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Nonlinear Short-Run Adjustments between House and Stock Prices in Emerging Asian Regions

Summary: This study uses the powerful nonparametric cointegration test to examine whether nonlinear cointegration exists between prices of used houses and corresponding stock markets in China and the four Asian Tigers. Then, it uses the smooth transition vector error-correction model (STVECM) to explore the adjustment efficiencies of the short-run house and corresponding stock-return dynamics when there is disequilibrium between house and stock prices. The empirical results indicate that there is a nonlinear cointegration between the house prices and corresponding stock prices in China, South Korea, Singapore, and Taiwan, and that the speed of price adjustment to equilibrium is always greater for houses than stocks when there are large positive and negative deviations. Moreover, the short-run speed of adjustment of the large negative and positive deviations is equal in China, South Korea, and Taiwan, but unequal in Singapore. With the exception of South Korea, the results of the Granger causality test indicate that stock prices clearly lead used house prices, which means a wealth effect exists in most Asian countries. Our study confirms that the STVECM can be used to analyze the short-run adjustment efficiency of house and stock return dynamics in China, South Korea, Singapore, and Taiwan; thus, supporting models of interaction between noise and arbitrage traders.

Key words: China, Four Asian Tigers, Smooth transition vector error-correction model, Nonparametric cointegration, Price discovery.

JEL: C32, C51, C52, D53, G11, R31.

Abundant government control exists in the form of price and trading limits and institutional investors tend to dominate prices in the stock and housing markets of Asian regions. Hence, the price adjustments can be nonlinear and asymmetric as reverting to equilibrium between both markets in these countries. Furthermore, because of the behavior patterns of different investors, the price adjustment speeds dynamically reverting to equilibrium in both markets can either be delayed or accelerated to result in variations in return dynamics governing the small and large deviations. Meanwhile, the trading of the used housing market in Asia is more active than that of the real estate investment trusts (REITs). Thus, institutional investors in Asian countries are more likely to simultaneously invest in the used housing and stock markets to perform the arbitrage trading or diversify investing risk. In terms of the four Asian Tigers (i.e., Taiwan, Hong Kong, South Korea, and Singapore) and China with the greatest potential for economic development in Asia, institutional investors who concurrently invest in both housing and stock markets are eager to know the lead-lag relation and short-run adjusting patterns between both markets. Therefore, this study focuses on analyzing the respective price transmissions with diverse dynamic adjusting speeds as reverting to equilibrium between the stock and housing markets in these countries, which can follow gradual and smooth translating patterns. Tables and estimation procedures are presented in the Appendix.

1. Literature Review

Although some scholars believe that there is no direct relationship between the stock market and the real estate market (David Geltner 1990; Mike Miles, Rebel Cole, and David Guilkey 1990; Arvind Pai and Geltner 2007), most scholars argue that a clear relationship exists between the two markets (Crocker H. Liu et al. 1990; Brent W. Ambrose, Esther Ancel, and Mark D. Griffiths 1992; Joseph Gyourko and Donald B. Keim 1992; Sorin A. Tuluca, F. C. Neil Myer, and James R. Webb 2000; Kim Hiang Liow and Haishan Yang 2005; Eddie Chi Man Hui and Shen Yue 2006). Different scholars have varying perspectives on whether an interactive relationship exists between the stock market and the market prices of real estate. If a direct relationship between stock and real estate prices is observed, then these prices will influence each other, leading to price fluctuations in both markets. Pursuant to the so-called wealth effect, investor wealth will increase when the stock price rises; perhaps, this response is meant to further diversify risk. In this situation, funds will be transferred from the stock market to real estate, which has the potential to appreciate, and as a result, the price of real estate will rise. Many previous studies confirm the existence of a cointegration relationship between the real estate and stock markets (Tuluca, Myer, and Webb 2000; Liow and Yang 2005; Hui and Yue 2006).

Meanwhile, recent studies suggest that the relationship between the two markets can be better identified by using a nonlinear model (John Okunev and Patrick J. Wilson 1997; John L. Glascock, Chiuling Lu, and Raymond W. So 2000; Tuluca, Myer, and Webb 2000; Liow and Yang 2005; Yu-Shao Liu and Chi-Wei Su 2010; Su 2011; Su, Hsu Ling Chang, and Meng Nan Zhu 2011; Benjamas Jirasakuldech and Riza Emekter 2012). Nikolaos Giannellis, Angelos Kanas, and Athanasios P. Papadopoulos (2010) demonstrate the strong interdependence and asymmetric behavior between stock market and real activity in the UK. Using a nonlinear method to test the degree of integration, Okunev and Wilson (1997) find that real estate markets have a nonlinear relation to stock markets. However, the timing of mean reversion between the two markets is quite slow, and deviations between the two markets may be prolonged. Using fractional cointegration, Wilson and Okunev (1999) do not find comemories between the stock and real estate markets in the US and the UK. However, they find evidence of long comemory in Australia and in relation to either side of the 1987 market correction. The nonlinear mean reversion between every real estate market and its stock market counterpart does not necessarily follow the result of long memory, but this phenomenon can exhibit both slow and fast price adjustments until the gradual smooth transition to the equilibrium.

According to theoretical models of the interaction between noise and arbitrage traders, noise traders tend to overreact to returns after the arrival of news (Harrison Hong and Jeremy C. Stein 1999; David G. McMillan 2004). When small deviations occur between house and stock prices, such noise traders tend to drive returns further away from equilibrium before a correction is made. At the moment, arbitrageurs are reluctant to immediately trade in price persistent when deviations occur from the equilibrium over a short time horizon based on the risk of "misprice deepening" (Andrei Shleifer 2000; McMillan 2004). However, when the large deviations from equilibrium occur in the two markets, arbitrageurs or hedgers are more likely to drive housing and stock prices to quickly revert to equilibrium, because their risk exposure to adverse price movements tends to be lower. More specifically, the theoretical model suggests that the trading behaviors of investors governing small return deviations from the fundamental equilibrium differ from those governing large return deviations. This phenomenon results in the notion that the relationship of the price movements to each market is represented by a nonlinear model. The smooth transition vector error-correction model (STVECM) should be able to capture the real estate and stock market dynamics with both large and small returns and to allow gradual movement between regimes.

Considering these findings, the current study analyzes whether a nonlinear cointegration relationship exists between house prices and the corresponding stock prices in specific areas. Furthermore, this study explores whether the STVECM can be used to describe the process, whereby house and stock prices dynamically adjust and return to equilibrium. In addition, past empirical findings on the leading and lagged relationships between stock and real estate prices have not yielded a consistent conclusion. Rather, past studies primarily tested the correlation between stock prices and real estate prices using the Granger causality test. Kwong Wing Chau, Vincent S. M. Ma, and Daniel C. W. Ho (2001) note that a rise in the S&P 500 stock price index can lead to a decline in the real estate price index developed by Jones Lang Wooten (JLW) in the next session. However, Hui and Yue (2006) find that the prices of used houses in Beijing and Shanghai influence the stock price index in Shanghai, but the stock price index does not influence the corresponding house prices. The results of Okunev, Wilson, and Ralf Zurbruegg (2000) show that an unstable nonlinear relationship and a two-way Granger causality exist between the prices of real estate and stocks. Using the Granger causality test, the results of Liu and Su (2010) indicate the existence of a long-run nonlinear relationship and asymmetric adjustment between the Shenzhen Composite Index and the Real Estate Price Index in China. Meanwhile, Cristiana Tudor (2011) proposes that the Granger causality test can examine the causal relationships among some financial markets. Therefore, in our study of the causal relationship between the real estate index and the stock index, we use the extensively applicable and detailed causality test proposed by Clive W. J. Granger (1969), which analyzes whether stock prices lead house prices, thus producing a wealth effect in these areas.

Because the economic growth of developed markets in Europe and the US has slowed down and certain European countries have experienced a credit crisis, global funds have continued to flow into emerging markets in recent years. In particular, these markets in Asian emerging markets have a large population; low average age, salaries, and wages; and plentiful natural resources. As funds will continue to be injected into the four Asian Tigers and China, the profits of investors in the housing and stock markets of such areas cannot be ignored. In fact, in its Global Property Guide, Forbes indicates that international funds will soon enter Asia on a large scale. Take Taiwan as an example. The funds injected into the housing market amount to at least $US 16.9 billion. This means that for each $US 3 billion increase in foreign reserves, nearly $US 1 billion in hot money is injected into the housing market. Net purchases of Taiwanese stocks funded by foreign investment reached $US 15.62 billion in the same year, driving stock prices up by 78% in compliance with the trend. Take Singapore as another example. The influx of funds drove house prices up by 38.1% in 2009 and, concurrently, drove stock prices up by 10.38%. During the early part of 2010, hot money continued to flow into Asia. According to statistical data provided by the various securities exchanges, net purchases of stocks in Asia, which are funded by foreign investments, amounted to $US 5.32 billion through January 20, 2010, surpassing the monthly level of net sales of $US 4.8 billion in 2009.

Given that most institutional investors in these Asian countries either make the arbitrage trading or diversify investing risk in the stock and housing markets, their interactions with individual investors (i.e., most noise traders) determine price transmissions in both markets accompanied by the small and large return dynamics deviating from equilibrium. The small return dynamics can be slow, whereas the large return dynamics can be fast until these price transmissions gradually and smoothly translate to the equilibrium.

2. Data and Analysis of Descriptive Statistics

2.1 Scope of the Data

The data used in this study are for the used housing and stock markets in the four Asian Tigers and China. The market prices of used houses are based on seasonal or monthly data from the housing price index of Sinyi Real Estate Development Corp. in Taiwan, the price index for private property in Hong Kong, the sales price index for dwellings in South Korea, the residential price index in Singapore, and the price index for Shanghai secondhand housing in China. The price indices of used houses of the former three regions are representative of the various market prices and are approved by international academic journals (Hyun Bang Shin 2009; Pei-Fen Chen, Mei-Se Chien, and Chien-Chiang Lee 2011; Hui and Ka Hung Yu 2012). Among them, Sinyi's house price index in Taiwan has been adopted by Chen, Chien, and Lee (2011), the private property price index in Hong Kong has been adopted by Hui and Yu (2012), and the sales price index for dwellings in Korea has been used by Shin (2009). Thus, the price indices of used houses in these three regions have international authority. The residential price index in Singapore and the private property price index in Hong Kong are separately compiled by official institutions, which are authorized by their respective governments. In addition, the price index for Shanghai secondhand housing in China, mostly represented by the prices of used houses in China, is compiled by the office of the index for Shanghai secondhand housing, which are formed by the academic associations and private institutions of house properties. Hence, the housing index in China has research authority. Moreover, the corresponding stock market prices are based on seasonal or monthly data from the representative and internationally recognized the Capitalization Weighted Stock Index of Taiwan, the Hang Seng Index of Hong Kong, the Composite Stock Price Index of South Korea, the Straits Times Index of Singapore, and the Shanghai Composite Stock Index of China.

Given that the representative used house price data sets for the four Asian Tigers and China cover different periods, the current study considers the beginning and end dates of the used house price index for both the house price and stock price indices that represent each area. Therefore, the data from the house price index and the stock price index in Taiwan extend from the first quarter of 1998 to the second quarter of 2010, whereas the Hong Kong data extend from January 1993 to February 2010, the Singapore data extend from the first quarter of 1995 to the first quarter of 2010, and the China data extend from November 2001 to March 2010. According to the arguments of Craig S. Hakkio and Mark Rush (1991), 18 years of observations should be enough to determine whether two time-series variables are cointegrated and the ability of detecting cointegration depends more on the total sample length relative to the long-run length than on the mere number of observations. The sample periods in the current study cover 1993/1995/1998 to 2010 with quarterly or monthly data (i.e., between 12 and 17 years), which very approaches 18 years. Thus, our results should be supposed to be the long-run period of the economic model. For this reason, we examine the long-run relationship between the used house price index and stock price index in each region in our sample. The data source for the used house price index is the Informational Center for Real Estate within the Ministry of the Interior in Taiwan, whereas that for the stock price index is the Taiwan Economic Journal Data Bank (2014)[1].

2.2 A Descriptive Statistical Analysis of House and Stock Prices

Overall, the trends in used house prices and the corresponding stock prices in the above locations, with the exception of Hong Kong, exhibit a positive relationship (Taiwan 0.48, Hong Kong -0.12, South Korea 0.82, Singapore 0.54 and China 0.60). The descriptive statistics for the used house index returns in China and the four Asian Tigers, as presented in Table 1a, indicate that the average real estate index return for used houses in China is significantly higher than that for the other four countries, which indicates that the return on the used house price index in China is higher on average than that in the four Asian Tigers. This result is partially due to the fact that economic growth in China during the last 10 years has resulted in an increase in local house prices. Regarding the standard deviations in Table 1a, we should note that the fluctuations in the real estate index return for used house prices in Singapore are significantly higher than those in the other countries, which indicates that the house price index return from investing in the used housing market in Singapore during the

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[1] **Taiwan Economic Journal.** 2014.http://www.finasia.biz/ensite/Database/tabid/92/language/en-US/Default.aspx (accessed January 01, 2014).

last 10 years has been accompanied by large fluctuations in prices. In addition, the performance of the real estate index return in Taiwan cannot be overlooked. In recent years, investors in China have flocked to Taiwan and inflows of hot money have surged, thereby causing house prices to increase rapidly and resulting in a continuous increase in house prices in Taiwan. Regarding the skewness coefficient, we note that the house price index returns for used houses in Korea, Hong Kong, and Singapore are left-skewed, whereas the returns for used houses in the other two countries are right-skewed. The house price index returns for used houses in these countries all exhibit leptokurtic behavior, which shows that the probability of extreme used house prices in these countries is high. Moreover, the same table indicates that the Jarque-Bera test results for the used house index returns for all countries, except Singapore, are significantly different from zero, which shows that the used house index returns in countries other than Singapore do not conform to the normal distribution. According to the Ljung-Box *Q* test, the used house price index returns in all countries considered, with the exception of Taiwan, exhibit time series autocorrelation.

The descriptive statistics for the stock index returns in China and the four Asian Tigers in Table 1b show that the average stock price index return in South Korea is significantly higher than that of the other four locations, which shows that the South Korean stock market has performed excellently in recent years. The standard deviations presented in the same table indicate that the fluctuations in the stock price index returns in Hong Kong and Taiwan are higher than those in the other three countries. In particular, the stock price index returns for Hong Kong have significantly greater fluctuations because stock prices have fallen sharply since Hong Kong's return to China and investor confidence has recovered gradually. Taiwan has significantly greater fluctuations in both its used house index returns and stock price index returns, which shows that house price fluctuations and stock price fluctuations in Taiwan should exhibit a close relationship. Regarding the skewness coefficient, we note that China, Singapore, and Hong Kong are left-skewed, whereas the other countries are right-skewed. Regarding the kurtosis coefficient, we note that the stock price index returns in these countries all exhibit leptokurtic behavior, which shows the high probability of extreme values for the stock prices in all countries considered. Moreover, the results in the same table indicate that the Jarque-Bera test results for the stock price index returns in China and the four Asian Tigers are significantly different from zero, which shows that these stock price index returns do not conform to the normal distribution. Based on the Ljung-Box *Q* test results, we can confirm that the stock price index returns in all countries considered, other than Korea and Hong Kong, exhibit time series autocorrelation.

Combining the results in Tables 1a and 1b, we find that the standard deviations of the used house index returns are larger than those of the stock index returns in China, South Korea, Singapore, Taiwan, and Hong Kong, respectively. The finding supports the notion that the speed of adjustment when house prices revert to equilibrium is greater than that for stock prices, perhaps because the volatility of changes in house prices is lower than the volatility of changes in stock prices. We also find that the average house index return is significantly higher than the average stock index return in China and Taiwan. This finding suggests that the habits of investors simultaneously investing in used houses and stocks in these two countries are very rigid.

3. Methodology

3.1 Unit Root Test

This study uses the KSS nonlinear stationarity test developed by George Kapetanios, Yongcheol Shin, and Andy Snell (2003), in addition to the traditional unit root tests. This is done so as to reinforce the power of the unit root test for nonlinear dynamic adjustments of the house and stock indices in China and the four Asian Tigers. Meanwhile, the goal of the KSS test is to detect the presence of nonstationarity against a nonlinear but stationary exponential smooth transition autoregressive (ESTAR) process. The procedure and illustration of ESTAR model is shown in the Appendix.

3.2 Nonparametric Cointegration Test

The nonparametric cointegration test developed by Herman J. Bierens (1997) and Johansen's LR approach (Søren Johansen 1988; Johansen and Katarina Juselius 1990) have similar properties. These properties are derived from the solutions to the test statistics for a generalized eigenvalue problem. However, the main difference is that in Bierens' nonparametric cointegration approach, the generalized eigenvalues are formulated based on two random matrices, which are constructed independently of the data generation process. In Johansen's approach, the system variables in levels and the first differences are constructed in the fixed-weight matrices.

Bierens' nonparametric cointegration test considers the following framework: π_0 and π_1 are the optimal mean and trend terms, respectively, and y_1 is a zero-mean unobservable process such that Δy_t is stationary:

$$Z_t = \pi_0 + \pi_1 t + y_t. \tag{1}$$

Bierens' method does not require the specification of a data generation process for Z_t, and this method is based on the generalized eigenvalues of the matrices A_m and $(B_m + cT^{-2} A_m^{-1})$. The illustrations about the elements and procedure of Bierens's nonparametric cointegration method are shown in the Appendix. As noted by Bierens (1997), one of the major advantages of this nonparametric cointegration test is its superior ability to detect cointegration, especially when the error-correction mechanism is nonlinear.

3.3 Estimations of the VECM or VAR

With the continued increase of the number of informed traders who have simultaneously invested in the stock and used house markets, price changes in such markets in the four Asian Tigers and China may occur simultaneously. With the aim of clarifying whether informed traders substantially participate in a single market or both markets, this part of the study individually examines each of the four Asian Tigers and China, to determine which market has more information implications in the process of price discovery. Working from the assumption that a long-term equilibrium exists between stock prices and house prices in these regions, as verified by David C. Ling and Andy Naranjo (1999) and by Tuluca, Myer, and Webb (2000), we use the VECM to determine the short-term adjustment speeds for stock and house prices that are reverting toward equilibrium when such prices deviate from the long-term equilibrium, and to examine which prices revert more efficiently. However, if a cointegration relationship does not exist between the stock price and the house price in these locations, we use a VAR model to explore the degree of dependence between prices. In what follows, this study considers a single location as a preliminary example that allows us to construct the VECM, as in Equation (2), where ΔP_t^h and ΔP_t^s represent the house price returns and the stock price returns, respectively, $Z_{t-1} = (P_{t-1}^s - c_0 - c_1 P_{t-1}^h)$ represents the error-correction term for the house price P_t^h and the stock price P_t^s. a_1^h (a_1^s) shows the speed of adjustment in the reversion to equilibrium after the house price (stock price) deviates from equilibrium.

$$\begin{aligned} \Delta P_t^h &= a_0^h + a_1^h Z_{t-1} + \sum_{i=1}^{q} a_{i+1}^h \Delta P_{t-i}^s + \sum_{i=1}^{q} a_{i+1+q}^h \Delta P_{t-i}^h + \varepsilon_t^h; \\ \Delta P_t^s &= a_0^s + a_1^s Z_{t-1} + \sum_{i=1}^{q} a_{i+1}^s \Delta P_{t-i}^s + \sum_{i=1}^{q} a_{i+1+q}^s \Delta P_{t-1}^h + \varepsilon_t^s. \end{aligned} \tag{2}$$

If a cointegration relationship exists between the current house price and stock price, a_1^h and a_1^s should have the "opposite" signals. If $\left|a_1^s\right|$ is less than $\left|a_1^h\right|$ ($s \neq h$), the stock price will revert to equilibrium more rapidly than the house price, which means that the stock price will have a greater influence on price discovery than the house price (referring to Qian Sun, Wilson H. S. Tong, and Yuxing Yan 2009). Then, we use one of the countries as a preliminary example to construct the VAR model, as in Equation (3):

$$\begin{aligned} \Delta P_t^h &= a_0^h + \sum_{i=1}^{q} a_i^h \Delta P_{t-i}^s + \sum_{i=1}^{q} a_{i+q}^h \Delta P_{t-i}^h + \varepsilon_t^h; \\ \Delta P_t^s &= a_0^s + \sum_{i=1}^{q} a_i^s \Delta P_{t-i}^s + \sum_{i=1}^{q} a_{i+q}^s \Delta P_{t-i}^h + \varepsilon_t^s. \end{aligned} \tag{3}$$

3.4 Nonlinearity Test and Estimations of the STVECM or STVAR

To further capture the different return dynamics of both the small and large deviations from the comovement between stock and house prices, this study uses the STVECM to allow for a smooth transition between different types of return behavior in different regimes. Thus, Equation (1) can be rewritten as follows:

$$\begin{aligned}\Delta P_t^h &= a_0^h + a_1^h Z_{t-1} + \sum_{i=1}^{q} a_{i+1}^h \Delta P_{t-i}^s + \sum_{i=1}^{q} a_{i+1+q}^h \Delta P_{t-i}^h + \\ &\left(\beta_0^h + \beta_1^h Z_{t-1} + \sum_{i=1}^{q} \beta_{i+1}^h \Delta P_{t-i}^s + \sum_{i=1}^{q} \beta_{i+1+q}^h \Delta P_{t-i}^h \right) \times F(Z_{t-d} : \gamma, \tau) + \varepsilon_t^h; \\ \Delta P_t^s &= a_0^s + a_1^s Z_{t-1} + \sum_{i=1}^{q} a_{i+1}^s \Delta P_{t-i}^s + \sum_{i=1}^{q} a_{i+1+q}^s \Delta P_{t-i}^h + \\ &\left(\beta_0^s + \beta_1^s Z_{t-1} + \sum_{i=1}^{q} \beta_{i+1}^s \Delta P_{t-i}^s + \sum_{i=1}^{q} \beta_{i+1+q}^s \Delta P_{t-i}^h \right) \times F(Z_{t-d} : \gamma, \tau) + \varepsilon_t^s.\end{aligned} \tag{4}$$

However, if a cointegration relationship does not exist between stock and house prices in any given location, we use the STVAR to smoothly transform the return dynamics under different regimes and to capture the different dynamics of the stock price returns and the house price returns under the lower and higher return regimes by location. Thus, Equation (3) can be rewritten as follows:

$$\begin{aligned}\Delta P_t^h &= a_0^h + \sum_{i=1}^{q} a_i^h \Delta P_{t-i}^s + \sum_{i=1}^{q} a_{i+q}^h \Delta P_{t-i}^h + \left(\beta_0^h + \sum_{i=1}^{q} \beta_i^h \Delta P_{t-i}^s + \sum_{i=1}^{q} \beta_{i+q}^h \Delta P_{t-i}^h \right) \times \\ &F(\Delta r_{t-d} : \gamma, \tau) + \varepsilon_t^h; \\ \Delta P_t^s &= a_0^s + \sum_{i=1}^{q} a_i^s \Delta P_{t-i}^s + \sum_{i=1}^{q} a_{i+q}^s \Delta P_{t-i}^h + \left(\beta_0^s + \sum_{i=1}^{q} \beta_i^s \Delta P_{t-i}^s + \sum_{i=1}^{q} \beta_{i+q}^s \Delta P_{t-i}^h \right) \times \\ &F(\Delta r_{t-d} : \gamma, \tau) + \varepsilon_t^s.\end{aligned} \tag{5}$$

The STVECM or STVAR is theoretically superior to the threshold model, which directly imposes an abrupt change in parameter values. $F(Z_{t-d} : \gamma, \tau)$ ($F(r_{t-d} : \gamma, \tau)$) in Equation (4) (Equation (5)) is the smooth transition function. As numerous traders in the stock and house markets act simultaneously and heterogeneously due to differing market expectations, the STVECM or STVAR is more appropriate to describe investment behavior associated with gradual changes according to different market compositions. This will only be a threshold transition model if all participants act simultaneously in the housing and stock markets. The STVECM (STVAR) is governed by the continuous transition function $F(Z_{t-d} : \gamma, \tau)$ ($F(\Delta r_{t-d} : \gamma, \tau)$). Z_{t-d} is the transition variable, *d* is the optimal lag length of the transition variable Z_{t-d} and Δr_{t-d} represents the fluctuation in the monthly deposit interest rate before period *d*. γ is the smoothness parameter that measures the speed of transition from the regime with small deviations to the regime with large deviations and τ is the threshold parameter that determines where the transition occurs. As in Timo Teräsvirta (1994), two alternative specifications of the transition function in Equation (4) (Equation (5)) are considered:

$$F(Z_{t-d}:\gamma,\tau)=\left\{1+\exp\left[-\gamma(Z_{t-d}-\tau)/\sigma_{Z_{t-d}}\right]\right\}^{-1},\gamma>0. \tag{6}$$

$$F(\Delta r_{t-d}:\gamma,\tau)=\left\{1+\exp\left[-\gamma(\Delta r_{t-d}-\tau)/\sigma_{\Delta r_{t-d}}\right]\right\}^{-1},\gamma>0. \tag{7}$$

$$F(Z_{t-d}:\gamma,\tau)=1+\exp\left[-\gamma(Z_{t-d}-\tau)^2/\sigma_{Z_{t-d}}\right],\gamma>0. \tag{8}$$

$$F(\Delta r_{t-d}:\gamma,\tau)=1+\exp\left[-\gamma(\Delta r_{t-d}-\tau)^2/\sigma_{\Delta r_{t-d}}\right],\gamma>0. \tag{9}$$

Equation (4) (Equation (5)) with transition function (6) (Equation (7)) is called the logistic STVECM or LSTVECM (logistic STVAR or LSTVAR). The LSTVECM (LSTVAR) implies different dynamics for the two return regimes with a smooth transition function $F(Z_{t-d}:\gamma,\tau)=0\sim 1$ as $Z_{t-d}=-\infty\sim+\infty$. A logistic transition function allows the parameters of the STVECM (STVAR) to change monotonically with Z_{t-d} (Δr_{t-d}). The illustrations about the characteristic and translating process of LSTVECM (LSTVAR) and ESTVECM (ESTVAR) are shown in the Appendix.

Equation (4) (Equation (5)) with transition function represented by Equation (8) (Equation (9)) is called the exponential STVECM or ESTVECM (exponential STVAR or ESTVAR). This equation implies that there are different dynamics in the transition period but similar dynamics under the extreme regimes, for $F(Z_{t-d}:\gamma,\tau)$ ($F(\Delta r_{t-d}:\gamma,\tau)$) → 1 as $|Z_{t-d}|\to+\infty(|\Delta r_{t-d}|\to+\infty)$. The ESTVECM (ESTVAR) may be viewed as a generalization of the TVECM (TVAR) with two thresholds used to distinguish among three regimes, where one is within the equilibrium and two are outside the equilibrium. The ESTVECM (ESTVAR) allows the parameters to change symmetrically around τ with Z_{t-d} (Δr_{t-d}).

4. Empirical Results

4.1 Results of the Unit Root Tests

The results of the KSS nonlinear stationarity test in Table 2 indicate that the used house price and corresponding stock price series in China and the four Asian Tigers all have linear unit roots with stationary first-order differences, confirming that the used house prices and stock prices are I(1) sequences in these Asian countries. Given the presence of nonlinearity, this study uses the powerful nonparametric cointegration tests proposed by Bierens (1997) to separately examine the cointegration relationship between the used house prices and stock prices in China and the four Asian Tigers.

4.2 Results of the Nonparametric Cointegration Test

Table 3 presents the results for both the $\lambda_{\min}$ and $g_m(r_0)$ test statistics for China and the four Asian Tigers. The $\lambda_{\min}$ test results for China, South Korea, Singapore, and Taiwan refute the hypothesis of r = 0 and support that of r = 1, and the minimum value of the $g_m(r_0)$ statistic appears in the cointegration rank of $r = 1$. These results consistently imply that there is comovement between house and stock prices in these Asian countries. Therefore, we use the comovement relationship in each region to establish the models for the short-run dynamics of house and stock prices. The $\lambda_{\min}$ test results for Hong Kong support the hypothesis of $r = 0$ and the minimum value of the $g_m(r_0)$ statistic appears in the cointegration rank of $r = 0$, implying that there is no comovement trend. Thus, we consider a non-comovement relationship (excluding the error-correction term) to establish a model for the short-run dynamics of house and stock prices in Hong Kong.

4.3 Nonlinear Test Results and Estimation Results for the VECM (or VAR) and STVECM (or STVAR)

The results of the Wald test of linearity against the nonlinear STVECM or STVAR in Table 4 provide significant evidence of nonlinearity in the relationship between house and stock prices in China and the four Asian Tigers. To specify d, we estimate a range of values for d, $(1 \leq d \leq 6)$, in which the F-statistics with the minimum p-value or the maximum F-statistics determine the optimal value of d. The results presented in Table 5 show that H_{03} is rejected for $d = 5$ ($d = 2$) and $d = 3$ in China (South Korea, Taiwan) and Hong Kong, indicating that the ESTVECM and ESTVAR are more appropriate models, while H_{04} is rejected for $d = 2$ in Singapore, indicating that the LSTVECM is a more appropriate model. The Z_{t-1} coefficients of house and stock prices in China, Korea, Singapore and Taiwan, as shown in Tables 6, 7, 8, and 9, all exhibit mean reversion toward equilibrium. In addition, the absolute values of the house price coefficients of the VECM in China, Korea, Singapore, and Taiwan are all smaller than those of the stock price coefficients. Thus, we can conclude that the mean reversion speed of house prices is greater than that of stock prices. This finding implies that the used house market drives the comovement equilibrium of house and stock prices.

To explore the predictive power of used house and stock prices in these Asian countries, this study uses the widely accepted and detailed Granger (1969) causality test to separately analyze the lead/lag relationship between house and stock prices. Results of the Granger causality test show that stock prices drive house prices in all regions, except in South Korea where the opposite result is observed. This result may be attributed to some investors opting to rebalance their portfolios by selling stocks and purchasing other assets, such as houses, to diversify their risks after their wealth increases resulting from the rise in stock prices in China, Singapore, Taiwan, and Hong Kong. Hence, this can lead to a natural surge in the respective housing markets of these regions (Panayotis Kapopoulos and Fotios Siokis 2005; Liu and Su 2010). In addition, the individual house and stock returns under LSTVECM (or STVAR) in China and the four Asian Tigers will have relatively lower residual variance than those under VECM (or VAR) without any evidence of the ARCH effects or error autocorrelation. The combined house and stock returns under STVECM (or STVAR) have lower AIC and SBIC values than those under VECM (or VAR), and their likelihood values are larger than those under VECM (or VAR).

The results for the house and stock returns under the STVECM (or STVAR) in Tables 6, 7, 8, 9, and 10 consistently show positive γ estimates and most of them are large, indicating that there is a rapid transition from one regime to another. Although the partial values of γ are not significantly different from zero, Lucio Sarno (2000) argues that the statistical significance of γ is not in question because the null hypothesis of linearity in the housing and stock markets has already been rejected by earlier tests. This finding confirms that the error-correction process for house and stock prices is a smooth transition. Teräsvirta (1994) claimed that the statistical insignificance of γ should not be interpreted as evidence of weak nonlinearity. Nicholas Sarantis (1999) further highlighted the difficulty of estimating γ. The estimated results for the smooth transition functions in the housing and stock price dynamics in China and the four Asian Tigers are listed in Equations (6), (7), (8), (9) and (10). These results further confirm that the smooth transition functions for house and corresponding stock returns in China, South Korea, Taiwan, and Hong Kong follow the exponential transition type, whereas those in Singapore followthe logistic transition type.

$$\begin{aligned}\text{China: } F(Z_{t-5} \mid \gamma,\tau) &= \{1-\exp[-92.219(Z_{t-5}+0.081)^2]\}\\ F(Z_{t-5} \mid \gamma,\tau) &= \{1-\exp[-151.166(Z_{t-5}+0.064)^2]\};\end{aligned} \tag{10}$$

$$\begin{aligned}\text{South Korea: } F(Z_{t-2} \mid \gamma,\tau) &= \{1-\exp[-18.588(Z_{t-2}-0.017)^2]\}\\ F(Z_{t-2} \mid \gamma,\tau) &= \{1-\exp[-84.060(Z_{t-2}-0.072)^2]\};\end{aligned} \tag{11}$$

$$\begin{aligned}\text{Singapore: } F(Z_{t-2} \mid \gamma,\tau) &= \{1+\exp[-0.05(Z_{t-2}-0.24)/0.115]\}^{-1}\\ F(Z_{t-2} \mid \gamma,\tau) &= \{1+\exp[-3.06(Z_{t-2}-0.22)/0.115]\}^{-1};\end{aligned} \tag{12}$$

$$\begin{aligned}\text{Taiwan: } F(Z_{t-2} \mid \gamma,\tau) &= \{1-\exp[-453.810(Z_{t-2}-0.162)^2]\}\\ F(Z_{t-2} \mid \gamma,\tau) &= \{1-\exp[-34.060(Z_{t-2}-0.143)^2]\};\end{aligned} \tag{13}$$

$$\begin{aligned}\text{Hong Kong: } F(\Delta r_{t-3} \mid \gamma,\tau) &= \{1-\exp[-158.849(\Delta r_{t-3}-0.131)^2]\}\\ F(\Delta r_{t-3} \mid \gamma,\tau) &= \{1-\exp[-604.860(\Delta r_{t-3}-0.007)^2]\}.\end{aligned} \tag{14}$$

Regarding the house and stock returns in China, we should note that the transition from the lower, smaller deviation to the symmetric upper, larger deviation is nearly instantaneous around the threshold values of Z_{t-5} = -0.58, -0.08 to 0.50, and -0.50, 0.06 to 0.62. For the house and stock returns in South Korea, the transition from the lower, smaller deviation to the symmetric upper, larger deviation is nearly instantaneous around the threshold values of Z_{t-2} = -0.43, 0.02 to 0.46, and -0.31, 0.07 to 0.44. For the house and stock returns in Singapore, the transition from the lower regime to the higher regime is at the threshold values of Z_{t-2} = 0 to 0.24 and 0 to 0.22. For the house and stock returns in Taiwan, the transition from the lower, smaller deviation to the symmetric upper, larger deviation is nearly instantaneous around the threshold values of Z_{t-2} = -0.20, 0.16 to 0.52, and -0.26, 0.14 to 0.54. For the house and stock returns in Hong Kong, the transition from the lower, smaller return regime to the symmetric upper, larger return regime is nearly instantaneous around the threshold values of Δr_{t-3} = -0.28, 0.13 to 0.41, and -0.46, 0.01 to 0.48. In China, South Korea, Taiwan, and Hong Kong, the short-run return dynamics of the house and stock prices reach the lower regime as $Z_{t-5}-\tau, Z_{t-2}-\tau, Z_{t-2}-\tau, Z_{t-2}-\tau, \Delta r_{t-3}-\tau \to 0$ and $F(Z_{t-5} \mid \gamma,\tau)$, $F(Z_{t-2} \mid \gamma,\tau)$, $F(Z_{t-2} \mid \gamma,\tau)$, $F(Z_{t-5} \mid \gamma,\tau), F(Z_{t-2} \mid \gamma,\tau), F(Z_{t-2} \mid \gamma,\tau)$, $F(Z_{t-2} \mid \gamma,\tau), F(\Delta r_{t-3} \mid \gamma,\tau) \to 0$ whereas they reach the upper regime as $Z_{t-5}-\tau$, $Z_{t-2}-\tau$, $Z_{t-2}-\tau$, $Z_{t-2}-\tau$, $\Delta r_{t-3}-\tau \to -\infty$ and $+\infty$ and $F(Z_{t-5} \mid \gamma,\tau), F(Z_{t-2} \mid \gamma,\tau)$, $F(Z_{t-2} \mid \gamma,\tau)$, $F(Z_{t-2} \mid \gamma,\tau)$, $F(\Delta r_{t-3} \mid \gamma,\tau) \to 1$.

In Singapore, the short-run return dynamics of the house and stock prices reach the lower regime as $Z_{t-5}-\tau, Z_{t-2}-\tau, Z_{t-2}-\tau, Z_{t-2}-\tau, \Delta r_{t-3}-\tau \to -\infty$ and $F(Z_{t-5} \mid \gamma,\tau)$, $F(Z_{t-2} \mid \gamma,\tau)$, $F(Z_{t-2} \mid \gamma,\tau)$, $F(Z_{t-2} \mid \gamma,\tau)$, $F(\Delta r_{t-3} \mid \gamma,\tau) \to 0$, whereas they reach the higher regime as $Z_{t-5}-\tau, Z_{t-2}-\tau, Z_{t-2}-\tau, Z_{t-2}-\tau, \Delta r_{t-3}-\tau \to -\infty$ and $F(Z_{t-5} \mid \gamma,\tau)$, $F(Z_{t-2} \mid \gamma,\tau), F(Z_{t-2} \mid \gamma,\tau), F(Z_{t-2} \mid \gamma,\tau), F(\Delta r_{t-3} \mid \gamma,\tau) \to 1$. Thus, the short-run adjustment dynamics for the negative and positive upper regimes are symmetric around τ in China, South Korea, Taiwan, and Hong Kong, whereas those for the large positive and negative deviations are asymmetric around τ in Singapore.

The Z_{t-1} coefficients of the used house (composite stock) returns in China with large negative and positive deviations are both -0.648 (2.164), and the Z_{t-1} coefficients of the housing price (composite stock) returns in South Korea with large negative and positive deviations are both -3.322 (46.059). The Z_{t-1} coefficients of the Sinyi house price (weighted stock) returns in Taiwan with large negative and positive deviations are both 4.239 (49.805), whereas the Z_{t-1} coefficients of the house price (stock price) returns in Singapore with large negative and positive deviations are 2.510 (-31.354) and 1.314 (-34.445), respectively. These results reveal that rapid mean reversions to the equilibrium of stock prices and housing prices with large negative and positive deviations consistently occur in China, South Korea, Singapore, and Taiwan. Regardless of the existence of large positive deviations (i.e., when stock prices are significantly higher than house prices) or large negative deviations (i.e., when stock prices are significantly lower than house prices), the speed of adjustment with which house prices revert to equilibrium is greater than that for stock prices based on $|\alpha_1^h+\beta_1^h|(|\alpha_1^h| \, or \, |\alpha_1^h+\beta_1^h|) < |\alpha_1^s+\beta_1^s|(|\alpha_1^s| \, or \, |\alpha_1^s+\beta_1^s|)$ for ESTVECM (LSTVECM). This may be because the returns are higher and the frequency of price changes is lower for investments in used houses relative to stocks. Thus, the speed of adjustment with which used house prices revert to equilibrium is all greater than that for stock prices in the four countries. Specifically, when stock prices are significantly higher than house prices (i.e., when large positive deviations exist), informed traders will tend to purchase relatively cheaper houses and the incentive to buy houses will increase. Thus, the speed of adjustment with which house prices revert to equilibrium will be greater than the speed of adjustment for stock prices. Nevertheless, when stock prices are significantly lower than house prices (i.e., when large negative deviations exist), the speed of adjustment of house prices when prices revert to equilibrium will still be higher than the speed of adjustment for stock prices, perhaps due to the high profitability of used houses.

Moreover, the adjustment speeds with which the house and stock prices revert to equilibrium for large positive and negative deviations are all equal in China, South Korea, and Taiwan based on ESTVECM, whereas they are unequal in Singapore based on LSTVECM. This finding may be due to the fact that the habits of investors simultaneously investing in used houses and stocks are very rigid in China, South Korea, and Taiwan because these regions are deeply affected by the Chinese cultural notion that land equals wealth and moderation. Consequently, more government limits of trading prices and volumes are imposed in both the used house and stock markets. Regardless of whether large positive deviations (when stock prices are significantly higher than house prices) or large negative deviations (when stock prices are significantly lower than house prices) occur, the incentives to invest in used houses and stocks remain nearly unchanged. Therefore, the adjustment speeds with which house and stock prices revert to equilibrium under the two regimes tend to be equal. However, the investing habits in Singapore, where it is more international than the other four countries and where there are less government limitations for foreign investors buying the used houses, are somewhat different with regard both house and stock prices.

In summary, the empirical results indicate that, when large deviations occur between house and stock prices in China, South Korea, Singapore, and Taiwan, the house and stock prices will revert to equilibrium, and the adjusting patterns of short-run return dynamics in both markets become quite evident. However, small and large deviations between housing and stock prices may exhibit different return dynamics based on the heterogeneous behaviors of different investors. Thus, the short-run price adjustments of reverting to equilibrium between both markets can follow the gradual and smooth translating process. More specifically, when large deviations from equilibrium between the prices of houses and stocks in these Asian regions exist, arbitrageurs or hedgers become more confident in driving the prices of the two markets in the appropriate direction based on lower risk exposure. Thus, house and stock prices in these areas will quickly revert to equilibrium, and the adjusting speed of used house prices reverting to equilibrium is all greater than that of stock prices. Conversely, when small deviations from equilibrium occur between the prices of houses and stocks, the arbitrageurs tend to be exposed to greater price risk and potentially adverse market movements if they pursue a price correction; thus, arbitrageurs exhibit price persistence in the house and stock markets. Our analysis demonstrates that the STVECM is appropriate for modeling the short-run return dynamics of the deviations from the comovement equilibrium between house and stock prices in China, South Korea, Singapore, and Taiwan. Furthermore, the ESTVECM is appropriate for modeling the short-run return dynamics of the deviations from the comovement equilibrium between house and stock prices in China, South Korea, and Taiwan, whereas the LSTVECM is appropriate for modeling the same relationship in Singapore. In addition, although no cointegration between house and stock prices exist in Hong Kong, the ESTVAR is appropriate for modeling the small and large return dynamics between the housing and stock markets.

5. Conclusion

The study has several main contributions to the literature. First, we use the more powerful nonparametric cointegration test to confirm the existence of a nonlinear cointegration relationship between house and stock prices in China, Korea, Singapore, and Taiwan. Second, we demonstrate the appropriate application of STVECM on analyzing the adjustment efficiency of short-run house and corresponding stock return dynamics in these Asian regions. Our findings also support the theory concerning the interaction between arbitrageurs and noise traders as well as the argument about the gradual and smooth translating process of short-run return adjustments in the used house and stock markets. We demonstrate that the price transmissions of used houses in reversing the equilibrium are faster than those of stocks. In addition, except for South Korea, a wealth effect caused by a price discovery function from the stock market exists in all regions. The adjusting speeds of return dynamics are equal in the region affected by Chinese culture, but those are unequal in the region affected by international characteristic. The results of our analysis on the relationships of long-run equilibrium, short-run adjustment, and causation between the housing and stock markets in China and the four Asian Tigers are a useful guide, especially for the related institutional investors, who often participate in arbitrage trading, dynamic hedging strategies, and asset allocationin both markets of these Asian regions.

References

Ambrose, Brent W., Esther Ancel, and Mark D. Griffiths. 1992. "The Fractal Structure of Real Estate Investment Trust Returns: The Search for Evidence of Market Segmentation and Nonlinear Dependency." *Real Estate Economics*, 20(1): 25-54. http://dx.doi.org/10.1111/1540-6229.00571

Bierens, Herman J. 1997. "Nonparametric Cointegration Analysis." *Journal of Econometrics*, 77(2): 379-404. http://dx.doi.org/10.1016/S0304-4076(96)01820-9

Chau, Kwong Wing, Vincent S. M. Ma, and Daniel C. W. Ho. 2001. "The Pricing of 'Luckiness' in the Apartment Market." *Journal of Real Estate Literature*, 9(1): 29-40.

Chen, Pei-Fen, Mei-Se Chien, and Chien-Chiang Lee. 2011. "Dynamic Modeling of Regional House Price Diffusion in Taiwan." *Journal of Housing Economics*, 20(4): 315-332. http://dx.doi.org/10.1016/j.jhe.2011.09.002

Geltner, David. 1990. "Return Risk and Cash Flow Risk with Long-Term Riskless Leases in Commercial Real Estate." *Real Estate Economics*, 18(4): 377-402. http://dx.doi.org/10.1111/1540-6229.00529

Giannellis, Nikolaos, Angelos Kanas, and Athanasios P. Papadopoulos. 2010. "Asymmetric Volatility Spillovers between Stock Market and Real Activity: Evidence from the UK and the US." *Panoeconomicus*, 57(4): 429-445. http://dx.doi.org/10.2298/PAN1004429G

Glascock, John L., Chiuling Lu, and Raymond W. So. 2000. "Further Evidence on the Integration of REIT, Bond, and Stock Returns." *The Journal of Real Estate Finance and Economics*, 20(2): 177-194.

Granger, Clive W. J. 1969. "Investigating Causal Relations by Econometric Models and Cross-Spectral Methods." *Econometrica: Journal of the Econometric Society*, 37(3): 424-438. http://dx.doi.org/10.2307/1912791

Gyourko, Joseph, and Donald B. Keim. 1992. "What Does the Stock Market Tell Us about Real Estate Returns?" *Real Estate Economics*, 20(3): 457-485. http://dx.doi.org/10.1111/1540-6229.00591

Hakkio, Craig S., and Mark Rush. 1991. "Cointegration: How Short Is the Long Run?" *Journal of International Money and Finance*, 10(4): 571-581. http://dx.doi.org/10.1016/0261-5606(91)90008-8

Hong, Harrison, and Jeremy C. Stein. 1999. "A Unified Theory of Underreaction, Momentum Trading, and Overreaction in Asset Markets." *The Journal of Finance*, 54(6): 2143-2184. http://dx.doi.org/10.1111/0022-1082.00184

Hui, Eddie Chi Man, and Shen Yue. 2006. "Housing Price Bubbles in Hong Kong, Beijing and Shanghai: A Comparative Study." *The Journal of Real Estate Finance and Economics*, 33(4): 299-327. http://dx.doi.org/10.1007/s11146-006-0335-2

Hui, Eddie Chi Man, and Ka Hung Yu. 2012. "Assisted Homeownership, Investment and Their Roles in Private Property Price Dynamics in Hong Kong." *Habitat International*, 36(2): 219-225. http://dx.doi.org/10.1016/j.habitatint.2011.08.007

Jirasakuldech, Benjamas, and Riza Emekter. 2012. "Nonlinear Dynamics and Chaos Behaviors in the REIT Industry: A Pre- and Post-1993 Comparison." *Journal of Real Estate Portfolio Management*, 18(1): 57-77.

Johansen, Søren. 1988. "Statistical Analysis of Cointegration Vectors." *Journal of Economic Dynamics and Control*, 12(2): 231-254. http://dx.doi.org/10.1016/0165-1889(88)90041-3

Johansen, Søren, and Katarina Juselius. 1990. “Maximum Likelihood Estimation and Inference on Cointegration - With Applications to the Demand for Money.” *Oxford Bulletin of Economics and Statistics*, 52(2): 169-210. http://dx.doi.org/10.1111/j.1468-0084.1990.mp52002003.x

Kapetanios, George, Yongcheol Shin, and Andy Snell. 2003. “Testing for a Unit Root in the Nonlinear STAR Framework.” *Journal of Econometrics*, 112(2): 359-379. http://dx.doi.org/10.1016/S0304-4076(02)00202-6

Kapopoulos, Panayotis, and Fotios Siokis. 2005. “Stock and Real Estate Prices in Greece: Wealth versus ‘Credit-Price’ Effect.” *Applied Economics Letters*, 12: 125-128. http://dx.doi.org/10.1080/1350485042000307107

Ling, David C., and Andy Naranjo. 1999. “The Integration of Commercial Real Estate Markets and Stock Markets.” *Real Estate Economics*, 27(3): 483-515. http://dx.doi.org/10.1111/1540-6229.00781

Liow, Kim Hiang, and Haishan Yang. 2005. “Long-Term Co-Memories and Short-Run Adjustment: Securitized Real Estate and Stock Markets.” *The Journal of Real Estate Finance and Economics*, 31(3): 283-300. http://dx.doi.org/10.1007/s11146-005-2790-6

Liu, Crocker H., David J. Hartzell, Wylie Greig, and Terry V. Grissom. 1990. “The Integration of the Real Estate Market and the Stock Market: Some Preliminary Evidence.” *The Journal of Real Estate Finance and Economics*, 3(3): 261-282. http://dx.doi.org/10.1007/BF00216190

Liu, Yu-Shao, and Chi-Wei Su. 2010. “The Relationship between the Real Estate and Stock Markets of China: Evidence from a Nonlinear Model.” *Applied Financial Economics*, 20(22): 1741-1749. http://dx.doi.org/10.1080/09603107.2010.524616

Luukkonen, Ritva, Pentti Saikkonen, and Timo Teräsvirta. 1988. “Testing Linearity against Smooth Transition Autoregressive Models.” *Biometrika*, 75(3): 491-499. http://dx.doi.org/10.1093/biomet/75.3.491

McMillan, David G. 2004. “Nonlinear Predictability of Short-Run Deviations in UK Stock Market Returns.” *Economics Letters*, 84(2): 149-154. http://dx.doi.org/10.1016/j.econlet.2003.10.014

Miles, Mike, Rebel Cole, and David Guilkey. 1990. “A Different Look at Commercial Real Estate Returns.” *Real Estate Economics*, 18(4): 403-430. http://dx.doi.org/10.1111/1540-6229.00530

Okunev, John, and Patrick J. Wilson. 1997. “Using Nonlinear Tests to Examine Integration between Real Estate and Stock Markets.” *Real Estate Economics*, 25(3): 487-503. http://dx.doi.org/10.1111/1540-6229.00724

Okunev, John, Patrick J. Wilson, and Ralf Zurbruegg. 2000. “The Causal Relationship between Real Estate and Stock Markets.” *The Journal of Real Estate Finance and Economics*, 21(3): 251-261.

Pai, Arvind, and David Geltner. 2007. “Stocks Are from Mars, Real Estate Is from Venus.” *The Journal of Portfolio Management*, 33(5): 134-144. http://dx.doi.org/10.3905/jpm.2007.698912

Sarantis, Nicholas. 1999. “Modeling Non-Linearities in Real Effective Exchange Rates.” *Journal of International Money and Finance*, 18(1): 27-45. http://dx.doi.org/10.1016/S0261-5606(98)00045-X

Sarno, Lucio. 2000. “Real Exchange Rate Behaviour in High Inflation Countries: Empirical Evidence from Turkey, 1980-1997.” *Applied Economics Letters*, 7(5): 285-291.

Shin, Hyun Bang. 2009. “Property-Based Redevelopment and Gentrification: The Case of Seoul, South Korea.” *Geoforum*, 40(5): 906-917. http://dx.doi.org/10.1016/j.geoforum.2009.06.009

Shleifer, Andrei. 2000. *Inefficient Markets: An Introduction to Behavioral Finance*. Oxford: Oxford University Press. http://dx.doi.org/10.1628/0932456022975402

Su, Chi-Wei. 2011. “Non-Linear Causality between the Stock and Real Estate Markets of Western European Countries: Evidence from Rank Tests.” *Economic Modelling*, 28(3): 845-851. http://dx.doi.org/10.1016/j.econmod.2010.10.021

Su, Chi-Wei, Hsu Ling Chang, and Meng Nan Zhu. 2011. “A Non-Linear Model of Causality between the Stock and Real Estate Markets of European Countries.” *Journal for Economic Forecasting*, 1: 41-53. http://dx.doi.org/10.1016/j.econmod.2010.10.021

Sun, Qian, Wilson H. S. Tong, and Yuxing Yan. 2009. “Market Liberalization within a Country.” *Journal of Empirical Finance*, 16(1): 18-41. http://dx.doi.org/10.1016/j.jempfin.2008.07.003

Teräsvirta, Timo. 1994. “Specification, Estimation, and Evaluation of Smooth Transition Autoregressive Models.” *Journal of the American Statistical Association*, 89(425): 208-218. http://dx.doi.org/10.1080/01621459.1994.10476462

Tudor, Cristiana. 2011. “Changes in Stock Markets Interdependencies as a Result of the Global Financial Crisis: Empirical Investigation on the CEE Region.” *Panoeconomicus*, 58(4): 525-543. http://dx.doi.org/10.2298/PAN1104525T

Tuluca, Sorin A., F. C. Neil Myer, and James R. Webb. 2000. “Dynamics of Private and Public Real Estate Markets.” *The Journal of Real Estate Finance and Economics*, 21(3): 279-296.

Wilson, Patrick J., and John Okunev. 1999. “Long-Term Dependencies and Long Run Non-Periodic Co-Cycles: Real Estate and Stock Markets.” *Journal of Real Estate Research*, 18(2): 257-278.

Appendix

1. List of Tables

Table 1a Descriptive Statistics of Used House Index Returns in China and the Four Asian Tigers

Items	China	Korea	Singapore	Taiwan	Hong Kong
Mean	0.009	0.009	0.002	0.009	0.002
Median	0.008	0.006	0.003	0.006	0.003
Maximum	0.059	0.080	0.146	0.146	0.093
Minimum	-0.013	-0.080	-0.152	-0.103	-0.126
Std. dev.	0.012	0.026	0.054	0.040	0.030
Skewness	1.289	-0.481	-0.318	0.599	-0.334
Kurtosis	5.271	6.328	4.071	5.283	4.774
Jarque-Bera	49.160 [0.000]	28.497 [0.000]	3.879. [0.144]	13.569 [0.001]	30.686 [0.000]
Ljung-Box Q(4)	171.640***	9.946**	33.033***	0.599	92.449***
Ljung-Box Q(8)	176.690***	13.381*	43.550***	4.886	114.060***

Notes: Numbers in [ ] indicate the *p*-values of the Jarque-Bera statistics. ***, **, and * denote significance at the 1%, 5% and 10% levels, respectively.

Source: Authors' calculations.

Table 1b Descriptive Statistics of Stock Index Returns in China and the Four Asian Tigers

Items	China	Korea	Singapore	Taiwan	Hong Kong
Mean	0.006	0.012	0.005	-0.004	0.006
Median	0.019	0.017	0.015	0.008	0.010
Maximum	0.243	0.638	0.394	0.732	0.265
Minimum	-0.283	-0.518	-0.424	-0.472	-0.348
Std. dev.	0.092	0.181	0.143	0.195	0.330
Skewness	-0.635	0.039	-0.064	0.823	-0.281
Kurtosis	4.053	5.024	4.430	6.072	5.058
Jarque-Bera	11.331 [0.003]	9.739 [0.008]	5.156 [0.076]	24.795 [0.000]	38.878 [0.000]
Ljung-Box Q(4)	17.285***	3.731	4.296***	9.348*	3.114
Ljung-Box Q(8)	21.685***	8.558	7.684***	18.048**	9.257

Notes: Numbers in [ ] indicate the *p*-values of the Jarque-Bera statistics. ***, **, and * denote significance at the 1%, 5% and 10% levels, respectively.

Source: Authors' calculations.

Table 2 Nonlinear KSS Unit Root Test Results for House and Stock Prices

Region	Statistics	House price		Stock price	
		Level	1st diff.	Level	1st diff.
China	*t*-statistics of $\hat{\delta}$	-1.491(1)	-12.723(1)***	-1.182(1)	-19.377(1)***
Korea	*t*-statistics of $\hat{\delta}$	-1.247(1)	-13.532(1)***	-1.129(1)	-19.831(1)***
Singapore	*t*-statistics of $\hat{\delta}$	-0.891(1)	-2.540(1)**	-1.657(1)	-1.984(1)*
Taiwan	*t*-statistics of $\hat{\delta}$	-1.524(2)	-8.135(2)***	-1.376(3)	-9.248(3)***
Hong Kong	*t*-statistics of $\hat{\delta}$	-1.604(2)	-11.257(2)***	-1.580(1)	-12.345(1)***

Notes: Numbers in ( ) indicate the lag lengths (*k*) from Equation (2). Critical values for the *t*-statistics of $\hat{\delta}$ are tabulated in Kapetanios, Shin, and Snell (2003), and the values at the 10%, 5% and 1% levels of significance are -1.92, -2.22 and -2.82, respectively.

Source: Authors' calculations.

Table 3 Bierens' Nonparametric Cointegration Tests for House and Stock Prices

λ_{min} **statistics**	**China**	**Korea**	**Singapore**	**Taiwan**	**Hong Kong**	**5% critical value**	**10% critical value**
$H_0: r = 0$ $H_0: r = 0$ $H_0: r \geq 1$:	0.001**	0.010**	0.005**	0.008**	0.001**	(0, 0.017)	(0, 0.050)
$H_0: r \leq 1$ $H_0: r \geq 2$	0.347	0.215	0.402	0.452	0.347	(0, 0.054)	(0, 0.111)
$g_m(r_0)$ statistics	China	Korea	Singapore	Taiwan	Hong Kong		
$r_0 = 0$	35.631	37.243	38.885	34.872	25.310		
$r_0 = 1$	21.016	26.383	27.628	23.943	29.686		
$r_0 = 2$	38.537	39.886	40.550	36.375	39.798		

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

Source: Authors' calculations.

Table 4 Wald Test of Linearity against Nonlinear STVECM or STVAR in China and the Four Asian Tigers

Region	***d***	**1**	**2**	**3**	**4**	**5**	**6**
China	H_0 *F*-stat	23.370	21.960	25.047	31.671	42.780	29.182
	p-value	0.325	0.402	0.245	0.063*	0.003***	0.110
Korea	H_0 *F*-stat	16.423	29.221	23.194	12.210	11.558	10.903
	p-value	0.424	0.023**	0.109	0.729	0.773	0.815
Singapore	H_0 *F*-stat	9.509	62.154	59.518	64.340	55.038	41.549
	p-value	0.947	0.000***	0.000***	0.000***	0.000***	0.001***
Taiwan	H_0 *F*-stat	27.116	43.936	22.618	8.964	17.193	11.384
	p-value	0.028**	0.000***	0.093*	0.879	0.307	0.725
Hong Kong	H_0 *F*-stat	16.682	23.139	29.553	6.126	13.480	23.036
	p-value	0.338	0.081*	0.014**	0.978	0.565	0.083*

Notes: The specification and null hypothesis of the nonlinear STVECM (or STVAR) are given in Equations (14) (or (15)) and (16), respectively. *d* is the optimal lag length of the transition variable Z_{t-d}. The test statistics are adopted in the Wald test, and the specification of the test statistic is listed in Equation (18).

Source: Authors' calculations.

Table 5 Model Specifications for the LSTVECM versus ESTVECM in China and the Four Asian Tigers

Region	***d***	H_{04}	***p*-value**	H_{03}	***p*-value**	H_{02}	***p*-value**
China	1	10.870	0.144	9.201	0.239	3.140	0.872
	2	6.145	0.522	12.591	0.083*	3.184	0.868
	3	13.514	0.061*	7.307	0.398	3.778	0.805
	4	7.780	0.352	20.717	0.004***	2.526	0.925
	5	10.151	0.180	27.830	0.000***	3.458	0.840
	6	7.286	0.400	18.653	0.009***	2.867	0.897
Korea	1	3.272	0.658	6.784	0.237	6.758	0.239
	2	8.740	0.120	14.765	0.011**	3.901	0.564
	3	9.654	0.086*	9.696	0.084*	3.019	0.697
	4	1.217	0.943	5.934	0.313	5.526	0.355
	5	4.408	0.492	2.473	0.781	4.635	0.462
	6	1.516	0.911	1.563	0.906	8.729	0.120
Singapore	1	1.339	0.969	2.207	0.900	6.835	0.336
	2	20.387	0.002***	11.884	0.065*	18.473	0.005***
	3	2.777	0.836	9.083	0.169	45.898	0.000***
	4	6.483	0.371	6.209	0.400	49.093	0.000***
	5	24.132	0.000***	5.404	0.493	15.651	0.016**
	6	8.828	0.184	11.756	0.068*	17.724	0.007***
Taiwan	1	10.097	0.073*	5.623	0.345	10.418	0.064*
	2	13.061	0.023**	17.232	0.004***	9.287	0.098*
	3	12.131	0.033**	4.247	0.514	4.964	0.420
	4	1.850	0.870	3.750	0.586	3.971	0.554
	5	3.595	0.609	6.574	0.254	7.084	0.215
	6	0.458	0.994	2.975	0.704	8.771	0.119

Hong Kong	1	4.898	0.429	3.809	0.577	7.943	0.159
	2	12.238	0.032**	3.649	0.601	6.863	0.231
	3	5.845	0.322	15.233	0.009***	7.980	0.157
	4	2.835	0.725	1.858	0.868	1.480	0.915
	5	1.873	0.866	2.634	0.756	9.176	0.102
	6	3.314	0.652	9.873	0.079*	9.783	0.082*

Notes: The null hypothesis of the nonlinear model specification for the LSTVECM versus the ESTVECM is given in Equation (19). *d* is the optimal lag length of the transition variable Z_{t-d}. The test statistics are adopted in the Wald test, and the specification of the test statistic is given in Equation (18).

Source: Authors' calculations.

Table 6 Estimated STVECM and VECM Results for House and Stock Returns in China

Variables	Coefficients	VECM-estimate		ESTVECM-estimate	
		Δp_t^h	Δp_t^s	Δp_t^h	Δp_t^s
Constant	α_0	0.156(1.967*)	1.408(1.273)	-0.330(-0.833)	-23.358(-20.523***)
z_{t-1}	α_1	-0.554(-1.961*)	1.071(0.276)	-1.686(-1.979**)	0.376(0.093)
Δp_{t-1}^h	α_2	0.832(16.484***)	2.437(1.756*)	1.536(5.206***)	-9.082(-6.471***)
Δp_{t-1}^s, Δp_{t-2}^h	α_3	0.018(2.660***)	-3.243(-2.383**)	0.049(2.125**)	-42.288(-30.815***)
Δp_{t-2}^s	α_4		0.218(2.227**)		-24.291(-24.668***)
Constant	β_0			0.491(1.194)	24.526(12.215***)
z_{t-1}	β_1			1.038(0.586)	1.788(1.992**)
Δp_{t-1}^h	β_2			-0.925(-3.342***)	11.577(2.230**)
Δp_{t-1}^s, Δp_{t-2}^h	β_3			-0.036(-1.399)	39.091(4.125***)
Δp_{t-2}^s	β_4				24.526(3.814***)
Transition speed	γ			92.219(2.175**)	151.166(9.827***)
Threshold value	τ			-0.081(-7.467***)	0.064(5.012***)
Granger causality test		<5.854***>	<0.070>		
ARCH-LM (1)		0.901[0.342]	0.384[0.536]	1.666[0.197]	0.405[0.524]
ARCH-LM (4)		11.023[0.026]	5.731[0.220]	7.890[0.096]	5.727[0.220]
L-B Q(6)		3.077[0.545]	8.155[0.086]	1.434[0.838]	10.070[0.189]
L-B *Q*(12)		14.122[0.293]	15.058[0.238]	11.902[0.454]	14.783[0.254]
SSR		37.822	8043.580	27.944	7145.295
Likelihood value		-5042.549		-2180.461	
AIC		1424.165		888.624	
SBIC		1480.581		911.889	

Notes: The specifications of the STVECM and VECM are given in Equations (11) and (12), respectively. The numbers in ( ) are the *t*-statistics, those in <> are the *F*-statistics and those in [ ] are the *p*-values. ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively.

Source: Authors' calculations.

Table 7 Estimated Results of STVECM and VECM for House and Stock Returns in Korea

Variables	Coefficients	VECM-estimate		ESTVECM-estimate	
		Δp_t^h	Δp_t^s	Δp_t^h	Δp_t^s
Constant	α_0	0.637(1.848*)	2.865(1.143)	1.253(3.637***)	-36.226(-14.454***)
z_{t-1}	α_1	-3.322(-1.146)	46.059(2.122**)	-4.980(-1.717*)	21.533(0.992)
Δp_{t-1}^h, p_{t-2}^h	α_2	0.292(2.406**)	-2.112(-2.326**)	-0.353(-2.912***)	-41.204(-45.362***)
Δp_{t-2}^s	α_3		0.194(1.530)		-24.333(-192.522***)
Constant	β_0			-0.616(-1.823*)	39.091(42.058***)
z_{t-1}	β_1			1.658(0.920)	24.526(0.236)
Δp_{t-1}^h, p_{t-2}^h	β_2			0.644(1.928*)	39.091(29.843***)
Δp_{t-2}^s	β_3				24.526(16.730***)
Transition speed	γ			18.588(0.945)	84.060(93.147***)
Threshold value	τ			0.017(0.337)	0.072(4.346***)
Granger causality test		〈 1.005 〉	〈 2.764* 〉		
ARCH-LM (1)		0.004[0.949]	0.003[0.959]	0.003[0.954]	0.003[0.959]
ARCH-LM (4)		1.345[0.854]	12.427[0.014]	1.358[0.851]	12.427[0.140]
L-B Q(6)		3.238[0.519]	4.072[0.396]	3.179[0.528]	4.072[0.396]
L-B *Q*(12)		12.257[0.425]	12.475[0.408]	12.002[0.446]	12.475[0.408]
SSR		352.576	18904.257	320.475	17089.962

Likelihood value		-4226.640		-2203.554	
AIC		564.068		550.016	
SBIC		977.929		941.797	

Notes: The specifications for the STVECM and VECM are given in Equations (11) and (12), respectively. The numbers in ( ) are the *t*-statistics, those in <> are the *F*-statistics and those in [ ] are the *p*-values. ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively.

Source: Authors' calculations.

Table 8 Estimated STVECM and VECM Results for House and Stock Returns in Singapore

Variables	Coefficients	VECM-estimate		LSTVECM-estimate	
		Δp_t^h	Δp_t^s	Δp_t^h	Δp_t^s
Constant	α_0	0.032(0.064)	0.432(0.242)	89.650(0.007)	0.431(0.242)
z_{t-1}	α_1	-6.648(-1.047)	-31.350(-2.175**)	2.51(0.281)	-31.352(-2.175**)
Δp_{t-1}^s	α_2	0.226(5.606***)	-0.049(-0.340)	-1.670(-0.062)	-0.056(-0.341)
Constant	β_0			-163.782(-0.045)	1.583(0.982)
z_{t-1}	β_1			-1.196(-0.693)	-3.093(0.098)
Δp_{t-1}^s	β_2			35.790(0.045)	2.531(1.283)
Transition speed	γ			0.085(0.004)	3.065(1.673*)
Threshold value	τ			0.240(0.009)	0.221(2.733***)
Granger causality test		〈 23.087*** 〉	〈 1.850 〉		
ARCH-LM (1)		0.274[0.600]	0.120[0.729]	1.241[0.265]	0.119[0.730]
ARCH-LM (4)		7.448[0.114]	21.229[0.000]	6.059[0.195]	2.123[0.285]
L-B *Q*(6)		14.433[0.006]	3.636[0.458]	8.040[0.090]	3.639[0.457]
L-B *Q*(12)		18.533[0.100]	9.046[0.699]	12.165[0.433]	9.053[0.698]
SSR		866.436	11050.066	462.188	11040.067
Likelihood value		-2980.854		-2034.582	
AIC		931.680		561.301	
SBIC		964.921		573.767	

Notes: The specifications for the STVECM and VECM are given in Equations (11) and (12), respectively. The numbers in ( ) are the *t*-statistics, those in <> are the *F*-statistics and those in [ ] are the *p*-values. ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively.

Source: Authors' calculations.

Table 9 Estimated STVECM and VECM Results for House and Stock Returns in Taiwan

Variables	Coefficients	VECM-estimate		ESTVECM-estimate	
		Δp_t^h	Δp_t^s	Δp_t^h	Δp_t^s
Constant	α_0	0.984(1.806*)	0.001(0.005)	12.513(5.208***)	-11.529(-4.161***)
z_{t-1}	α_1	5.381(1.646*)	27.970(1.656*)	-80.778(-4.635***)	10.714(0.636)
Δp_{t-1}^s , Δp_{t-1}^h	α_2	0.058(2.120**)	0.067(0.096)	-1.615(-3.891***)	-24.514(-36.157***)
Constant	β_0			-11.165(-4.507***)	11.577(5.380***)
z_{t-1}	β_1			85.017(4.798***)	39.091(1.918**)
Δp_{t-1}^s , Δp_{t-1}^h	β_2			1.745(4.232***)	24.526(2.987***)
Transition speed	γ			453.810(4.595***)	34.060(3.152***)
Threshold value	τ			0.162(10.606***)	0.143(2.445**)
Granger causality test		〈 3.728** 〉	〈 1.921 〉		
ARCH-LM (1)		0.743[0.389]	2.393[0.122]	0.001[0.999]	2.399[0.121]
ARCH-LM (4)		1.326[0.857]	3.050[0.550]	1.890[0.756]	3.078[0.545]
L-B *Q*(6)		4.251[0.373]	7.301[0.121]	4.970[0.290]	7.258[0.123]
L-B *Q*(12)		22.083[0.037]	33.705[0.001]	12.182[0.431]	13.601[0.358]
SSR		683.619	16903.072	308.006	16891.370
Likelihood value		-3021.005		-2578.412	
AIC		490.456		479.229	
SBIC		890.556		860.617	

Notes: The specifications for the STVECM and VECM are given in Equations (11) and (12), respectively. The numbers in ( ) are the *t*-statistics, those in <> are the *F*-statistics and those in [ ] are the *p*-values. ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively.

Source: Authors' calculations.

Table 10 Estimated STVAR and VAR Results for House and Stock Returns in Hong Kong

Variables	Coefficients	VAR-estimate		ESTVAR-estimate	
		Δp_t^h	Δp_t^s	Δp_t^h	Δp_t^s
Constant	α_0	0.009(0.061)	0.578(1.002)	184.942(121.212***)	192.390(332.261***)
Δp_{t-1}^h	α_1	0.454(6.499***)	0.017(0.243)	-185.255(-265.677***)	-115.072(-163.729***)
Δp_{t-2}^h	α_2	0.075(1.211)		20.909(335.534***)	
Δp_{t-1}^s	α_3	0.161(8.767***)		-55.375(-300.317***)	
Δp_{t-2}^s	α_4	0.020(0.908)		-51.404(-237.546***)	
Constant	β_0			-184.939(-98.145***)	-191.842(-130.665***)
Δp_{t-1}^h	β_1			185.711(146.215***)	115.073(103.461***)
Δp_{t-2}^h	β_2			-20.836(-84.713***)	
Δp_{t-1}^s	β_3			55.537(79.936***)	
Δp_{t-2}^s	β_4			51.422(63.882***)	
Transition speed	γ			158.849(112.408***)	604.860(203.841***)
Threshold value	τ			130.696(95.561***)	6.779(1.254)
Granger causality test		〈1.191〉	〈3.959***〉		
ARCH-LM (1)			0.134[0.715]	19.241[0.000]	0.126[0.723]
ARCH-LM (4)			7.823[0.098]	22.663[0.000]	7.733[0.102]
L-B Q(6)			3.267[0.514]	3.113[0.539]	3.345[0.502]
L-B Q(12)			19.230[0.083]	20.923[0.052]	20.380[0.060]
SSR		982.045	13652.468	935.166	13614.960
Likelihood value		-4428.938		-3014.510	
AIC				1946.913	
SBIC				1970.105	

Notes: The specifications for the STVAR and VAR are given in Equations (11) and (12), respectively. The numbers in ( ) are the *t*-statistics, those in <> are the *F*-statistics and those in [ ] are the *p*-values. ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively.

Source: Authors' calculations.

2. The Procedure and Illustration of ESTAR Model

ε_t is the random residual ~iid$(0,\sigma^2)$ and $\theta \geq 0$ is the adjustment speed of the exponential smooth transition. Under the null hypothesis $H_0 : \theta = 0$, Y_t is a linear unit root process, while under the alternative hypothesis $H_0 : \theta > 0$, Y_t is a nonlinear constant ESTAR process. Because γ cannot be identified under the null hypothesis, Ritva Luukkonen, Pentti Saikkonen, and Teräsvirta (1988) and Kapetanios, Shin, and Snell (2003) used the first-order Taylor series to approximately estimate $\left\{1 - \exp(-\theta Y_{t-1}^2)\right\}$.

$$\Delta Y_t = rY_{t-1}\left\{1 - \exp(-\theta Y_{t-1}^2)\right\} + \varepsilon_t . \tag{15}$$

With respect to the null hypothesis $\theta = 0$, Equation (15) can be rewritten as follows:

$$\Delta Y_t = \zeta + \delta Y_{t-1}^3 + \sum_{i=1}^{k} \rho_i \Delta Y_{t-1} + \varepsilon_t,\ t = 1,2,....,T . \tag{16}$$

If the estimate does not refute the hypothesis $H_0 : \delta = 0$ after it is examined, the sequence is a unit root; otherwise, the sequence is a nonlinear constant ESTAR.

3. The Illustrations about the Elements and Procedure of Bierens's Nonparametric Cointegration Method

A_m and B_m are computed as the sums of the outer-products of the weighted means of Z_t and ΔZ_t, where T is the sample size.

$$A_m = \frac{8\pi^2}{T}\sum_{k=1}^{m} k^2 \left(\frac{1}{T}\sum_{t=1}^{T}\cos(2k\pi(t-0.5)/T)Z_t\right)\left(\frac{1}{T}\cos(2k\pi(t-0.5)/T)Z_t\right); \tag{17}$$

$$B_m = 2T\sum_{k=1}^{m} \left(\frac{1}{T}\sum_{t=1}^{T}\cos(2k\pi(t-0.5)/T)\Delta Z_t\right)\left(\frac{1}{T}\cos(2k\pi(t-0.5)/T)\Delta Z_t\right). \tag{18}$$

Like the properties of Johansen's likelihood ratio test, the ordered generalized eigenvalues used in this nonparametric method are the solutions to $\det[P_T - \lambda Q_T] = 0$. At this time, the pair of random matrices P_T and Q_T are defined as $P_T = A_m$ and $Q_T = (B_m + cT^{-2}A_m^{-1})$. Thus, this method can be used to test the hypothesis of cointegration of rank r. Bierens (1997) proposed two statistics, $\lambda_{\min}$ and $g_m(r_0)$, as a means to estimate r. As in Johansen's maximum likelihood procedure, the $\lambda_{\min}$ statistic tests the hypothesis of $H_0(r)$ against $H_1(r+1)$. The $g_m(r_0)$ test statistic is computed from Bierens's generalized eigenvalues as follows:

$$\hat{g}_m(r_0)=\left[\begin{array}{l} \left(\prod_{k=1}^{n}\hat{\lambda}_{k,m}\right)^{-1}, if\ldots r_0=0; \\ \left[\left(\prod_{k=1}^{n-r}\hat{\lambda}_{k,m}\right)^{-1}\left(T^{2r}\prod_{k=n-r+1}^{n}\hat{\lambda}_{k,m}\right)^{-1}, if\ldots r_0=1,\ldots,n-1; \right. \\ T^{2n}\prod_{k=1}^{n}\hat{\lambda}_{k,m},=if\ldots r_0=n. \end{array}\right. \tag{19}$$

This statistic employs the tabulated optimal values in Bierens (1997) for m when $n>r_0$, whereas $m=n$ when $n=r_0$. n is the number of system variables. This value approaches infinite probability if $r\neq r_0$, and verifies $\hat{g}_m(r)=\mathrm{O}_p(1)$ if $r=r_0$. Therefore, when $\hat{\gamma}=\arg\min 0\le r\le 1\{\hat{g}_m\ (r)\}$ is used, the estimator r is consistent; that is, $\lim_{n\to\infty}\Pr(\hat{\gamma}_m=r)=1$. This statistic can be used to reconfirm the determination of rank r.

4. The Illustrations about the Characteristic and Translating Process of LSTVECM (LSTVAR) and ESTVECM (ESTVAR)

If $\gamma\to+\infty$, then $F(Z_{t-d}:\gamma,\tau)$ ($F(\Delta r_{t-d}:\gamma,\tau)$) $\to 1$ in a regime with large positive deviations when the stock prices are significantly higher than house prices (with large positive returns when the changes in the deposit interest rate are significantly high) for $Z_{t-d}>>\tau(\Delta \mathrm{r}_{\text{t-d}}>>\tau)$, and $F(Z_{t-d}:\gamma,\tau)$ ($F(\Delta r_{t-d}:\gamma,\tau)$)$\to$0 in a regime with large negative deviations when stock prices are significantly lower than house prices (with large negative returns when the changes in the deposit interest rate are significantly low) for $Z_{t-d}<<\tau(\Delta \mathrm{r}_{\text{t-d}}<<\tau)$. If $\gamma\to 0$, the model is reduced to a linear VECM (VAR). Because $F(Z_{t-d}:\gamma,\tau)$ ($F(\Delta r_{t-d}:\gamma,\tau)$ is not symmetric around τ, the LSTVECM (LSTVAR) is capable of generating asymmetric short-run dynamics. The LSTVECM (LSTVAR) can be regarded as a two-regime threshold model. When $\gamma\to 0$, ESTVECM (ESTVAR) model is also reduced to a linear VECM (VAR). Because the nonlinear STVECM (STVAR) can only be identified under the alternative hypothesis of nonlinearity $H_0:\gamma>0$ (the null hypothesis of linearity is $H_0:\gamma=0$), it is inappropriate to apply the conventional Lagrange multiplier (LM) test of linearity. Luukkonen, Saikkonen, and Teräsvirta (1988) proposed that it is feasible to replace $F(Z_{t-d}:\gamma,\tau)$ ($F(\Delta r_{t-d}:\gamma,\tau)$ =0) with its third-order Taylor series approximation around $\gamma=0$. This study uses the Wald test to directly examine whether the parameters of the third-order Taylor series expansion in Equations (20) and (21) are 0; that is:

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

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

where $\mathrm{W}_t = (Z_{t-1}, \Delta P_{t-1}^s ..., \Delta P_{t-q}^s, \Delta P_{t-1}^h ..., \Delta P_{t-q}^h)$ ($\mathrm{W}_t = (\Delta P_{t-1}^s ..., \Delta P_{t-q}^s, \Delta P_{t-1}^h ..., \Delta P_{t-q}^h)$).

After the delay parameter d with the smallest p-value is determined, the linearity test is equivalent to the test of the hypothesis: It is necessary to test for linearity with $F(Z_{t-d} : \gamma, \tau) = 0$ ($F(\Delta r_{t-d} : \gamma, \tau) = 0$) for various values of d before estimating the nonlinear STVECM (STVAR).

$$\mathrm{H}_0 : \kappa_{11}^{'} = \kappa_{12}^{'} = \kappa_{13}^{'} = \kappa_{21}^{'} = \kappa_{22}^{'} = \kappa_{23}^{'} = 0\,. \tag{22}$$

Auxiliary regression Equation (23) (Equation (24)) can be used to complete the test in Equation (17). That is:

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

$$\begin{aligned} \hat{\varepsilon}_t^h &= \pi_{10} + \pi_{11}^{'} W_t + \kappa_{11}^{'} W_t(\Delta r_{t-d}) + \kappa_{12}^{'} W_t(\Delta r_{t-d})^2 + \kappa_{13}^{'} W_t(\Delta r_{t-d})^3 + \nu_{1t} \\ \hat{\varepsilon}_t^s &= \pi_{20} + \pi_{21}^{'} W_t + \kappa_{21}^{'} W_t(\Delta r_{t-d}) + \kappa_{22}^{'} W_t(\Delta r_{t-d})^2 + \kappa_{23}^{'} W_t(\Delta r_{t-d})^3 + \nu_{2t}, \end{aligned} \tag{24}$$

where $\hat{\varepsilon}_t^h \left(\hat{\varepsilon}_t^s\right)$ is the residual under the null hypothesis of linearity in Equation (2) (Equation (3)). To examine the linear *versus* nonlinear STVECM or STVAR using the Wald test, we use the following statistic:

$$W = g(\kappa)^{'} \left(\frac{\partial g(\kappa)}{\partial \kappa} \hat{V}(b) \frac{\partial g(\kappa)}{\partial \kappa^{'}} \right) g(\kappa) \,|_{\kappa = b}, \tag{25}$$

where $\kappa = \begin{bmatrix} \kappa_{11}^{'} & \kappa_{21}^{'} \\ \kappa_{12}^{'} & \kappa_{22}^{'} \\ \kappa_{13}^{'} & \kappa_{23}^{'} \end{bmatrix}_{3\times 2}$ is a vector in the parameter estimations. All restrictions on the parameters under the residual $\hat{\varepsilon}_t^h \left(\hat{\varepsilon}_t^s\right)$ can be expressed as $H_0 : g(\kappa) = 0$. This is equivalent to Equation (17). Here, g is a smooth function derived from the residual $\hat{v}_t$ in Equation (23) (Equation (24)) with q restrictions on κ, and the defined and corresponding areas of g are $g : R^{\kappa} \to R^{g}$. In Equation (19), b is an estimator in the nonrestrictive parameter vector and $\hat{v}$ is the covariance estimation with b items. $\hat{v}$ is defined as $\widehat{v}(b) = s^2 \left(\frac{\partial f(\kappa)}{\partial \kappa} \frac{\partial f(\kappa)}{\partial \kappa'} \right)^{-1} |_{\kappa=b}$, and s^2 is a general estimator of the residual variance in the non-restrictive situation, expressed as $s^2 = (u'u)/(T-K)$, where u is a non-restrictive residual vector and *T* is the number of observations. Under a linear null hypothesis, such a statistic is an asymmetric *F* distribution with degrees of freedom *q* and where *T-k*. Furthermore, a good way to examine whether the LSTVECM (LSTVAR) or ESTVECM (ESTVAR) is more suitable is to implement a sequence of tests, as in Equation (26). We consider the following sequence of the null hypothesis in order to identify the type of transition:

$$\begin{aligned} &H_{04} : \kappa_{13}' = \kappa_{23}' = 0; \\ &H_{03} : \kappa_{12}' = \kappa_{22}' = 0 \mid \kappa_{13}' = \kappa_{23}' = 0; \\ &H_{02} : \kappa_{11}' = \kappa_{21}' = 0 \mid \kappa_{12}' = \kappa_{22}' = \kappa_{13}' = \kappa_{23}' = 0. \end{aligned} \tag{26}$$

We select the LSTVECM (LSTVAR) if H_{04} is rejected. Under the alternative, we adopt the ESTVECM (ESTVAR) if H_{03} is also rejected. Accepting both H_{04} and H_{03} but rejecting H_{02} means selecting the LSTVECM (LSTVAR).