0.004 (0.261)	-0.0085(-0.675)	0.020(0.864)	-0.467 (-0.732)
Δp_{t-1}^s	α_3	0.017(0.988)	-0.010 (-0.572)	-0.030(-0.989)	0.858 (0.894)
Constant	β_0	-0.100 (-8.124***)	0.254 (10.066***)	-0.516 (-1.928*)	-11.779(-0.848)
z_{t-1}	β_1	-0.001(-0.014)	-0.380 (-4.405***)	3.262(1.681)	-19.295(-0.840)
Δp_{t-1}^h	β_2	0.032(1.553)	0.063(1.981***)	-0.434 (-5.421***)	0.674 (1.055)
Δp_{t-1}^s	β_3	-0.124 (-6.665***)	-0.128 (-3.1636***)	0.237 (1.508)	-0.945(-0.980)
Transition Speed	γ	844.465 (1.607)	34.092 (15.720***)	15.435 (0.197)	8.129 (3.153**)
Threshold Parameter	τ	-0.040(-1.199)	-0.062(-13.652***)	-0.159 (-4.401***)	0.072 (5.713***)
Variance and Covariance Equations		$h_{h,t}$	$h_{s,t}$	$h_{h,t}$	$h_{s,t}$
Constant	ϕ_0, δ_0	0.013 (13.179***)	0.012 (15.204***)	0.027 (4.728***)	0.014 (4.680***)
$\varepsilon_{h,t-1}^2, \varepsilon_{s,t-1}^2$	ϕ_1, δ_1	0.087 (51.512***)	0.087 (41.669***)	0.144 (10.119***)	0.098 (8.798***)
$h_{h,t-1}, h_{s,t-1}$	ϕ_2, δ_2	0.901 (566.770***)	0.897 (501.108***)	0.858 (70.041***)	0.890 (79.782***)
$h_{h.s,t}, h_{h1.h2,t}$,	ρ	0.534 (51.158***)		0.122 (6.369***)	

Notes：1. The specifications of the STVECM and VECM are given in equations (9)
2. The numbers in ( ) indicate the t-statistics.
3. ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively.

Table 6 Results of the Nonlinear Granger Causality Test

Panel A: US Equity REIT and Stock Indices		
Equity REIT and Stock Indices		
Large Positive Deviation	(-0.900)	(3.617***)
Large Negative Deviation	(-1.149)	(2.191**)
Hybrid REIT and Stock Indices		
Large Positive Deviation	(0.759)	(2.459***)
Large Negative Deviation	(-0.597)	(2.300**)
Mortgage REIT and Stock Indices		
Large Positive Deviation	(-0.160)	(3.374***)
Large Negative Deviation	(0.932)	(3.450***)
Panel B: Australian REIT and Stock Indices		
Large Positive Deviation	(1.312*)	(1.643*)
Large Negative Deviation	(4.14***)	(4.802***)
Panel C: US and Australian REIT Indices		
Large Positive Deviation	(0.079)	(3.55***)
Large Negative Deviation	(-0.21)	(2.516**)

Notes：1. The numbers in ( ) indicate the t-statistics.
2. ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively.