學術論文

大中華經濟圈跨境房價之擴散與動態傳遞分析
House Price Diffusion and Cross-Border House Price Dynamics in the Greater China Economic Area

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摘　要

　　本文針對大中、台、港、新等四個經濟體之房價進行關連性檢驗，在研究方法上以Toda & Yamamoto(1995)因果檢定、變異數分解與衝擊反應函數來分析此四經濟體房價密切程度。本文得到下列結果：第一、此四經濟體之跨境房價間具有共整合之長期關係。第二、因果檢定顯示台灣房價會單向領先中國房價。第三、衝擊反應函數結果顯示香港房價對於新加坡房價有顯著正向衝擊。第四、變異數分解顯示中國房價在長期下為最外生，表示中國房價不易被其他市場影響；台灣房價對其他房價之影響程度則為最高。

關鍵詞：跨境房價擴散、大中華經濟圈、共整合、因果檢定、變異數分解

ABSTRACT

　　This paper examines the lead-lag relationships and dynamic linkages among the cross-border house prices of four economies in the Greater China Economic Area(GCEA). We determine the extent and magnitude of their relationships by applying the Toda & Yamamoto(1995) causality test, variance decomposition analysis(GDVC), and impulse response analysis(GIRF). Our empirical results reveal compelling implications. First, the empirical results illustrate a long-run equilibrium among cross-border house prices in the GCEA. Second, the results of the Granger causality test provide evidence of a unidirectional relationship running from Taiwan to China. Third, the GIRF demonstrate that Hong Kong initially has a significantly positive impact on Singapore. Finally, the GDVC results indicate that house prices in China are the most exogenous in the long term, implying that China's market cannot be influenced easily by other markets, whereas Taiwan's market more crucially influences the markets of other regions' in the GCEA.

Key words: cross-border house price diffusion, Greater China Economic Area (GCEA), cointegration, granger causality, variance decomposition analysis

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1. Introduction

There is a voluminous amount of literature examining the ripple effect of regional house prices. If a ripple effect is indeed present, then it is predicated on a degree of long-run relative constancy between regional house prices. The empirical literature has examined this topic through different methods for different countries, but few have discussed the interrelationships between cross-border house prices. In the past two decades, regional integration schemes have multiplied and the importance of regional groups in trade, money, and politics is increasing dramatically, as shown by the many agreements of regional economic integration, such as the EU, NAFTA, ANDEAN, APEC, ASEAN, etc. With regional economic integration increasing significantly, what causes cross-border house prices to be cointegrated? Kasparova & White (2001) indicated that *"if convergence in the economic environment leads to convergence in economic behaviour, structural differences between the countries might be reduced, and housing market developments may become more similar."* In an integrated economic region, housing prices could be anticipated to reveal some comovement, even though local factors exhibit a key role in housing price dynamics (Gupta et al., 2014).

Reviewing the past relative literature, some work has been done to examine the overall impact of European economic integration on real estate markets, with findings presenting significant barriers to the flow of real estate investment across European borders (Rydin et al., 1990; Parsa, 1993). An alternative descriptive analysis of the European markets is found in a report produced by Worzala & Bernasek (1996), who found evidence of some convergence, but the extent is small and major institutional differences within the countries remain. Yang et al. (2005) showed that the real estate markets of larger European Monetary Union (EMU) economies became more integrated with other European markets after EMU's establishment in 1999. The empirical results of Gupta et al. (2014) also note that Belgium and Germany seem to be cointegrated with the majority of other countries under pairwise comparisons.

The Asia Pacific region, and in particular East Asia, has seen rapid growth and economic integration at an extraordinary speed and depth. The only other region with comparably deep links is Europe. Although regional economic cooperation in East Asia is still in its growing stage, some important progress has been made in the areas of trade and finance for regional institution building. Does regional economic integration in the Greater China Economic Area (GCEA) cause cross-country and cross-border house prices to be cointegrated? This paper examines the lead-lag relationships and the dynamic linkages among cross-border house prices in four regions in GCEA: China, Taiwan, Hong Kong, and Singapore. The reasons for choosing these four economies in this study are as follows.

First, property investment has taken on increased importance in recent years, as global property investors have expanded from traditional mature markets (e.g. U.S., UK, and Europe) to emerging markets. In 2008, Asian property markets accounted for 19% of global investible property and made up over 25% of global commercial property transaction volumes (Newell et al., 2009). The growth of real estate markets in Asia has attracted significant interest from global investors. Therefore, we

attempt to discover any relationships, lead-lag relationships, and dynamic linkages among cross-border house prices in these four regions of GCEA.

Second, China and the surrounding East Asia have been a sustained growth center for decades and economic integration has also made considerable progress. Production networks in East Asia, particularly in the manufacturing sector, have been the top runner of the second unbundling in the world, and the formation of free trade agreements (FTAs) has also been active. The number of concluded FTAs in Asia jumped from only 3 to 61 over the period from 2000 to 2010. Compared with 2.9 FTAs per country on average for the Americas, Asia has concluded 3.8 FTAs per country on average (Kawai & Wignaraja, 2010). In respect of both inter-regional and intra-regional trade, East Asian economies show less resistance to trade than the EU, North America, and especially South Asian countries. As economic integration has made considerable progress in East Asia, what causes cross-country and cross-border house prices to be cointegrated?

Third, ever since the late 1980s, GCEA - an informal economic region that embraces China, Hong Kong, and Taiwan - has rapidly emerged as a new epicenter for industry, commerce, and finance. Recently, the accessions of CEPA and ECFA[1] have opened up the gate even wider for the development of GCEA. At the same time, an emerging culturalist discourse has produced a "Greater Chinese sphere" myth, hypothesizing that ethnic Chinese from Hong Kong, Taiwan, Singapore, and elsewhere in Southeast Asia can present a seamless web of businesses through regional trade and investment linkages in China based upon a common culture and heritage (e.g. Brown, 1998; Yeung, 2000). Hence, Singapore is also included in the linkages with China, Taiwan, and Hong Kong.

This paper therefore examines the following questions. First, is there an integration of cross-country and cross-house prices between China, Taiwan, Hong Kong, and Singapore[2]? We use the cointegration method to evaluate whether these cross-border house prices are cointegrated or segmented. We apply the Toda & Yamamoto (1995) approach that particularly specifies the transmission mechanism among various cross-border house prices in GCEA. This paper also aims to evaluate the relative strengths and the transmission mechanisms between these regional house prices, using generalized forecast error variance decompositions (GVDC) and the generalized impulse response approach (GIRF) of Pesaran & Shin (1998). We want to know: Is there one region whose house prices play a leading role in another region?

The remainder of the paper is as follows. Section 2 introduces an overview of economic integration and housing markets in GCEA. Section 3 provides a brief summary of the literature. Section 4 describes the methodology. Section 5 presents the empirical results. Section 6 provides some conclusions.

2. Economic Integration and Housing Markets in GCEA

2.1 Economic Integration in GCEA

Ever since the late 1980s, GCEA has emerged as a new epicenter for industry, commerce, and

finance. There are some theorems in the literature to explain how GCEA became so integrated. The first one is the cultural integration theorem (Chao, 2003). The second theorem of integration is that of economics, which indicates that economic integration can ramify and cause spillover effects. The third theorem of integration is political. It is believed that as China grows in power, nations and sub-national regions in the continental vicinity will be sucked into its orbit and become satellites. Chao (2003) indicated that the growing economic integration within GCEA reflects the triumph of economic forces over political constraints.

Encompassing China, Hong Kong, Taiwan, and Singapore (as Figure 1), GCEA is one of the most dynamic regions in the world. Since the reforms of China in 1978, its importance to the global economy has widely expanded. GCEA's fast economic growth, especially China, in the last 30 years is an economic miracle. While the expansion of GCEA is attributable to the economic transition in China, it also reveals the success of the export-oriented development policy executed by these economies. The economic characteristic of the four economies are strong complements - China owns abundant and cheaper resources; Taiwan provides advanced technological know-how and capital; and Hong Kong and Singapore offer supporting capital, sophisticated financial services, modern management skills, and well-developed legal systems. Thus, the integration of these economies have achieved fantastic cooperation(Cheung & Yuen, 2004).

Figure 1. Map of GCEA

One way to assess the extent of integration is to look at trade and investment flows. First, we shed light on trade relationships within GCEA. According to the calculation of Thorbecke(2011),

in 2009 the proportions of China's exports to the other three regions, Hong Kong, Singapore, and Taiwan, were respectively 20.57%, 3.36%, and 1.86%. In 2009 the proportions of China's imports from these three regions were 16.96% from Taiwan, 2.18% from Singapore, and 1.32% from Hong Kong. The trade figures indicate that China has significantly intensified its trade relationship with Hong Kong and Taiwan, while lowering that with Singapore.

Second, in light of the foreign direct investment relationships of GCEA, in 2011 Hong Kong, Taiwan, and Singapore were the top 3 foreign direct investors in China (see Table 1). Incontrovertibly, the capital from these three economies has played an important role in China's recent economic success. The three economies made up the main share of foreign capital to China - a total of 77.7% - in 2011. All three economies are not major capital suppliers in the world, yet their investment agreements with China are supported by China's policy and the kinship networks already in place across GCEA. These investment opportunities mean that GCEA produces complementary resources, fosters economic growth, and promotes the framework of a Greater China to the world economic stage (Cheung & Yuen, 2004).

Table 1. Top10 FDI in China in 2011

Ranking	FDI Origin	Amount (US$ billions)	As % of Total FDI
1	Hong Kong	77.0	66.5
2	Taiwan	6.7	5.8
3	Japan	6.3	5.4
4	Singapore	6.3	5.4
5	U.S.	3.0	2.6
6	South Korea	2.5	2.2
7	UK	1.6	1.4
8	Germany	1.1	0.9
9	France	0.8	0.7
10	Netherlands	0.8	0.7
	Total	106.1	91.6

Source: Ministry of Commerce of the PRC.

If economic integration leads to convergence in economic behavior, then structural differences of cross-border economies might decrease and housing market developments may become more similar. Therefore, if GCEA shows growing economic integration, then it could bring forth some similarities to the housing market cycles of the GCEA economics.

2.2 Housing Markets in GCEA

By the late 1990s a consensus had emerged in GCEA around the promotion of home ownership through government policies, which increasingly sought to expand the number of owner-occupiers and

established housing markets. Home ownership levels grew significantly across the region in the 1980s and 1990s along with state stimulus measures, intense urbanization, and high annual GDP growth. In Singapore, home ownership grew from 29% to 92% between 1970 and 2003 (Chua, 2003), while in Hong Kong the increase went from 23% to 52% between 1976 and 1997 (Ronald, 2010). Although Taiwan has had a very high rate of home ownership, it still saw home ownership grow from 73% in 1981 to 85% by 1999. China's state-led housing marketisation increased urban home ownership from 17% in 1985 to 82% by 2003 (Wang & Murie, 1999).

One characteristic for the period from 1960 to 1990 of high-speed economic growth in GCEA was government participation in the housing sector, with some in the literature discussing East Asia housing policies. Doling (1999) suggested that the newly industrialized societies of East Asia demonstrate a 'type' of housing provision approach with core similarities in their dimensions of state-market and private-collective. Ronald (2010) indicated that policy frameworks are diverse in GCEA, with the nature of 'housing provision chains' different from Western types. In GCEA the state arranges the developmental stage with grand, highly directive plans and state control over the economy. Construction is executed by private companies, and housing sold as a market good is in terms of a person's ability to pay.

The reasons for this special development path questionably lay in the features of the 'developmental state', very much characteristic to industrialized Asian economies. Social policies in GCEA are restricted to the interests of economic productivity and expansion. Welfare regimes in this region have thus been described as "productivist" (Ronald, 2010). The family, being the primary provider of welfare, is a particular focus of state support. Housing policies have thus taken a special role in GCEA's social and economic development. Ronald (2007) presented that governments use housing development to improve urban development and economic growth, making property asset holding or owner-occupied households increasingly welfare self-reliant in terms of family housing equity.

There are some considerable historic differences in the relationship between housing and productivist welfare objectives in each economy. First, Singapore and Hong Kong have experienced strong state control over land and high levels of state provision. Public housing has come to take over both systems. In Singapore the state controls the supply, plays a central role in home purchase financing, and regulates a large part of the market. Hong Kong developed a large public rented housing sector in the 1960s and 1970s. In the 1990s, the government there shifted toward the promotion of home ownership by constructing home ownership schemes and selling off public rental flats. Taiwan alternatively has used more selective state intervention with subsidies that ensure that the housing needs of low-income groups are met within a market framework. Until the 1980s, China focused on the provision of collective rental housing, but in the 1990s it adopted a strong interventionist approach to urban commodification and the expansion of owner-occupation.

The turning point in policy and housing system trajectories in GCEA was 1997. The Asian financial crisis had a significant impact on the region's stock markets, and there was also a deep crash

in housing markets. Hong Kong's and Singapore's house prices fell the hardest, while Taiwan's house price witnessed a slower decline of about 12% between 1998 and 2002 (Chiu, 2006). The Severe Acute Respiratory Syndrome (SARS) epidemic that hit the region in the first half of 2003 also caused house prices to plummet a further 5% in April 2003 in Hong Kong (Forrest & Lee, 2004), and house prices in Taiwan and Singapore also fall sharply during the same period. Among these three regions, the variations in house price trends and the conditions of the housing markets were partly caused by their different economic conditions and partly the result of different housing policies implemented for rescuing the respective property markets. Conversely, China's house prices progressively rose higher, caused by strong economic growth and its closed financial system feeling fewer shocks from the regional financial crisis. On the whole, the changes in the housing policies in GCEA after 1997 converged towards a similar direction - that is, increasingly market-led - for the purpose of facilitating economic recovery. As such, subsidy policies protecting low-income groups were retained or even expanded.

By 2004 the housing markets in GCEA had recovered from the late-1990s crisis and were beginning to reflect the ongoing global explosion. However, the beginning of the global financial crisis (GFC) in late 2008 caused house prices to slump across East Asia. Figure 2 shows changes in the house prices of these four regions leading up to and after the 2008 crisis. Reactions to the crisis varied, with significant drops in value of up to 25% in Hong Kong and Singapore, just 2-3% in China, while Taiwan faced a decrease of 11% by the first quarter of 2009.
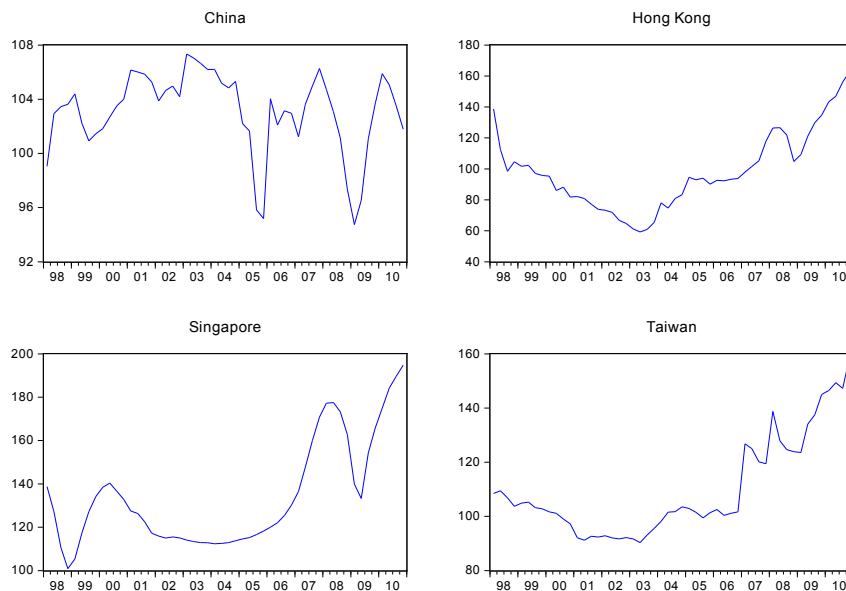
Notes: Y-axis is house price, X-axis is quarters.

Figure 2. Price movements of GCEA real estate markets

Hong Kong and Singapore reversed course with a remarkable housing market price rise in 2009 of 15% and 21%, respectively. China's November 2008 stimulus package boosted liquidity, with cash-rich Chinese buying significant numbers of properties in Hong Kong (Ronald, 2010). Taiwan also showed a strong upturn with house prices rising 9.4% by the third quarter of 2009. Whereas China's property markets had been more prone to overheating leading up to before 2008, GFC only caused a brief downturn in Chinese property values, with them soon rising higher again.

3. Related Literature

An important line of empirical research refers to a convergence or divergence in regional house prices. Alexander & Barrow (1994) demonstrated that the economic theory does not consider regional house prices to exhibit a common trend over time, but rather the migration of households due to economic changes within regions brings about the possibility of convergence in regional house prices. Some other papers have also indicated the role of migration as one of the mechanisms for price adjustments (Jones et al., 2004; Jones & Leishman, 2006). Except for pointing out the role of migration to cause price adjustments, Meen (1999) showed that interregional migration flows in the UK are too weak to cause price adjustments, even taking the effect of regional equity transfer or a spatial arbitrage diffusion process into account. The spatial pattern in the determinants of house prices is also another explanation.

Applying the technique of cointegration, the empirical results of MacDonald & Taylor (1993) and Alexander & Barrow (1994) confirm the notion that long-run interregional relationships exist between regional house prices in the UK. Contrary to this, Ashworth & Parker (1997) did not find evidence to support the ripple hypothesis. Jones & Leishman (2006) studied household migration and price ripples of local housing markets, applying data from Strathclyde, a sub-region of Scotland. According to the results from testing lead-lag relationships and cointegration, Jones & Leishman (2006) noted that house price dynamics in the Ayr cluster are independent of the Glasgow local housing market, but the opposite is true for the Paisley cluster.

There is also related research using data from other countries. Applying the Granger causality test, Berg (2002) indicated that the Stockholm region leads price changes in other Swedish housing markets. Stevenson (2004) studied the long-run relationships among cross-border house prices between the Republic of Ireland and Northern Ireland, finding that long-run relationships exist within the Irish housing market. Chen et al. (2011) also supported the existence of long-run cointegration within Taiwan's regional housing markets, employing the techniques of Johansen cointegration and TY's Granger causality test. More recent studies, using advanced methodology, have tended to examine the convergence of regional house prices, including some using a panel unit test (Holmes, 2007; Holmes & Grimes, 2008), some employing unit root tests allowing structural breaks (Chien, 2010; Canarella et al., 2012; Lean & Smyth, 2013), some applying the pairwise approach of the unit root test (Holmes et al., 2011; Abbott & De Vita, 2012), and some examining non-linear pair-wise causality (Kyriazakou & Panagiotidis, 2014). The above studies in literature have provided cross regional evidence, while

others have examined the ripple effect across submarkets within a city (Oikarinen, 2004; Ho et al., 2007; Sing et al., 2006; Liao, et al., 2014). However, while such empirical literature has examined this topic by different methods for different countries, they lack any consensus.

The above empirical literature has not discussed the interrelationships between cross-border house prices except Stevenson (2004), even as over the past two decades, regional integration systems have multiplied. As regional economic integration becomes increasingly significant, what causes cross-border house prices to be cointegrated? Kasparova & White (2001) showed that convergence in the economic environment could cause convergence in economic behavior. Structural differences between countries also might decrease, and housing market developments may become more similar.

Reviewing the past relative literature, some works have studied the overall impact of European economic integration on real estate markets, with a few showing significant barriers to the flow of real estate investment across European borders (Rydin et al., 1990; Parsa, 1993). An alternative descriptive analysis of the European markets is found in a report produced by Healey & Baker (1992), who analyzed the prospects for commercial property in the 1990s in the U.K. and continental Europe and indicated major divergent trends between the member states. Worzala & Bernasek (1996) found evidence of some convergence, but the extent is small, which implies that barriers to the efficient flow of investment funds into real estate remain, and distinct markets will continue to characterize real estate within the European Community. Examining housing markets in selected EU countries and investigating the degree of similarity in housing market responses to changes in underlying demand- and supply-side variables, the empirical results of Kasparova & White (2001) also do not exhibit the integration of housing markets across those countries.

Some papers have subsequently achieved more optimistic results about the integration of housing markets. The empirical results of Yang et al. (2005) show, after EMU's establishment in 1999, that the real estate markets of larger economies became more integrated with others, while the real estate markets of some smaller economies did not. In other words, EMU has provided benefits in terms of increasing real estate market integration among those EMU member countries with more advanced industrial structures. Using a global VAR estimation for three housing demand variables for 7 euro area countries, Vansteenkiste & Hiebert (2011) found house price spillovers in the euro area, but the magnitude is relatively low. Employing fractional integration and cointegration, Gupta et al. (2014) indicated that the data for the euro area are cointegrated with Belgium, Germany, and France, and the first two countries seem to be cointegrated with the majority of other countries in pairwise comparisons. Except for the above literature studying European data, there is also related research using data from other countries. Applying the U.S. and 17 other advanced countries to examine the co-movements in housing, credit, and business cycles within countries and internationally, Igan et al. (2011) noted that the U.S. housing cycle generally leads the respective cycles in other countries.

In light of the literature investigating GCEA's regional house markets, Huang et al. (2010) examined the ripple effect of regional house prices in China, displaying that housing price fluctuations among nine Chinese cities do have ripple effects. Using a regional panel dataset, Zhang & Morley

(2014) showed little evidence of convergence across the regions, although there is evidence of a ripple effect starting in Shanghai, Guangzhou, and Beijing. According to a synthesis of different models of house market dynamics, Ho et al. (2007) examined spatial "ripple effects" across different quality tiers of houses within the city of Hong Kong, and Sing et al. (2006) empirically looked at house price dynamics combined with the mobility of households in the public resale and private house markets of Singapore. In the past few decades, little attention has been paid to examining the dynamic links among Taiwan's regional house price indices. One exception is that after studying the dynamic relationship of house prices between Taipei City and Taipei County, Tseng et al. (2005) found that the former's house prices move ahead of the latter's. Recent papers that have studied the convergence of regional house prices in Taiwan include Chien (2010), Lee & Chien (2011), and Chen et al. (2011)[3].

From the papers listed above, little attention has been paid on the integration of cross-border house prices in GCEA. As with what has happened in the European Community, are these cross-border house prices in GCEA cointegrated when regional economic integration turns increasingly significant? To fill the gap in empirical cross-border house price studies for GCEA, this paper investigates lead-lag relationships and the dynamic linkages among cross-border house prices in GCEA.

4. Methodology

4.1. Granger Causality Tests of Toda & Yamamoto (1995)

The approach used in this paper is a modified version of the Granger causality test proposed by Toda & Yamamoto (1995). The advantage of the TY procedure is that it does not need pre-testing for the cointegration, which avoids the potential bias associated with unit roots and cointegration tests (Zapata & Rambaldi, 1997; Shan & Tian, 1998). Masih & Masih (2001) indicated that *"the Toda-Yamamoto procedure is simple and convenient to apply and permits linear as well as non-linear tests of restrictions. These restrictions themselves would then imply long run causal inference since, unlike ordinary difference VARs, this formulation involves only variables appearing in their levels."* The application of the TY procedure derives the usual test statistic for Granger causality with the standard asymptotic distribution, which circumvents invalid inferences. Hence, many papers have applied the TY version of the Granger non-causality test to study different topics[4].

To carry out the TY version of the Granger non-causality test, we represent each GCEA member's house prices (in natural logarithms) - Taiwan (LTW), China (LCH), Hong Kong (LHK), and Singapore (LSP) - in the following four-variable VAR system:

$$Z_t = \Phi_0 + \Phi_1 t + \Phi_2 t^2 + \Pi_1 Z_{t-1} + \ldots + \Pi_k Z_{t-k} + U_t, \ t = 1, \ldots T, \ \text{.......................... (1)}$$

where $U_t \sim N(0, \Omega)$; $Z_t = \left(LTW_t, LCH_t, LHK_t, LSP_t \right)$, and t is a deterministic time trend. Economic hypotheses can be expressed as restrictions on the coefficients in the model in accordance with the following:

$$H_0 : F(\pi) = 0 , \ \text{.. (2)}$$

where $\pi = vec(P)$ is a vector of the parameters in equation (1), $P = (\Pi_1 \ldots \Pi_k)$, and $F(.)$ is a twice continuously differentiable m-vector-valued function.

TY supply a simple procedure that facilitates testing for Granger non-causality in level VARs estimated by OLS with integrated variables. The augmented *(k+d)* VARs are estimated, where d is the maximal order of integration. To examine Hypothesis (2), TY confirm that the Wald statistic converges in distribution to an χ^2 random variable, with m degrees of freedom, apart from whether the process Z_t is stationary, possibly around a linear trend, or whether it is cointegrated.

4.2. Generalized Forecast Error Variance Decomposition and Generalized Impulse Response

To evaluate the relative strengths among different cross-border house prices in GCEA and to examine the transmission mechanism between these regional house prices, we employ generalized forecast error variance decompositions and the generalized impulse response approach of Pesaran & Shin (1998). We consider the VAR model as follows:

$$Z_t = A\sum_{i=1}^{p}\psi_i Z_{t-1} + \varepsilon_t ,\ \text{.. (3)}$$

where ψ_1 through ψ_p are (4×4) coefficient matrices, A is a vector of constants, Z_t is a (4×1) vector of jointly determined endogenous variables, and ε_t is a (4×1) vector of well-behaved disturbances with covariance $\Sigma = \sigma_{ij}$ $(i, j=1,2,3,4)$. Assuming that all the roots of $\left|I - \sum_{i=1}^{p}\varphi_i z^i\right| = 0$ fall outside the unit circle, we then can amend equation (3) to a limited vector moving average model as follows:

$$Z_t = \sum_{i=0}^{\infty}G_i \varepsilon_{t-i}, t = 1,2,\ldots,T ,\ \text{.. (4)}$$

where $G_i = \varphi_1 G_{i-1} + \varphi_2 G_{i-2} + \ldots + \varphi_p G_{i-p}, i = 1,2,\ldots,$ $G_0 = I$, $G_i = 0$ *for* $i < 0$.
We now define the generalized impulse response function of Z_t at horizon *n* by:

$$GI_x\left(n,\delta,\Omega_{t-1}\right) = E\left(Z_{t+n}\middle|\varepsilon_t = \delta,\Omega_{t-1}\right) - E\left(Z_{t+n}\middle|\Omega_{t-1}\right),\ \text{.. (5)}$$

where Ω_{t-1} is the non-decreasing information set that is the known history of the economy up to time *t-1*. Based on equations (4) and (5), we have $GI_x\left(n,\delta,\Omega_{t-1}\right) = A_n\delta$, which is independent of Ω_{t-1}, but depends on the composition of shocks defined by *j*. If there is only one element *j*, then we amend equation (5) as:

$$GI_x\left(n,\delta_j,\Omega_{t-1}\right) = E\left(x_{t+n}\middle|\varepsilon_{jt} = \delta_j,\Omega_{t-1}\right) - E\left(x_{t+n}\middle|\Omega_{t-1}\right)\ \text{.. (6)}$$

Assuming that ε_t has a multivariate normal distribution, then the *j*th shock's conditional expected value is as follows:

$$E\left(\varepsilon_t\middle|\varepsilon_{jt} = \delta_j\right) = \left(\sigma_{1j},\sigma_{2j},\ldots,\sigma_{mj}\right)' \sigma_{jj}^{-1}\delta_j = \Sigma e_j \sigma_{jj}^{-1}\delta_j\ \text{.. (7)}$$

By setting $\delta_j = \sqrt{\sigma_{jj}}$, we set up the scaled generalized impulse response function as:

$$GIRF(n) = \sigma_{jj}^{-\frac{1}{2}} G_n \Sigma e_j, n = 0, 1, 2, \mathrm{K} \ ,$$ .... (8)

where e_j is a (4×1) selection vector with unity as its jth element and zero elsewhere.

One may also apply the above generalized impulses to derive the forecast error variance decompositions. Let us indicate the generalized forecast error variance decompositions by:

$$GVDC_{ij}(n) = \frac{\sigma_{ij}^{-1} \sum_{l=0}^{n} \left(e_i' G_l \Sigma e_j \right)^2}{\sum_{l=0}^{n} \left(e_i' G_l \Sigma G_l' \sum e_i \right)^2}$$ .... (9)

5. Data and Empirical Results

5.1. Data and the Results of the Cointegration Test

This empirical analysis applies the cross-border house price indices of four Asia economies in GCEA, from the first quarter of 1998 to the fourth quarter of 2010. All variables used are nominal and in natural logarithms. The data for Taiwan are obtained from the housing index database of Sinyi Real Estate Development Company. The Sinyi house price index is a constant quality index, applying the hedonic housing price model to control for changes in the quality and location of houses sold. The housing price index is adjusted quarterly based on the actual transactions of different types of dwellings (Wang & Lee, 2008)[5]. The other data are collected from the Institute for Physical Planning and Information (IPPI) of Taiwan, which compiles data on international residential prices and rent indices from China, Hong Kong, and Singapore. The real estate data for China are published by the National Statistical Bureau, which is a weighted index on different property types, including residential, luxurious residential, retail, other types, and so on[6] (Wang, et al., 2011). The data for Hong Kong are published by the Hong Kong Rating and Valuation Department and make up a basket of actively transacted residential developments of five unit sizes[7] (Chow & Wong, 2011). The data for Singapore are published by the Urban Redevelopment Authority (URA) of Singapore and are transaction-based indices constructed using a representative basket of properties that are weighted from all residential transactions[8] (Deng et al., 2012).

We start by testing for the presence of a unit root in regional house prices using the ADF, DF-GLS, PP, KPSS, and NP (Ng & Perron, 2001) unit root tests. Table 2 reports the results of these univariate unit root tests with intercept and trend[9]. The results show that all variables follow I(1) processes. According to the empirical results of all unit-root tests, all four regional house prices in GCEA follow are I(1) processes. Hence, we further use Johansen's (1988) cointegration to analysze the long-run relationships among the four cross-border regional house prices: LTW, LSP, LHK, and LCH. From the test results of SC to determine the number of lags, we select lag 1.

We next perform the tests for the number of cointegrating vectors, and the results are in Table

3. According to the results of the trace, we confirm that among the variables there is a stable long-run equilibrium relationship. The results of the cointegrated coefficients of the long-run relationship equation are shown as equation (10), and all of these coefficients in this equation have been tested for significances based on Johansen and Juselius' (1990) approach in Table 8.

$$LTW_t = 2.949 * LCH_t + 0.485 * LHK_t + 0.177 * LSP_t + 0.006 * trend \text{ .... (10)}$$

Table 2. Univariate Unit-root Test

Country	ADF	DF-GLS	PP	KPSS	NP(MZ_α^{GLS})
Level					
China	-2.525 (4)	-2.806 (0)	-3.138 (6)	0.224 (0) ***	-11.347
Hong Kong	-2.472 (0)	-0.630 (1)	-2.427 (2)	0.232 (5) ***	-1.662
Singapore	-3.046 (1)	-2.838 (1)	-2.189 (2)	0.195 (5) **	-2.763
Taiwan	-1.517 (0)	-1.144 (0)	-0.960 (16)	0.240 (5) ***	-2.685
First-Difference					
China	-6.244 (0) ***	-5.505 (0) ***	-6.219 (3) ***	0.039 (3)	-23.233 **
Hong Kong	-6.527 (0) ***	-4.782 (0) ***	-6.563 (5) ***	0.079 (3)	-20.650 **
Singapore	-5.570 (1) ***	-4.766 (1) ***	-3.584 (2) **	0.043 (1)	-32.275 ***
Taiwan	-8.005 (0) ***	-7.983 (0) ***	-16.202 (28) ***	0.042 (3)	-24.452 ***

Notes: The numbers in parentheses are the lag order in the ADF and DF-GLS tests. The lag parameters are selected on the basis of SC. The truncation lags are for the Newey-West correction of the PP and MZ_α^{GLS} tests in parentheses.

Table 3. Johansen's Cointegration Test

	λ_{max}		TRACE	
Model	Statistics	5% critical value	Statistic	5% critical value
r=0	25.921	32.118	66.505**	63.876
r=1	18.836	25.823	40.583	42.915
r=2	15.726	19.387	21.747	25.872
r=3	6.021	12.517	6.021	12.517

Notes: We construct 5% critical values, having been adjusted for small samples, from the asymptotic critical values of Osterwald-Lenum (1992) using the method of Cheung & Lai (1993).

Table 4. Cointegration Vector Coefficient Significance Test

	LHK	LCH	LSP
Statistic	2.243	5.777	0.297
P-value	[0.134]	[0.016] **	[0.585]

Notes: We obtain the LR test statistic by means of the $\chi^2(r)$ test; numbers inside [ ] are the p-values.

According to the results of cointegration, from equation (10) and Table 4, the coefficient of LCH is positive and significant at the 5% level, while the coefficients of LHK and LSP are also positive, but insignificant. In other words, only the ripple effect of cross-border house prices between China and Taiwan is significant in the long run. What causes this? In the last decade, the impressive economic growth of China and the resulting increased links between China and Taiwan have produced a complex network of trade, cultural interaction, tourism, etc. According to Taiwan Customs' statistics in 2011, China is the number one export destination for Taiwan and the second largest source of imports.

Not only has Taiwan grown more dependent on China as a market, but Taiwan is also a main contributor to China's FDI. Taiwan's FDI to China accounted for over 60% of Taiwan's total FDI in the past decade and 9.86% of Taiwan's domestic investment in 2009. At present, one to two million Taiwanese, or 5-10% of Taiwan's population, frequently work or live in China, with most of them accompanying Taiwanese firms' reestablishment or investment in China. There is obviously a close and complex network of trade, investment, and migration between the two. As a matter of fact, because of the ease-of-movement factor between them, the relationship can be described as that of two domestic regions.

5.2 Results of Granger Causality Tests and Impulse Response Analysis

5.2.1 Results of Granger causality tests

Table5 summarizes all empirical results of Toda & Yamamoto(1995) Granger causality tests between cross-border house price indices of GCEA. We observe a bidirectional relationship between house prices in Taiwan and Hong Kong. Due to political and ideological differences and occasional tensions between Taiwan and China, much trade and investment from Taiwan to China went through the intermediary trading hub of Hong Kong in past decades. Among the surveyed Taiwanese companies, 80.9% indicate they use Hong Kong banks for fund transfers between Taiwan, China, and Hong Kong (Wang & Thi, 2010). These closer interactions, in investments or business activities between Taiwan and Hong Kong, cause the bidirectional relationship of house prices between these two regions.

There is a unidirectional relationship running from Taiwan to China. Why do Taiwan's house prices lead China's house prices? To some extent, the housing market in China has some substitute effects on the housing market in Taiwan. In the past decade, firms became highly mobile across Taiwan and China, with more than 60% of Taiwan's outward FDI having gone to China, and trade

barriers between China and Taiwan have fallen, causing some Taiwanese firms to choose to invest in China instead of Taiwan in order to target the larger demand in China. As noted earlier, 5-10% of Taiwan's population are working or living in China. In other words, these two areas' house prices have some linkages through migration and equity transfer, which have caused some Taiwanese firms and some migrants to choose China over Taiwan for investing and working.

Table 5. Granger Causality Test of Toda & Yamamoto (1995)

| Dependent variable	LSP	LTW	LHK	LCH	Result
LSP	–	0.770	7.154**	0.052	LHK➔LSP
		[0.385]	[0.010]	[0.820]	
LTW	1.678	–	4.095**	0.174	LHK➔LTW
	[0.202]		[0.049]	[0.679]	
LHK	0.635	5.509**	–	0.005	LTW➔LHK
	[0.431]	[0.024]		[0.941]	
LCH	2.176	6.737**	0.026	–	LTW➔LCH
	[0.148]	[0.013]	[0.872]		

Notes: ** represents significance at the 5% levels. Significance implies that the column variable Granger causes the row variable. The reported estimates are asymptotic Wald statistics. The values in parentheses are *p*-values.

Being geographically far away from the other three, there is no causality between Singapore and any one of the other three at the 5% significance level, which confirms that house prices' causal relationships do not work between different regions far away from each other (Oikarinen, 2004). However, there is a unidirectional relationship that runs from Hong Kong to Singapore. Hong Kong and Singapore represent developed Asian property markets, and both have the most established and efficient capital markets in the Asia region, aside from Japan. Hence, their financial markets, including real estate, are in direct competition, causing an existing causality between the two cities.

5.2.2 Results of impulse response analysis

To discuss the extent and the persistence of the response of house prices in one region to unanticipated changes in other areas, we use the GIRF analysis of Pesaran & Shin(1998) for investigation. Figures 3(a) to 3(d) show the mutual impacts of shocks among LSP, LTW, LHK, and LCH. As can be seen in the four figures, in the first two quarters there is an unexpected positive shock from all four house prices that has a positive and significant impact effect on itself. This "own" effect then diminishes over a horizon of two periods after the shock. The point estimates of these "own" effects show that the impact effects are respectively about 40% for Singapore and Taiwan, around 60% in Hong Kong, while just 20% in China. A shock from house prices in Hong Kong initially has a significantly positive impact on house prices in Singapore (in Figure 3(c)) within the first and second

quarters. The point estimate presents that the impact effects are respectively about 10%-30%. In other words, after evaluating the relative strengths and the transmission mechanism of these four cross-border house prices in GCEA, the results of GIRF show that Hong Kong initially has a significantly positive impact on Singapore, while all the other responses from each house price shocks are insignificant.
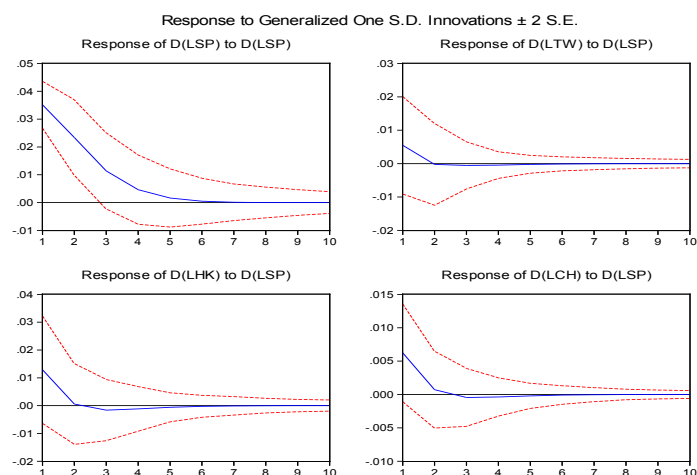

Notes: The horizontal axis denotes the quarters ahead and the vertical axis denotes the extent of the response, scaled such that 1.0 equal one standard deviation. The dashed lines indicated confidence bands.

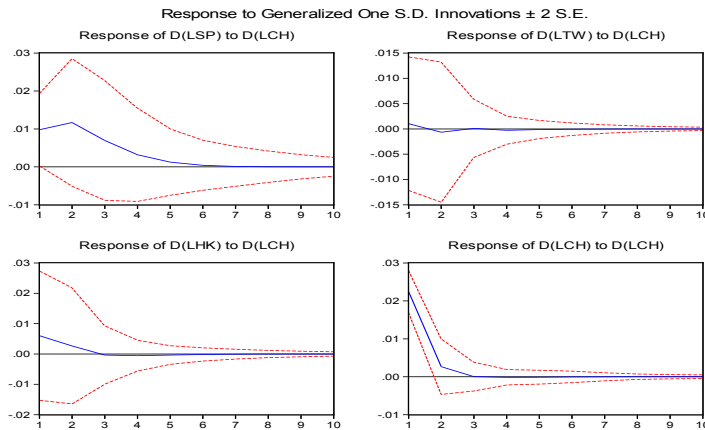Figure 3(a). Generalized impulse responses (a shock from Singapore)
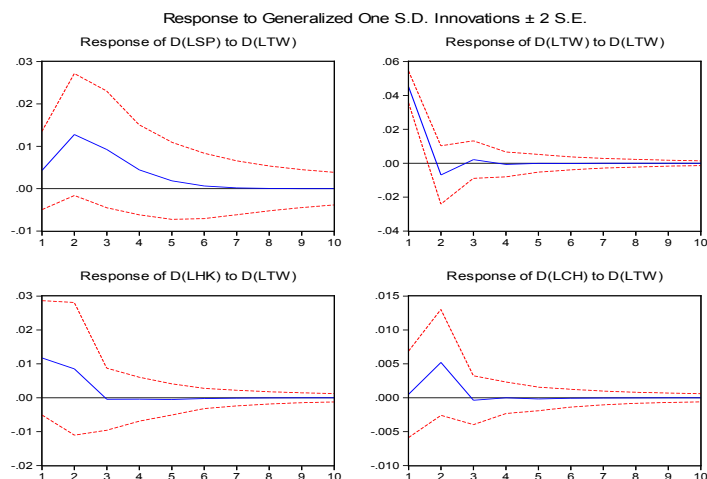
Notes: same as the notes of figure 3(a)

Figure 3(b). Generalized impulse responses (a shock from Taiwan)
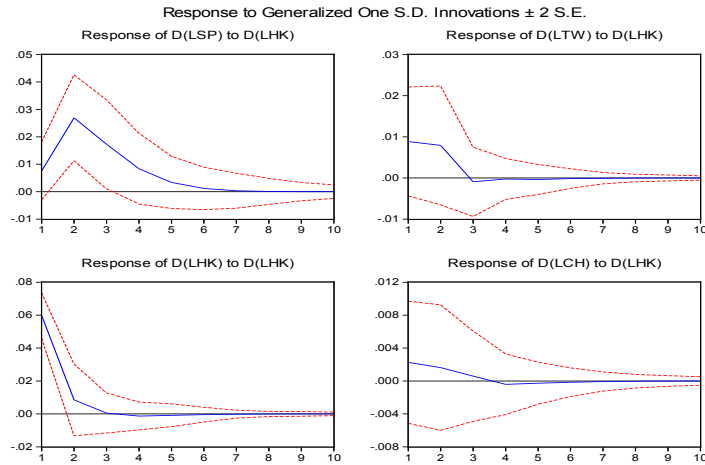
Notes: same as the notes of figure 3(a)

Figure 3(c). Generalized impulse responses (a shock from Hong Kong)

Notes: same as the notes of figure 3(a)

Figure 3(d). Generalized impulse responses (a shock from China)

5.3 Results of Generalized Variance Decomposition

The result of cointegration, as seen in section 5.1, helps us discuss the relationship of cross-border house prices' level among these four economies in the long run, and the result of TY shows that a causal inference can be noted in the house prices' level in the short run. This section applies GVDC to explain the volatility of each other shock among these four house prices. According to GVDC's result, the percentage of forecast variance explained by innovations of each variable, no matter in the short run or in the long run, can show the endogenous extent of variables and can measure the relative importance of different regional house prices.

Table 6. Generalized Variance Decomposition

Dependent variables	Horizon (quarter)	Percentage of forecast variance explained by innovations in %			
		ΔLSP	ΔLTW	ΔLHK	ΔLCH
ΔLSP	1	100.0000	0.000000	0.000000	0.000000
	2	86.06385	9.009018	4.189592	0.737544
	3	79.12362	16.12998	3.883864	0.862532
	4	76.57934	18.28518	4.273325	0.862156
	5	75.97254	18.81349	4.348588	0.865378
	10	74.17292	20.47219	4.470007	0.884884
ΔLTW	1	7.143794	92.85621	0.000000	0.000000
	2	12.35230	71.69032	14.58440	1.372983
	3	14.19920	69.90295	14.19788	1.699968
	4	17.63056	65.91049	14.70128	1.757674
	5	19.75063	62.75721	15.53878	1.953375
	10	26.63626	53.99352	16.87286	2.497367
ΔLHK	1	2.472737	16.28643	81.24083	0.000000
	2	3.654446	24.43344	71.85945	0.052673
	3	2.673076	28.11337	69.17524	0.038317
	4	2.579593	27.50278	69.88459	0.033036
	5	2.415070	28.37350	69.18343	0.028006
	10	1.944947	29.73161	68.30785	0.015594
ΔLCH	1	2.563802	0.359590	1.002760	96.07385
	2	2.595036	2.603046	1.746546	93.05537
	3	2.346256	2.073434	1.875264	93.70505
	4	2.254411	1.875592	1.956053	93.91394
	5	2.198749	1.729788	1.990616	94.08085
	10	2.080779	1.459767	2.109544	94.34991

Note: The first-differences' operator is denoted by Δ.

Table 6 presents the results of GVDC over a ten-quarter period for each region. Table 6 indicates house prices in Singapore are clearly the most exogenous in these four areas in the short run. The other areas can explain the fluctuations of house prices in Singapore around 30% one quarter later (short run), and the portions are respectively 7.14%, 18.76%, and 3.93% for Taiwan, Hong Kong, and China. Ten quarters later, the portions increase to 25.83% for Singapore, with the largest shock from Taiwan at around 20%, while the other two regions' shocks are small.

No matter in the short run or long run, Taiwan is clearly the most endogenous in these four areas:

over 46% of its fluctuations are explained by other regions' house prices after 10 quarters. The price level of Singapore explains more than 26% of the variance in Taiwan after 10 quarters, Hong Kong explains around 17%, while China just explains around 2.5%. Versus others in GCEA, Taiwan's government uses less intervention to control the house market, as described in Section 2.1, which results in a more flexible house market in Taiwan and makes Taiwan's house market more easily impacted by others.

In the long run, China's house prices have become the most exogenous, implying that the large scale of China's market cannot be easily impacted by other housing markets' fluctuations. Ten quarters later, the portion of their fluctuations are explained by other regions' is 5.66% for China, which is smaller than the portions of the others, respectively at 25.83%, 46.01%, and 31.70% for Singapore, Taiwan, and Hong Kong. As to Singapore and Hong Kong, in the long run around 26% and 31% of their fluctuations are explained by other regions' house prices after 10 quarters. For these two regions, both have the same largest shock from Taiwan, respectively around 20% and 30%. In other words, for the relative strengths of these four cross-border house prices in GCEA, the results of GDVC show that the fluctuation of Taiwan's market has greater influences on the fluctuations of the other three in GCEA.

6. Conclusions and Implications

This paper examines the lead-lag relationships and the dynamic linkages among cross-border house prices in 4 regions of GCEA. We have used the cointegration method to evaluate whether these cross-border house prices are integrated, finding lead-lag relationships by applying the Toda & Yamamoto(1995) causality test. To evaluate the relative strengths among different cross-border house prices in GCEA and to examine the transmission mechanism between these regional house prices, we have employed GDVC and GIRF. Our main findings and some policy implications are as follows.

First, our empirical results of the cointegration test show that there is a long-run equilibrium among these four GCEA cross-border house prices, while only a diffusion effect of cross-border house prices between China and Taiwan is significant in the long run. There is an ease-of-movement factor between Taiwan and China, which is a distinguishing characteristic, versus the other inter-country relationships, and makes cross-border house prices between China and Taiwan more integrated. Hence, one policy implication is that a house price stabilization policy, no matter for Taiwan or China, may well not have a permanent effect on the domestic housing market in the long run. Perhaps there is no need for artificial intervention in the housing market in the long run.

Second, the results of TY's Granger causality test provide evidence of a unidirectional relationship running from Taiwan to China, as well as from Hong Kong to Singapore. Moreover, there is a bidirectional relationship of house prices between Taiwan and Hong Kong. For policy makers, the causalities within these four cross-broad markets are very complicated, meaning that any housing policy in one economy not only influences the domestic housing market, but also the three other economies in GCEA.

Third, for evaluating the relative strengths and the transmission mechanism of these cross-border house prices, the results of GIRF show that Hong Kong initially has a significantly positive impact on Singapore, while the responses from the other countries' house price shocks are all insignificant. The results of GDVC indicate that house prices of China are the most exogenous in the long run, implying that China's market, due to its large scale, cannot easily be impacted by the others. Taiwan's market can more easily be impacted by other regions' markets in GCEA, because its government has used less intervention, which results in a more flexible house market there. This finding suggests that policy makers in GCEA should pay more attention to Taiwan's house price shocks in order to adjust their own housing market and prevent significant changes therein.

Fourth and finally, the results of the panel causality test indicate that there is uni-directional Granger causality running from real income to house prices in both the long run and short run. This means real income is strongly exogenous and whenever a shock hits the system, house prices make short-run adjustments in order to restore the long-run equilibrium.

Endnotes

1. ECFA is the "Economic Cooperation Framework Agreement" between Taiwan and China.

2. The data for Taiwan are obtained from Sinyi Real Estate Development Company, and the data for China, Hong Kong, and Singapore are published by the National Statistical Bureau, the Hong Kong Rating and Valuation Department, and the URA of Singapore, respectively. All variables used are nominal and in natural logarithms.

3. Although few papers have examined the ripple effect of regional house prices in Taiwan, many papers recently have studied the volatility and risk of house prices in Taiwan (Tsai & Chen, 2008; Chang et al., 2009; Chiang et al., 2011, etc.).

4. Many papers have applied TY's causality test for different topics, some for energy (Wolde-Rufael, 2004; 2006; Soytas et al., 2007; Lee & Chien, 2011), some for FDI (Chowdhury & Mavrotas, 2006), some for export (Awokuse, 2003), some for monetary policy (Awokuse & Yang, 2003), some for stock markets (Masih & Masih, 2001), and some for housing markets (Chen et al., 2011).

5. The characteristics of Taiwan are that there are few detached houses, with apartments and high-rise apartments the popular dwelling types in Taiwan. The Sinyi house price index covers the prices of apartment and high-rise apartments.

6. It is a weighted index on different property types, including 4 categories: residential housing (typical residential and luxurious residential), non-residential (office, retail, and other type), old stock transaction (residential and retail), and public housing.

7. The units are categorized by sizes and districts, and there are five classes of size. The five classes of size are defined as: Class A is premises with saleable area not exceeding $39.9m^2$, Class B is $40m^2$ to $69.9m^2$, Class C is $70m^2$ to $99.9m^2$, Class D is $100m^2$ to $159.9m^2$, and Class E is $160m^2$ or above.

8. The URA residential property price index is computed for all residential transactions on a quarterly basis, and the housing type includes detached house, semi-detached house, terrace house, apartment, and condominium, and this index uses the median price approach.

9. In this paper, *, **, and *** in all of the tables indicate significance at the 10%, 5%, and 1% levels, respectively.

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