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Ripple effect of housing market in the Greater Bay Area, China: A spatial-temporal analysis using different spatial weights matrices

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Summary

Regional integration and urbanization are the two intertwining trends that are shaping the economic geography landscape of cities. During this process, the dynamic intercity relationships within urban clusters has important impacts on regional housing markets. In the case of GBA, various types of spatial interaction have been forming a network structure, which provided possibilities for close linkages across housing markets. Therefore, the spatial-temporal patterns of ripple effects are potentially one of the most significant characteristics in understanding the regional housing markets and urban agglomeration as a whole.

The thesis adopts the GBA as a case to examine the ripple effects from the different channels of regional integration, and tests how the interface of intra-city socio-economic fundamentals and inter-city relationships function in ripple effects, that is influencing the housing price of cities itself as well as the spill-over effect.

The analysis of the thesis was developed in three aspects. Firstly, it evaluated the characteristics of ripple effect in terms of short-term volatility, spatial aggregation and diffusion, and spatial lead-lag relationships. This is the fundamental validation of ripple effects as spatial-temporal patterns of housing prices across markets. Secondly, it described the patterns and compared relationships of multi-dimensional regional integration as the potential transmission channels of ripple effect. The five facets of regional integration are geographical contiguity, transportation accessibility, economic gravity, institutional proximity and information transmission. The last part explores the mechanisms of how multi-dimensional integration functions as the transmission channels of the ripple effect by estimation in dynamic spatial models.

In this context, geographical adjacency is not necessarily associated with spatial diffusion of housing price in this case. Instead, spatial linkages other than physical distance are considered as structuring elements in the spatial framework for ripple effects. However, conclusion verified that geographical distance is still the physical condition that influences the formation of other spatial linkages. But its role has becoming more and more indirect and subtle, as it is not the single determination for spatial leading-lag relationships. As for the impacts of regional integration on ripple effect. The results of dynamic Spatial Durbin Models indicated that the general direction of ripple effects is threefold: positive spatial diffusion effects, positive time lag effects and negative spatial-temporal diffusion effects. However, the magnitudes are different across matrices. Information transmission is the most prominent channel for spatial diffusion and time lag effects, while transportation accessibility is more significant for the negative spatial-temporal diffusion effects. Also, common factors are considered to explain the role of general markets situations, while marginal effects are further analysed to test the the direct and indirect effect of socio-economic fundamentals in both the short- and long- run.

In terms of policy recommendation, it is to design a regional management mechanism that the multi-dimensions relationships in a comprehensive and dynamic way, instead of limited on the static geographical profiles. Also, it is crucial for each city to reconsider and establish its general and sector strategy under the framework of regional development.

Keywords

Ripple effect, regional integration, housing price, dynamic Spatial Durbin Model

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Chapter 1: Introduction

1.1 Background

Regional integration and housing market interrelations are related but marked different dynamic processes.

On the one hand, through improving transportation accessibility and relocating resources, regional integration implies a series of structural changes within and between cities as interactions characterising the spatial pattern of regional development. On the other hand, embedded in the integrating economic network, the demand and supply factors of real estate markets are not bounded within the city but also react and evolve with internal urban structure changes and city interactions at the regional level.

As for housing market interrelations, the “ripple effect hypothesis” is regarded as the basic concept in analysing spatial-temporal development and diffusion patterns of cities and urban regions. A house pricing development starts off in a certain place, and diffuses over space in ripples covering larger spheres of impact – either physically or in networked environments (e.g. according to functions or sizes of places in the urban region). However, this hypothesis has gradually developed into an assemblage of different interpretations and qualifications to capture the different spatial-temporal pattern of housing prices. The “ripple effect hypothesis” is more than the statistical phenomena of cross-section relationship in housing price. It is the concretized and specified mechanism that defines the emergence and evolvement nature of ripple effect.

To some extent, validation of the existence and examination of the mechanism of ripple effects are two sides of the same coin in terms of the “ripple effect hypothesis”. Only with the investigation of what gives rise to the ripple effect we can gain real insight into regional housing market dynamic, especially on the scale of an integrating region with intensive internal structural changes (nodes) and social-economic interactions (flows).

1.2 Problem statement

Since the urban housing system reforms in 1998, China’s housing market has experienced a rapid development along with economic growth and urbanization. On the one hand, economic growth and urbanization have generated strong housing demand. On the other hand, the booming real estate industry has become one of the powerful engines for stimulating economic growth.

The Guangdong-Hong Kong-Macao Greater Bay Area (GBA) is a typical example representing this co-prosperity of economic growth and real estate market. Originating from the spatial concept of the Pearl River Delta, the GBA is one of the urban agglomerations with the most significant economic growth and booming housing market in the past decades. Consisting of the Hong Kong Special Administrative Region (HKSAR), the Macao Special Administrative Region (Macao SAR) as well as the municipalities of Guangzhou, Shenzhen, Zhuhai, Foshan, Huizhou, Dongguan, Zhongshan, Jiangmen and Zhaoqing in Guangdong Province, the GBA covers a total area of 56 000 square kilometres with a combined population of approximately 70 million at the end of 2017.

As a designated Special Economic Zone in the national economy, the spatial heterogeneity and cyclical adjustment of the real estate industry are the reflection of regional economic transformation. Although there is a general growing trend in economic growth and the housing market, there are differentiations across time and space.

One important trend along that of economic growth is the process of regional integration. Under the Outline Development Plan for the Guangdong-Hong Kong-Macao Greater Bay Area (the New GBA Plan) issued by China's central government on February 18, 2019, the regional economic integration of GBA has been upgraded to a national strategy. Aiming at developing the region into a globally competitive world-class metropolis, the process of regional integration involves vibrant socio-economic interaction in goods, people, capital and information. There are numerous large-scale infrastructure projects in the region, including the Guangzhou-Shenzhen-Hong Kong Express Rail Link and the Hong Kong-Zhuhai-Macao Bridge, which will significantly reduce travel time within GBA and create various "one-hour living circles" to enhance the flow of people and goods. Also, based on comparative advantages, the cities are forming a strong urban network of competition and complementarity.

As for the housing market, the integrating regional network development also indicates a new perspective to examine housing market dynamics: as cities within a region are becoming economically interdependent, their housing markets may also be interrelated with other cities. One of the prominent hypotheses for these spatial interrelationships in housing markets is the "ripple effect hypothesis", which explains the spreading out of leading house price changes from one area to others (Meen, 1999). Various factors are found to strengthen this housing price transmission, including migration, equity transfer, spatial arbitrage, information flow, expectations and spatial infrastructural patterns in the determinants of housing prices (Meen, 1999, Gray, 2012).

The presence of such spatial-related transmission factors has been observed in China, but it is not clear to what extent these factors relate to regional integration and how it may collectively affect the pattern of regional housing market dynamics. For example, the loosening of Hukou restrictions has largely accelerated labour mobility and induced the equity transfer. The "superstar cities", with more experienced market participants, higher frequency of transactions and lower information costs, are usually the source of price signals, which facilitates the chance of spatial arbitrage between "superstar cities" and "normal cities"(Wu, J. and Deng, Y. 2015).

According to the development objectives set in the Outline Development Plan for the Guangdong-Hong Kong-Macao Greater Bay Area (the New GBA Plan), by 2022, "regional development should become more coordinated, and a city cluster which has a reasonable division of labour, complementary functions and coordinated development should basically be established". Under this strategy of coordinated regional development, it is important to prompt the policy synergy from two dimensions: between policy domains and between municipal governments. On the one hand, aiming at stabilization the local or regional housing market, the effectiveness of policies is increasingly affected by a series of structural changes within cities and in intercity interaction. On the other hand, the inter-municipal cooperation in regional governance is becoming more important, because of the interaction and evolution of market factors embedded in the integrating economic and social networks.

1.3 Research objective

This thesis takes the GBA as a case to analyse the fundamental mechanisms of housing price transmission during regional integration. The specific objectives are:

- To test the validity of ripple effects of housing price processes from three defining characteristics:
  Spatial aggregation and diffusion, that is the spatial autocorrelation in terms of geographical contiguity; Short-term volatility, that is the scale and magnitude of housing price change; Spatial lead-lag relationships, that is the spatial causality between housing

markets. To be more specific, to what extent can the historical house price information in one market be used to predict the current house prices in other markets.

- To describe the patterns of multi-dimensional regional integration, including geographical adjacency, institutional proximity, transportation accessibility, economic gravity and information transmission, which are identified as potential transmission channels of ripple effects.
- To explore the potential influence of regional integration as transmission channels for ripple effect in house market.

1.4 Research Question

Main research question

What mechanisms are responsible for intercity transmission of housing prices ("ripple effects") during the process of regional integration in the Guangdong-Hong Kong Macau Greater Bay?

Sub-research question

- What are the patterns of regional housing price dynamic in terms of ripple effects?
- What are the patterns of multi-dimensional regional integration in the region, and which transmission channels represent and explain the ripple effect in this integration process?
- How does the multi-dimensional integration by means of various transmission channels explain the ripple effect?

1.5 Significance of the Study

Firstly, this thesis enriches the empirical evidence for the ripple effect hypothesis. In terms of methods, two classical mechanisms, that is spatial dependence and coefficient heterogeneity, will be incorporated into spatial panel models simultaneously. For the specific case, The GBA in China is a case of regional integration in a transitional society, and the regional housing market is largely influenced by the regional spatial economic structure, thus making this research a typical case for the testing of the ripple effect hypothesis.

Secondly, it introduces the context of regional integration into the ripple effect hypothesis, thus contributing to the theoretical development in cross-sectional dependence. Various spatial weight matrices are incorporated to represent the patterns of interaction and diffusion as spatial autocorrelation. Combined with spatial heterogeneity, it contributes to a new approach to rethink the economic fundamentals of housing markets through cross-sectional dependence in a spatial-temporal framework.

Thirdly, this research is related to regional policy both in fields of housing markets and regional integration. Narrowly defined policies on either the housing market, economic cooperation and regional integration in isolation, often misses the critical impact of policy actions or non-action on other relevant areas. Acknowledging that the housing market is related to regional integration indicates the importance of considering these two policy domains in a comprehensive manner. Thus, it allows for potential synergy between stabilization of the regional housing market and the enhancement of regional economic development, both contributing to achieving the ambitious regional development strategy. Also, the identification of different facets of regional integration can be helpful for sustainable, coherent and coordinated planning and management.

1.6 Scope and Limitations

1.6.1 Definition scope

The defining characteristics of ripple effect and types of regional integration are highly abstracted and strictly selected. To be specific, the ripple effect is validated by three conditions: spatial aggregation and diffusion, short-term volatility and spatial lead-lag relationships. Multi-dimensional regional integration is decomposed as transportation, economic, industry, institutional and expectation integration within the GBA.

As this thesis focuses on the causal relationships between regional integration and ripple effect, the primary concern for the definition is to balance the theoretical and empirical relation between these two concepts. Instead of trying to trace all the possible aspects related to regional integration, this thesis only selects the very distinct matrices reflecting very distinct processes of transmission that are most prominent based on current research trend and limited experience.

1.6.2. Methodology scope

The selection of spatial weights in the modelling part imposes an a priori structure of spatial dependence, which will highly affect the answer to the question as to whether spatial dependency is present. However, this process is largely restricted to the specific economic context and data availability, which may not correspond to reality. As stated by (Gibbons and Overman, 2012), spatial econometric models may suffer from misspecification since the weight matrix which is central to those models is constructed in an ad-hoc manner. Besides, the accuracy of measurement for these spatial weights may also largely affect the estimation of spatial dependence models (Anselin, 2002, Fingleton, 2003) . To minimise these threats, the definition and conceptualization of integration is based on cautious consideration of theory feasibility and realistic relevance. And the selection of specific data representing each matrix is with reference to the most adopted treatments from existing research. In this way, the implication of each matrix is not specially limited to this thesis, but also share the same theoretical and empirical background with a large range of related research.

1.6.3 Geographical scope

The research case is the GBA in China, consisting of nine cities of PRD in mainland China and two special administration districts. On the one hand, this difference in administrative and economic systems restricts the accessibility of comparable data. The process of indicator calculation and unification may decrease the accuracy of the research results. On the other hand, this difference makes the case of the GBA so typical that it allows for the analysis of potential boundary effect which may affect the spatial diffusion of housing price in an integrating region .

Chapter 2: Theory Review

To explore the potential influence of regional integration as transmission channels for ripple effect in house market, the spatial interrelationships of housing markets and regional integration are investigated and combined to formulate relevant theoretical linkages.

This literature review consists of four parts: the first part focuses on the interaction of market mechanisms and policy in housing markets, especially in the case of China. The second part introduces the spatial interrelationships in housing markets in terms of the ripple effect hypothesis. The third part is concerned with meaning and implication of regional integration as a form of spatial organization of cities. The last part discusses the conceptual framework about the impact of regional integration on spatial housing price correlation.

2.1 Housing price determinants: market-government interface

The mechanisms of housing prices have generated extensive debate from economists and policy analysts. Generally, existing studies on price determination mechanisms of housing markets can be categorized into three part: fundamentals, cyclical adjustment and bubble components.

As for policy, it does not operate on a blank background but is shaped by varying context. On the one hand, it is designed to meet certain goals in remedying the market failure of pricing mechanisms. In this, the analysis of housing prices from the policy perspective is closely associated with the specific situations that housing markets confront. On the other hand, it tends to be dominated by path dependency (Harloe, 2008). The legacies of past investment, institutional and organisational arrangements and cultures and practices will shape the policy direction and potential reform (Wang, Shao, et al., 2012). In the case of contemporary China, remarkable price growth, strong cyclical patterns and spatial disparity of housing price are the prominent features since the market-oriented housing reforms in 1998 (Logan, Bian, et al., 1999, Yang and Chen, 2014, Timberlake, Wei, et al., 2014). In this respect, housing market stability is on the top of policy agenda for central and local government (Glaeser, Huang, et al., 2017) Therefore, the following review on policy emphasizes on the various restrictive measures with price stability targets.

2.1.1 Threefold factors of market mechanism

A great deal of previous research into factors impacting on housing prices regards these as economic fundamentals. Macroeconomic variables have been examined in this scope under different contexts of countries across time: GDP, demographics, money supply, interest rates, and inflation (Case, Quigley, et al., 2003, Tsatsaronis and Zhu, 2004, Himmelberg, Mayer, et al., 2005, Hwang and Quigley, 2006, Mikhed and Zemčík, 2009, Rapach and Strauss, 2009, De Bruyne and Van Hove, 2013)

The second part of analysis in the literature focuses on the cyclical adjustment of housing markets, which explains the housing price dynamics as a process of equilibration with fundamental factors and short-term trends or momentum. Case and Shiller (1989) are among the first who argue that house prices are predictable. They find evidence of positive serial correlation in price changes of single-family homes. Abraham and Hendershott (1996) argue that the actual change of house prices can be explained by the mean reversion term and the changes in the economic variables.

Compared to the predictable deviation from fundamental values, the "irrational" factors such as bubble components are also introduced to explain the volatilities of housing price. Glindro et al.(2011) analyse the house price overvaluation and distinguish two components including inherent imperfections in housing markets (lags in supply adjustments, credit market friction) and overly optimistic expectation of future house price movements or housing market developments.

2.1.2 Government intervention in China

In China, governmental regulatory policies exert an important influence on housing prices. These interventions impact all actors in the housing market (Bramley and Leishman, 2005, Islam and Asami, 2009). The restriction of land conversion from agricultural to urban uses and mandating development of apartments with certain sizes influence the supply side from developers perspectives (Glaeser, Huang, et al., 2017) .Besides, there are restriction measures targeting individual traders from the demand side, typical examples of these are restricted bank loans ("xiandai"), restricted sale prices ("xianjia") and restricted housing purchases ("xiangou") (Zhou, 2016).

In the context of China's marketization and decentralization, the relations between central government and local governments also plays an important role in policy response to market(Fu and Lin, 2013, Zhu and Tang, 2018). Although central governments in China emphasizes the authority and top-down consistency of policies, there is tension of interests and incentives between higher- and lower governments (Ma, 2005). As a result of fiscal decentralization, land sales revenue collected in the transfer of state-owned land to developers is the key source of local fiscal income. It spurred incentives for local authorities to foster construction in housing market (Heberer and Senz, 2011). While the housing market stability has become the primary focus of central government, local governments are facing the challenges of balancing the benefits of land sales revenue with the role as agents of higher-level government. This bureaucratic decision-making process is described as “fragmented authoritarianism” (Lieberthal and Lampton, 1992) and a “muddling through” model (Zhou, Lian, et al., 2013).

2.2 spatial interrelationships of housing markets: ripple effect hypothesis

The “ripple effect hypothesis” is one of the typical hypotheses to explain the temporal-spatial housing price correlation. It was first observed by research in the UK as a phenomenon in housing markets where a perturbation of price is spread out from part of the region to the rest over time (Giussani and Hadjimatheou, 1991, MacDonald and Taylor, 1993, Meen, 1999). Research in the “ripple effect hypothesis” generally takes two directions. One is to empirically test the existence of ripple effect in the housing market. Another approach is to explain its patterns and mechanisms.

2.2.1 Validation of ripple effect: long term convergence and leading-lag relationships

Ripple effects are primary approached as an econometric phenomenon of unit root, which implies long term convergence of housing price of different submarkets (MacDonald and Taylor, 1993, Alexander and Barrow, 1994, Ashworth and Parker, 1997). Besides convergence, the leading-lag relationship of housing price is regarded as the defining characteristics of ripple effects. A large volume of literature has used the VAR model, combined with impulse-response analysis and variance decomposition, to reveal the leading-lag relationships among movement of housing prices in regions. (Cook and Thomas, 2003) tested the existence of ripple effect in the UK by detecting the leading regions which are most volatile and are first to display market up and down turns through volatility analysis and business cycle dating methods. The empirical study of Ireland suggested that ripple effect started firstly from Dublin and spread to the six peripheral areas of Cork, Waterford, Limerick Galway and Northern Ireland. Stevenson (2004) and Oikarinen, Peltola (2006) also validated the existence of ripple effect in Helsinki metropolitan area with substantial evidence of leading-lag relations between house price changes in the main economic centre and surrounding regions. Comparable results were found in Belgium (Buyst and Helgers, 2013), South Africa (Balcilar, Beyene, et al., 2013) and the Netherlands (Teye and Ahelegbey, 2017).

However, instead of only one leading area, Luo et al (2007) found a complex leading-lag network among 8 capital cities in Australia. Using the Granger causality test, this research suggested that the Sydney house prices only had impact on Melbourne, while house prices in Adelaide and Perth Granger-caused house price movements in all the other cities. Similarly, empirical studies in China revealed that while the housing price of Guangzhou and Dongguan were the Granger reasons for each other, the housing price of Shenzhen was the Granger reason for both (CHEN and HUANG, 2007). This complicated inter-market correlation pattern was also supported by evidence of 10 cities in the Pan Pearl River Delta, China (Gong, Hu, et al., 2016). However, since the Greater Bay Area is an relatively new regional concept, there is almost no empirical study aiming at analysing the leading-lag network on this scale. Therefore, this thesis tries to fill this research gap by adding a new regional scope.

2.2.2 Examination of mechanisms: spatial dependence and coefficient heterogeneity

Another approach to investigate the ripple effect hypothesis is to examine its causing mechanisms. As the effect of each factor or mechanism is not observable directly from housing prices, far too little attention has been paid to this quantitative examination. The theoretical rationale in this field can be categorized as focusing on “spatial dependence” or “coefficient heterogeneity”, which was first differentiated by (Meen, 1996). However, a systematic understanding with empirical support about the transmission mechanism of ripple effect is still lacking.

a. Spatial dependence

Spatial dependence was first termed as “spatial lag” analysis (Munro and Tu, 1996) to describe the house price diffusion between neighbouring housing markets. However, as noted by (Pollakowski and Ray, 1997) spatial dependence will not necessarily be bounded within neighbouring housing market, but also requires some forms of economic interrelationship. (Meen, 1996) further provided three possible mechanisms of interrelationship based on household behaviour: migration, equity transfer and spatial arbitrage.

Meen’s statements provide a basic theoretical framework for the other scholars who later found empirical evidence to elaborate on each mechanism. According to Canarella, Miller, et al(2012), migration may lead to house price ripple effect if households relocate in response to changes in the spatial distribution of house prices. Related to migration is equity transfer, households sell high in one region, then buy low in an adjacent region (Brady, 2014). Considering the inherent characteristics of property markets, including high transaction costs, infrequent transactions, lumpy investments and heterogeneity in subdistricts, there is an extensive potential of arbitrage across regional housing markets ((Nanda and Yeh, 2014).

Furthermore, house owners expectation as a psychological factor may influence their behaviour in housing market (Boelhouwer, Haffner, et al., 2004, Shiller, 1990). The empirical study by (Gray, 2012) found evidence for the case of district house price movements in England and Wales 1997–2007, that information flows and expectations were likely to reinforce price transmission.

b. Coefficient heterogeneity

Instead of spatial linkages among different markets, coefficient heterogeneity focuses on the internal structural difference of local markets. From this view, ripple effect can be explained irrespective of spatial linkages, but by the distinct spatial patterns of house prices determinants in submarkets, which lead to different market reaction to some common mechanism (Muellbauer and Murphy, 1994).

With this regard, ripple effect is examined under the specific context of exogenous shocks. Significant heterogeneity in housing price would suggest the spatial distribution of the effect of monetary policy (Yang, Wang, et al., 2010). A large volume of literature has investigated the heterogeneity of regional market performance in response to monetary shocks in many countries (Fratantoni and Schuh, 2003, Del Negro and Otrok, 2007, Owyang and Wall, 2009, Yu and Huang, 2016). As for the changes in interest rate, it may lead to changes in arbitrage cost between financing housing and other assets that influence housing prices (Poterba, 1984, Miles, 1992). Shocks in the interest rates may also increase the risk premium of house consumption, which motivates the households to diversify their portfolios away from housing (Kearl and Mishkin, 1977, Wong, Yiu, et al., 2012).

2.3 Regional integration: concepts, concretisation and measurement

Regional integration is a widely used concept referring to the interactions between different territories. However, the exact meaning and implication are to be defined according to the scale and approach or perspective.

The interpretation of regional integration can be scale-dependent, ranging from relations between nations (Dabinett and Richardson, 2005), between regions (Vickerman, 1995, Anderson and Wever, 2003), between cities (Cheshire, 1999, Van Oort, Burger, et al., 2010) and intra-metropolitan (Hansen and Serin, 2007, Sohn, Reitel, et al., 2009).

2.3.1 Concepts: central places theory, urban agglomeration and PURs

In terms of regional integration between cities, early works could be traced back to the tradition of Walter Christaller's Central Place Theory (Christaller, 1933). Based on a study in southern Germany, the central place theory use "the sphere of influence" of goods and services to explain the orderly spatial distribution and formation of hierarchy among different size of settlements. "The sphere of influence" is determined by two basic factors: population as threshold and distance or transport as range. To achieve an equilibrium in spatial and functional arrangement, these factors are assumed to follow three principles: marketing, transport and administrative (political -social). Although there are critiques in terms of strict assumptions, simplicity of spatial decision and lack of dynamics, it lays the groundwork for future research into the hierarchical distribution of size and functions of cities, which is an indispensable perspective for examining the result and structuring factors of regional integration between cities.

The concept of urban agglomeration, first proposed by Gottman (1957) as "megapolis", provided an expanded viewpoint for regional integration: from population and transportation to division of labour and a variety of flow among cities. As observed in the "BosWash corridor" (Kahn and Wiener, 1974), which included the largest cities in the north-eastern US (Boston, New York, Providence, Hartford, New Haven, Philadelphia, Baltimore and Washington), the defining features of urban agglomeration are not only geographical proximity and connection in terms of highways, railways and other main transportation lines, but also procession of concentrated and complete industrial chains.

This multidimensional view towards factors in urban agglomeration is even more relevant under the globalization and knowledge economy regime of nowadays. With the interaction of "space of places" and "space of flows", the research on regional spatial structure is shifting from the central place theory with hierarchical system of size towards a network model with openness, flatness and multi-centricity (Castells, 2010). It is noted by Friedman (1986) that the identification and importance of urban agglomerations depends largely on their ability to participate in global socioeconomic activities and to possess, process, and allocate capital and information, rather than the population of the city. Portnov and Schwartz (2009) suggested that urban agglomeration is not only a geographically continuous entity but also a closely integrated spatial existence of networks (people, cargo, capital and information) and nodes (central and peripheral cities). Therefore, regional integration can be regarded as a defining feature of urban space, proximately located and functional networked, clustered around one or two large cities, and drawing economic strength from a new functional division of labour (Hall, 1999).

A typical paradigm of network analysis under urban agglomeration is polycentric urban regions (PURs). It is related to regional integration in two ways. On one hand, a high level of regional integration is consistent with an equal and balanced spatial and economic arrangement in polycentric urban regions. PUR indicates a policy orientation in strategic spatial planning, which is to promote a more equal spatial distribution of economic opportunities across cities and improve the urban and regional competitiveness (Meijers and Romein, 2003). On the other hand, regional integration could be regarded as a combination and synergy of both morphological and functional polycentricity. PUR provides a theoretical context based on which some defining characteristics of spatial organization, like morphological polycentricity and functional polycentricity are identified and evaluated. These two characteristics both refer to the equality of relative importance among urban centres (Kloosterman and Lambregts, 2001, Meijers, 2008), but morphological polycentricity focuses on the size of nodes while functional polycentricity focus on the links (Burger, Van Der Knaap, et al., 2014). As argued by (Burger and Meijers, 2012), these two aspects are not mutually exclusive, as the links and flows also contribute to the basis of nodes size. (Glückler, 2007) provided another perspective by noting that the localized profile of material, social and institutional resources comprise the structural aspects of links, through which these resources are accessed and transferred.

2.3.2 Multiple dimensions of regional integration: concretisation and influencing paths and measurement

Based on actor-network theory and assemblage theory, there is a trend in urban research to construct "rhizomatic networks of urban relata"(Scott and Storper, 2015). Instead of using urban or urbanization as a vague concept, a series of related but distinguished elements are abstracted and organized to form a systematic concept framework for the analysis of the complicated urban issues. . Indeed, cities do not link with each other and form an integrated region automatically. It is the flows of people, goods, information, energy and money and the relationships established between people, firms and organisations that connect cities at different geographical scales (Li and Phelps, 2018). The identification of these elements enables the delineation of regional integration, thus allows for more comprehensive and also in-depth analysis about its impact to other part of the economic system, such as housing market.

a. Transportation

Transportation is one of the key ingredients of regional interaction and relationships. As transport infrastructure lower costs and increase accessibility to various market actors: input suppliers, labor, and customers, which in turn led to market expansion and increased integration (Lakshmanan, 2011). Empirical studies suggested that the transportation network promoted market integration as convergence of product price and wage. The specific mechanisms are summarized as mass production, distribution and consumption of goods (Latrille, Lakshmanan,et al.,2017, Kim and Margo, 2004), gains from trade (Metzer, 1974) and labor mobility (Collins, 1999). Under the framework of new economic geography, monopolistic competition, increasing returns to scale and transportation cost are the three factors structuring the economic geography landscape. The high level of transportation cost and price volatility imply more arbitrage space and less market integration (Krugman, 1991).

Considering the immobility and uniqueness of real estate, housing markets are spatially segmented. The influence of transportation on the integration of housing market is different from other factors and product markets. However, previous studies remain narrow in ether focus on the changes of local housing price levels caused by transportation, or the different price level across locations with different transportation accessibility.

To be more specific, the first type of studies tended to be developed based on hedonic price model, where transportation facilities are treated as local amenity in isolated market. And its effect on housing price level of neighbouring area varied by infrastructure type, distance and time (Yiu and Wong, 2005, Wang and Zhang, 2014, Chen and Haynes, 2015).The second type of research focuses on the accessibility to core municipalities. Based on the spatial general equilibrium framework of Roback (1982), Partridge (2009) proposed a theoretical framework, suggesting that transportation accessibility to higher-tier centres enhances the firm's profitability and household's utility by providing access to a greater markets and consumer services. De Bruyne and van Hove (2013) investigated the effect of transportation accessibility from the perspective of commuters' behaviour, as housing expenditure is compensated by cost of commuting and loss in leisure. Using the case of Belgium, they provided evidence that good accessibility to economic centres, like capital city or provincial capital, will have a positive effect on house price.

Although this research captured the local effect of transportation in different manners, there is a missing context of regional markets as a whole, where spatial dependence or spillovers might exist and affect local markets indirectly. Relatively little is known about how transportation accessibility influences the housing price dynamic in an inter-city context, or regional integration perspective.

As for the measurement of transportation networks, its impact varies depending on spatial scale. For a global scale, the passenger statistics on international flight routes are the common method to measure the transportation network (Smith and Timberlake, 2001, Derudder and Witlox, 2005, Mahutga, Ma, et al., 2010). For the nation scale, most research have utilised the accessibility of railway infrastructure (Kobayashi and Okumura, 1997, Fengjun and Jiao'e, 2004, Wang, Jin, et al., 2009). For transportation within urban agglomeration, public transportation frequency and travel time are adopted to measure the transport relation between cities in urban agglomeration (Fang, Tu, et al., 2011).

b. Economic development

In the context of regional integration, the unbalanced development theories are one of the key entry points. The micro economic mechanism for unbalanced development could traced back to externality of scale economy and economic aggregation, which is first examined by Marshall (1965). Perroux(1970) proposed the growth pole theory to explain the uneven spatial distribution of economic activities. It emphasised the concentration of activities in propulsive poles as the "engine" for the regional economy, which promote the development of surrounding area through diffusion effects. However, as noted in cumulative causation theory (Kaldor, 1981), the core area may also have a negative impact, as return effect, on the undeveloped area, which would bring challenges to the coordinated economic and development in the region.

Under the scope of new economic geography, Friedmann(1986) developed the core-periphery theory to explain the emergence and evolution of spatial structure of urban economy on different stages. For the pre-industrial stage, economies are limited to small settlements isolated from each other and the spatial structure is dispersed and discrete. For the transitional stage, the core-periphery pattern starts to appear, with capital accumulation and industrial growth concentrate in the core area. In the industrial stage, as the rising production cost in the core areas and improving accessibility of transportation, the economic activities diffuse from core areas to periphery areas. In the post-industrial stage, the specialization of industry and division of labour contribute to a fully integrated and balanced regional spatial structure. The division of core-periphery structures are continually diminishing.

The core-periphery pattern of economic development provided directions for analysing the spatial interdependence of housing price. Studies have found that price appreciation initially states in major urban centres, also called "urban core", and spreads to periphery markets (Meen, 1996, Oikarinen and Peltola, 2006, Zhang, Hui, et al., 2017). Based on the empirical studies of Los Angeles and Las Vegas, Riddel (2011) puts forward two possible explanations for this core-periphery interaction pattern, namely "income effects" and "price effects". For "income effects", the housing demand and price in peripheral areas are driven up by income growth from core areas indirectly, as the new income may be invested in periphery areas. Also, as a result of economic expansion spreads from core to periphery, the income growth of peripheral areas in itself may also stimulate the local demand and push prices higher. For both paths, income growth is the primary driving force of housing price integration. Another possible explanation is the "price effects". It refers to speculative forces which flow from core to peripheral areas, driven by the expectation that housing in the periphery is undervalued and would converge with core markets in absolute price level or rate of appreciation.

However, it is worth noting that inter-market correlation of housing prices is not limited to the dual division between core and periphery areas in a networked urban structure. The international turn towards the knowledge economy created a new hierarchy of global economic networks (Sassen, 1991, Castells, 1996, Salet, 2006). It not only implies new characteristics of regional integration, but also raise concerns as to the multidirectional effect of housing price diffusion. Therefore, although it is reasonable to analysis the lead-lag relationships in terms of core-periphery division, this a priori assumption may risk from missing the whole picture of housing market dynamic on the region level, especially the interaction in “horizontal networks” (Meijers, 2007).

c. Institution integration

In the analysis of regional integration, the field of institutions is much more complicated and under researched. Firstly, the concept of institutions per se contains a bundle of related concepts that remain to be defined and classified. Secondly, there are many obstacles for empirical studies on institutions to be carried out on regions within countries, where sovereignty or separation are less prominent. Last but not least, the implications of institution on regional integration are of both economic and politics relevance.

Generally speaking, institutions are a “set of common habits, routines, established practices, rules, or laws that regulate the relations and interactions between individuals and groups” (Edquist and Johnson, 1996). A broad division of institutions is suggested by North (2006) from macro and micro level: for macro level, institutions refers to the formal rules of political institutions which affect the economic performance; for micro level, it refers to informal de facto governance, which is embodied in specific and detailed application and relations between actors that shape the belief and norms.

The research on institutions is even more complex when it comes to city-regions within a country. For empirical studies, the distinction of institutions patterns are more prominent on national level, with abundant evidence from politics structures, law and international survey (Djankov, Glaeser, et al., 2003, Hall and Soskice, 2001). But comparable evidence is less available at the regional level. Furthermore, as suggested by Storper (2010), the formal institutional structure of a city-region is an “intricate assemblage of local, semilocal, and regional government agencies”, thus it should be considered “a multiscalar patchwork of jurisdictions, decision-making processes, scales and capacities”.

In the case of the GBA, the governance framework of “one country, two systems” determines the fundamental landscape of the institutional pattern between the nine municipalities in mainland China and two Special Administrative Regions (SARs). As a provincial-level unit in the Chinese administrative hierarchy, SARs have a “high degree of autonomy” in its economic, political, cultural affairs and legal system, which is separated from China’s communist system. According to the Basic Law, the constitutional document of the Hong Kong Special Administrative Region, “the socialist system and policies should not be practiced in the Hong Kong Special Administrative Region, and the previous capitalist system and way of life shall remain unchanged for 50 years.” , “the laws previously in force in Hong Kong, that is, the common law, rules of equity, ordinances, subordinate legislation and customary law shall be maintained, except for any that contravene this Law, and subject to any amendment by the legislature of the Hong Kong Special Administrative Region.” Considering the complex geopolitics between mainland China and SARs, the regional integration is a “non-tension-free process” in many fields (Wong, 2004, Lui, 2015), including cross-border urban governance “border effect” in market integration (Ash and Kueh, 1993, CHEUNG, CHINN, et al., 2003) and social inclusion for immigrants (Chan, Huxley, et al., 2016).

d. Information flow

With the development of communication networks and interactive multi-media applications, there is a transformation of existing social and economic relationships into an "Information Society" (Lo and Marcotullio, 2000). This background lays the foundation for incorporating information flows into the socio-economic analysis of regional integration.

Information plays an important role in the market interdependence, especially in the short term. The theory of "gradual information flow" was first developed in analysis of asset prices in financial markets, suggesting that market expectations and behaviour are influenced by investors' constraints in information, informational transmission efficiency of the price system will affect the market equilibrium (Grossman and Stiglitz, 1976, Hong and Stein, 1999). Under the field of behavioural economics, the pattern of information flow is associated with emotion and sentiment, which lead to the collective irrationality of investors in terms of "herd behaviour" and "information cascades" (Banerjee, 1992, Bikhchandani, Hirshleifer, et al., 1992, Economou, Hassapis, et al., 2018). Besides, not all information is justified by rational interpretation; the transmission of pseudo-signals will amplify the unpredictability and volatility of asset market through the irrational behaviours of "noise traders"(Kyle, 1985, Black, 1986, Brown, 1999).

When it comes to regional markets, it is important to analyse the effect of information flows on cross-market herding. Several studies found that cross-market herding is related to diversification, contagion and market destabilization, and attribute to other submarkets' dynamic(Chiang and Zheng, 2010, Economou, Kostakis, et al., 2011, Balcilar, Demirer, et al., 2013, Mobarek, Mollah, et al., 2014, Economou, Gavriilidis, et al., 2015).

While that research focuses on the international financial markets, there is limited evidence for cross-market herding of regional housing market. As the information flows cannot be accurately measured directly, most of prior literature use records of web search queries as the measurement for direction and density of intercity information flow (Engelberg and Gao, 2011, Bank, Larch, et al., 2011). Following this approach, empirical studies found that internet search behaviour proxies demand in housing markets and Google searches is strongly predictive for housing prices and sales in the Netherlands and the US ((van Dijk and Francke, 2018, Steegmans and Hassink, W. 2017, Bank et al,2001, Wu and Deng, 2015) . As for the research in China, only one recent study employed the web search queries of Google as information diffusion to investigate the inter city housing market. Based on Granger causality tests and dating point detection, it revealed the nation-wide correlation between spatial patterns of intercity house price information flows and lead-lag patterns in business cycles. The national "superstar" cities, like Beijing and Shanghai, and regional "star" cities, like Tianjin and Chongqing, took the lead to the boom of newly-built house prices from 2006 to 2011(Wu and Deng, 2015). However, besides comparing the patterns, more quantitative evidence still needs to further investigate the causality relationships between information flow and housing price diffusion, especially within highly integrated city-region and during the booming and recession periods of business cycle.

Considering the previous literature, this thesis attempts to fill the research gap as exploring the influence of regional integration on the ripple effect hypothesis checking on the mechanisms of integration vis-à-vis each other. As a classic hypothesis in housing price interference, the mechanisms that underpin the ripple effect hypothesis are not fully understood in a systematic manner. Much of the research up to now has been either descriptive in nature, or restricted to testing specific factors behind "spatial dependence" and "coefficient heterogeneity". This thesis attempts to propose a holistic methodology for testing the ripple effect hypothesis as not only a validation of housing price diffusion, but an explanation for interaction between "spatial dependence" and "coefficient heterogeneity". Although the critical role of regional integration in shaping geo-economic landscapes has been recognized, very little attention has been paid to the quantitative analysis of its impact on housing markets. As a correspondence of the urban land nexus from household side, housing market dynamics is an important entry point for analysing the spatial and functional integration of the region as a whole. This thesis therefore examines and compares the different dimensions of regional integration in terms of it influence on housing market interdependence.

2.4 Conceptual Framework

The review of theoretical and empirical research shows that the discourse of ripple effects is mainly approached through incorporating the dynamics of specific socio-economic factors into the twofold mechanisms of "spatial dependence" and "coefficient heterogeneity". However, some dynamic of specific socio-economic factors has its spatial and temporal pattern, which take its shape from regional integration. From this perspective, regional integration is more than a geographical background where ripple effect occurs, but sets of spatial-temporal patterns of socio-economic characteristic of submarkets and its relationships. As illustrated in Figure 1, this thesis develops an extended conceptual framework for mechanism of ripple effects.

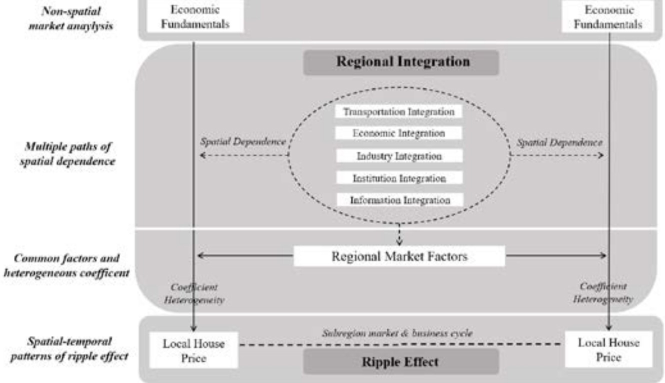
To start with, the base of this framework is the non-spatial market analysis, according to which local economic fundamentals are the direct driven force of the housing dynamic of independent submarkets. These factors may include GDP, population, urbanization rate, industry structure and FDI.

The first extension of this framework is the introduction of regional integration. Through the five different but related transmission channels or paths: geography, transportation, economic, industry, institution and information. The indirect effect of regional integration on housing markets is specified as spatial dependence.

The second extension is the introduction of common factors. Besides the spatial dependence embodied by concrete elements, the regional housing price itself is employed to capture the general market background that defines the spatial-temporal context of ripple effects. It is worth noting that both the direct factors of its own local market and indirect factors of regional markets are under the influence of coefficient heterogeneity.

To further investigate detailed patterns of ripple effects, the analysis of variance of subgroups and subperiods is adopted, as border effects and cycle effects respectively. In this way, regional integration is assumed to function as an indirect mechanism that influences the interrelationship of housing prices as ripple effects.

Figure 1: Conceptual framework



Chapter 3: Research Design and Methods

3.1 Revised Research Questions

Main research question

What are the mechanisms which emerges during the process of regional integration that influence the intercity transmission of housing prices in terms of a "ripple effect" in the case of Guangdong-Hong Kong Macau Greater Bay?

Sub-research questions

- What are the patterns of regional housing price dynamics in terms of ripple effects?
- What are the patterns of multi-dimensional regional integration, which are probable transmission channels of ripple effects?
- How does multi-dimensional integration function as the transmission channels of the ripple effects?

3.2 Research strategy

The primary purpose of this research is to test the hypothesis of "ripple effects" in housing markets, as well as to explore the spatial-temporal influence of regional integration on housing price interaction. Different dimensions of regional integration are defined and hypothesised as transmission channels in order to be incorporated in the analysis of housing market dynamic.

To achieve these research objectives, desk research and secondary quantitative analysis are adopted in this thesis. Quantitative analysis is irreplaceable as the validity of ripple effect is preliminarily tested as a statistical phenomenon. It also allows for more comprehensive, precision and comparable analysis for further exploration of the patterns and mechanisms of ripple effects: to what extent regional integration affects the housing price interaction among cities. The socio-economic indicators involved are collected and released by governments and research institutes on a regular basis, making the secondary quantitative data available and relatively reliable. Different type of data can be processed, analysed and visualized by various software packages (Stata, ArcGIS, GeoDa, and UCINET. etc).

The research consists of three parts:

- The first part tests the validity of ripple effects from three perspectives: spatial aggregation and diffusion, short-term volatility and spatial lead-lag relationships. Correspondingly, Moran' I, unit root test and volatility tests are adopted in ArcGIS, GeoDa and Stata to examine these three definitive features of ripple effects. The data involved in this part are geographic data with administrative boundaries and the panel data of Housing Price Index (HPI) in 11 cities.
- The second part describes the patterns of multi-dimensional regional integration, which are identified as the potential transmission channels of ripple effects. The five facets of regional integration are geography, transportation, economics, institutions and information. The spatial-temporal patterns of the latter are approached through social network analysis. Geographical data and socio-economic data are analysed and visualized by ArcGIS and UCINET.
- The third part explores the mechanisms by which multi-dimensional integration functions as the transmission channel of ripple effects. The five facets of regional integration discussed in the second part are further reframed as weight matrices for spatial regression. Based on the nature of effects and their scope of influence, the effect of integration is distinguished and compared as two related but different dimensions: a node effect,

referring to the direct effect on local house price dynamic; flow effect, referring to the indirect effect on neighbouring house price dynamic.

3.3 Data Collection methods

Two types of secondary quantitative data are collected in this research: geographical data and socio-economic data. While socio-economic data are attached as either city attributes or intercity attributes, geographical data are all transformed as intercity attributes. For the time-varying data, time ranges in quarters of years from 2011:1 to 2018:4.

Geographical data of 11 cities are the administrative boundary at municipality level and the highway map of GBA. The source for the former is GADM, which is a constantly updating dataset providing maps and spatial data of administrative areas at all levels of sub-division of more than 230 countries. This research uses the municipality level data of the 11 cities in version 2.8. The highway map is based on the public information from websites of National and Provincial Ministries of Transportation.

Social-economic data include HPI, GDP, industrial value added of different sectors, FDI, population, hospitals, length of city road, travel time and search popularity.

HPI is the growth rate of average housing price compares to the previous statistical period, which is quarter in this case. As the housing market in mainland China and special administration regions of Hong Kong and Macao are inherently different in institutional arrangements as well as statistical standards, there is no ready-made unified HPI for the 11 cities. To ensure the accuracy and comparability of HPI, the original data for HPI calculation are obtained from three most authoritative and statistically-matched indices from nine cities in mainland China, Hong Kong and Macao respectively.

For the nine cities in mainland China, HPI is generated from the CREIS (China Real Estate Index System) of China Index Academy, which monitors the transaction price of all registered new residential property in China and release the “Housing Price Index of 100 cities” for each city monthly. This index is calculated using the formula:

$$P_j^t = \frac{\sum P_{ij}^t * Q_{ij}}{\sum Q_{ij}}$$

P_j^t is average housing price of city j in period t, P_{ij}^t is the price of property $i$of city j in period t, $Q_{ij}$is the construction area for residential usage for the property i. HPI is calculated as the precious period variance of P_j^t.

Hong Kong HPI is collected from CCI (Centa-City Index) of CENTADATA. It is a monthly index based on all transaction records as registered with the Land Registry to reflect property price movements in previous months. The CCI is calculated by aggregating the prices of the constituent estates using the formula:

$$CCI^t = \frac{\sum P_i^t}{\sum P_i^t} * CCI^{t-1}$$

CCI^t and $CCI^{t-1}$is CCI in period t and t-1, $P_i^t$is the market value of a constituent estate, which is the product of the total saleable area and the adjusted unit price.

Macao HPI are collected from RPPI (Residential Property Price Index) of DSEC (Macao Statistics Bureau). It is a quarterly data with the statistic base of 2011:1 as 100. The calculated formula is similar to CCI.

As for GDP, industrial value added of different sectors of industries, FDI, population, number of hospitals and length of city road, the data are collected from national, provincial and city statistical yearbooks from 2011 to 2018. The number of hospitals and the length of city roads are annual data, while the rest are all quarterly data. To improve the validity of data, various research institution databases are used, including CEIC Data, Wind and World Bank Database.

The data of travel time are collected from the Website of China Railway Corporation and Google Maps. Highway, railway and waterway transportation are considered to identify the quickest travel time between cities.

The data of keywords search popularity are collected from the Baidu Index. Being the largest search engine in China, Baidu index offers weekly data for search trend for certain keywords and phrases from January 2011 from municipality, provincial and national level.

3.5 Data Analysis Techniques

3.5.1 What are the patterns of regional housing price dynamic in terms of "ripple effect" in cities within GBA?

Table 1: Operationalization of sub question 1

Concepts	Variables	Indicators	Data collection methods and sources	Data analysis methods and software
Short-term volatility	-	The Friedman statistics	Secondary data including quarterly HPI of 11 cities from 2011:1 to 2018:4: - CREIS (China Real Estate Index System) of China Index Academy - CCI (Centa-City Index) of CENTADATA - Residential property price index of DSEC	Friedman's non-parametric test of ranking at Stata
Spatial aggregation and diffusion	Spatial distribution of residential housing price	-HPI (Housing price index, %) -Global Moran's I (number) -Local Moran's I(number)		Global Moran's I, Anselin Local Moran's I at ArcGIS and GeoDa
Spatial leading-lag relationships	-			Unit root test, Toda-Yamamoto Granger causality test at Stata

a. Non-parametric testing of house price volatility

According to Drake (1995), one of the important features of ripple effects is detecting the regions where changes in house prices are more extensive. When different submarkets of cities are viewed as one market, the different volatility pattern of prices in each city may be regarded as observed evidence for ripple effects, while the degree of differentiation reflects its intensity.

Cook (2003) used the Friedman's non-parametric test of ranking to examine the short-term volatility of ripple effect. In this approach, cities are ranked by the HPI in each quarter with the ranking 1 representing the city with the largest values and 11 represents the smallest value. In order to test whether the volatility of housing prices differs across the 11 cities of GBA in the same period, the Friedman test statistic is calculated as below:

$$\mathrm{Fr} = \left[\frac{12}{T(k)(k+1)}\sum_{j=1}^{k} s_j^2\right] - 3T(k+1)$$

Where T is the number of cities, k is the number of cities and s_j^2 is the sum of squared rankings of city j. The Fr statistic can be compared to χ_{k-1}^2critical value to examine the null hypothesis that there is equal volatility in housing price growth across cities.

b. Spatial aggregation and diffusion of housing price

- Global Moran's I

Global Moran's I is a measure of spatial autocorrelation which is characterized by a correlation in signal among locations in space. Global Moran's I is defined as

$$\text{Global Moran's I} = \frac{N}{\sum_i \sum_j w_{ij}} \frac{\sum_i \sum_j w_{ij} (X_i - \bar{X})(X_j - \bar{X})}{\sum_i (X_i - \bar{X})^2}$$

Where i =1,2,3…,n; j=1,2,3,…m; xi refers to HPI of city i, x_j refers to HPI of the adjacent city j, and X is the average HPI of GBA. W_{ij} is the elements of spatial weight matrix W.

Global Moran's I Scatter plot and P value are the summarized indicators for the extent and significance of global spatial aggregation and diffusion in housing price dynamic. The standardized statistic Z is used to test the significant levels of spatial correlation. The indexes of Global Moran's I range from [-1, 1]. When Moran's I >0, the positive correlation indicates cities with similar housing market dynamic have significant spatial distribution. The larger the number is, the stronger the spatial distribution correlation is; Global Moran's I<0 means negative correlation, which indicates cities with comparable properties distribute sparsely; when Global Moran's I=0, cities are randomly distributed.

- Local Moran's I

Local Moran's I, also named LISA (Local Indicators of Spatial Association) evaluates the clustering in individual units at local levels. LISA cluster map is used to show the precise spatial structure and types of aggregation and diffusion in housing price dynamic for several cross-sections. The formula is expressed as follows:

$$\text{Local Moran's I} = \sum_{i \neq j}^{n} W_{ij} X_i X_J$$

The definitions of variables are the same as Global Moran's I.

Both Global Moran's I and Local Moran's I are tested on a quarterly basis in order to depict the evolution of spatial correlation of house prices in this region from 2011:1 to 2018:4. However, it is worth noting that the application of these two methods are limited by the model setting and conceptual relevance. Indicators of Moran's I are more reliable when more than 30 observations are included. In this case, since each test only contains 11 cities at one time, it may not lead to conclusive result. But as the spatial relationship is embodied as the prior spatial matrix based on geographical contiguity, the result, correspondingly, only refers to the spatial aggregation and diffusion of housing price under that certain type of conceptualization of spatial relationship. Therefore, this strategy served as the initial examination of the ripple effect, and it will be combined with more quantitative and specific analysis for the further identification of spatial autocorrelation.

c. Toda-Yamamoto Granger causality test for spatial leading-lag relationships

The Granger causality test is one of the most common and well-established approaches for testing the spatial leading-lag relationship between intercity housing market dynamics. Similar to Teye and Ahlegbey (2017), this research applies the Toda-Yamamoto Granger causality test as the method to examine the lead-lag effect across cities (Toda and Yamamoto, 1995). Compared to the original formulation of Granger causality test which only allows for stationary time series, the Toda-Yamamoto Granger causality test is suitable for non-stationary time series integrated or cointegrated of an arbitrary order.

The VAR(m+p) system in the TY procedure is decided by the total of both maximum integration order of (m) and the optimal lag lengths(p) for the city-pair. Correspondingly, the determination of m is usually analysed through unit root test, and the p is selected by the Bayesian information Criterion (BIC).

3.5.2 What are the patterns of regional integration as transmission channel of ripple effects in cities within GBA?

a. Identification of multi-dimensional regional integration

It is important to specify and examine the patterns of regional integration itself before further incorporating it into the analysis of housing markets that it may affect. Based on existing theory and empirical studies, five types of regional integration are elaborated in this thesis as the possible transmission channels of ripple effects: geography, transportation, economic, institutional and information.

Each form of integration is measured based on macroeconomic, geographic and demographic data to capture the magnitude of connections between cities within GBA. Geographical integration is measured by rook contiguity (neighbours have to share an edge). This is the classic definition of geographical contiguity and are adopted as the default type in ArcGIS. Transportation integration is measured by the shortest travel time. Under the scale of urban agglomeration, travel time are widely adopted to measure the transport relation between cities (Fang, Tu, et al., 2011). Economic integration is presented using urban gravity modelling, which is a well-established method to quantify the intercity economic linkages. The formula is defined as follows:

$$R_{ij} = \frac{\sqrt{P_i V_i} \cdot \sqrt{P_j V_j}}{D_{ij}^2}$$

Where R_{ij} represents the economic linkages between cities. P_i and P_j represent the population size of city i and j, V_i and V_j represent the economic size of city i and j (represented by GDP), D_{ij} represent the distance between city i and j (represented by the shortest travel time). Institutional integration is measured by the difference in administrative and economic systems. The values are either 1 or 0 depends on whether the two cities are both in mainland China or special administrative districts. Informational integration is measured by the Baidu Index, which shows the transmission of housing market information as “keywords searching popularity”. The targeted keywords are constructed as a text combination of “city name” and “Fangjia” (Housing price).

b. Social network analysis

Since the spatial patterns of regional integration is neither balanced across cities nor unified across dimensions, it is interesting to further explore the complicated relationships of different cities from the perspective of similarity and correlation in different dimensions of integration. We adopted the QAP (Quadratic assignment procedure) (Krackhardt, 1987) Social network analysis, which is a popular method for testing the association between two networks with permutation (Hubert and Golledge, 1981). The Pearson correlation coefficients (Pearson’s r) would be calculated between pairs of cities in terms of their strength of tie in two matrices.

Table 2: Operationalization of sub question 2

Concepts	Variables	Indicators	Data collection methods and sources	Data analysis methods and software
Geographical integration	Geographical adjacency	-rook contiguity (binary)	Secondary data from Google map	-Matrices generation and Social network analysis at UCINET -Visualization at ArcGIS
Transport integration	Transportation accessibility	-shortest travel time(number)	Secondary data including highway linkages and travel time by train: - Website of Ministry of Transportation of Guangdong, China -Website of China Railway Corporation -Google map	
Economic integration	Disparity of urban economic development	-PGDP (number) -geographical distance(number)	Secondary data including PGDP of 11 cities from 2011:1 to 2018:4 and distance - Yearbooks of 11 cities - Geographical data of administrative boundary by GADM	
Institutional integration	Difference in political and economic system	Institutional arrangement of constitution, local law and related policies(binary)	Secondary data of institutional arrangement - Website of national and municipal government	
Information integration	Transmission of housing market sentiment	Keywords search popularity on internet	Secondary data of keywords search popularity from 2011:1 to 2018:4 -Baidu index	

3.5.3 How does the multi-dimensional integration functions as the transmission channels of the ripple effect in cities within GBA?

Spatial panel models are constructed in this thesis to explore the influence of regional integration on housing market dynamics as ripple effects. It is in accordance with the characteristics of the spatial panel data with observations of 11 cities from 2011:1 to 2018:4. The data will be analysed based on three models which are typically used in spatial econometrics, namely, the spatial lag model (SAR), the spatial error model (SEM), and the spatial Durbin model (SDM). Each model allows for different combinations of spatial interaction effects. The SAR includes the spatial lag of dependent variables, the SEM involves the spatial correlation of error terms, and the SDM consists of the spatial lag of both dependent and independent variables.

To account for the time lag effect, the dynamic space-time panel data model is further adopted, where the dependent variable of last period is included as independent variable (Debarsy, Ertur, et al., 2012).

To distinguish the effect of common factors and spatial dependence, which are also regarded as “strong” cross-sectional dependence and “weak” cross-sectional dependence in the literature (Chudik, Pesaran, et al., 2011), the simultaneous model developed by (Vega and Elhorst, 2016) is used as an extension of the SDM model.

The model formulas are below:

SAR: $HPI_{it} = \rho \sum_{j\neq i} W_{ij}\, HPI_{jt} + \sum_k X_{kit}\, \beta_k + \alpha_{it} + \varepsilon_{it}$
SEM: $HPI_{it} = \sum_k X_{kit}\, \beta_k + \alpha_{it} + \xi_{it};\ \ \xi_{it} = \lambda \sum_{j\neq i} W_{ij}\, \xi_{jt} + u_{jt}$
SDM: $HPI_{it} = \rho \sum_{j\neq i} W_{ij}\, HPI_{jt} + \sum_k X_{kit}\, \beta_k + \sum_k (\sum_{j\neq i} W_{ij}\, X_{kit})\, \theta_k + \alpha_{it} + \mu_{it}$

Dynamic SDM with common factors:

$$HPI_{it} = \tau HPI_{it-1+}\rho \sum_{j\neq i} W_{ij}\, HPI_{jt} + \eta \sum_{j\neq i} W_{ij}\, HPI_{jt-1} + \sum_k X_{kit}\, \beta_k + \sum_k (\sum_{j\neq i} W_{ij}\, X_{kit})\, \theta_k + \varphi CF_t + \alpha_{(it)} + \mu_{it}$$

HPI_{it} stands for the housing price index in each spatial unit (i= 1, . . . N) at time t (t = 1, . . . T); X_{kit} is the kth independent variable, including GDP per capita, industry structure, population, urbanization, FDI, hospital, city road length; CF_t is the common factors, which include the indicators for regional housing market, inflation and monetary policy at time t(t = 1, . . . T); α_{it} is the intercept term, which is determined by the fixed and random effects test. In the fixed effects model, a dummy variable is introduced for each spatial unit and for each time period (except one to avoid perfect multicollinearity), while in the random effects model, α_{it} are treated as i.i.d random variables; W_{ij} is the spatial weighted matrix which refers to different types of intercity integration.

β_k is the k-dimensional parameter indicating the degree of direct effect on local housing price dynamic, which is regarded as node effect; ρ and θ_k are the coefficients of spatial autocorrelation of dependent and independent variables, respectively. They collectively represent the degree of indirect effect on neighbouring house price dynamic, which is regarded as flow effect; λ is the coefficient of spatial error in the SEM model.

As the dependent variable, housing price dynamics is measured by the housing price index (HPI). Several macroeconomic variables are included to measure the inherent characteristics of each city: GDP per capita, population, urbanization rate, industry structure and FDI. These are the mostly acknowledged factors in the classic supply and demand analysis of housing price, thus are regarded as economic fundamentals. Besides, originated from hedonic models, the numbers of hospitals and length of city road per capita are also included to control for the quality of intra-city amenities and public services. To represent the different type and degree of regional integrations, five spatial weighted matrices are constructed correspondingly. These matrices would be set to enter the model solely in order to compare the separate and combined effect of the different five transmission channels.

As for the model selection, following the strategy described in LeSage and Pace (2009) and Elhorst (2010), this thesis starts with the static fixed-effect SDM as the basic specification and test for the alternatives. To be more specific, we first compare between the fixed-effects and random- effects models, so as to make sure the constant unobservable heterogeneity is treated properly. The model with Common factor of average HPI is also included in this part. Hausman test and comparison of different R square (within and between) would be employed. Secondly, the model selection among SAR, SEM and SDM are evaluated by Wald test with different null hypotheses of coefficients. Thirdly, based on the model selected before, the time-lagged terms would be included to compromise a dynamic model.

To estimate the marginal effects, it is important to distinguish the direct and indirect effect in both short-term and long-term under dynamic model settings. According to Elhorst (2014), the four types of effects are defined as follows:

Short-term direct effects: $[(I-\rho W)^{-1} \times (\beta_k I + \theta_k W)]^{\bar{d}}$

Short-term indirect effects: $[(I-\rho W)^{-1} \times (\beta_k I + \theta_k W)]^{\overline{rsum}}$

Long-term direct effects: $[(1-\tau)I - (\rho+\psi)W)^{-1} \times (\beta_k I + \theta_k W)]^{\bar{d}}$

Long-term indirect effects: $[(1-\tau)I - (\rho+\psi)W)^{-1} \times (\beta_k I + \theta_k W)]^{\overline{rsum}}$

The $\bar{d}$ denotes the operator that calculates the mean diagonal element of a matrix and the superscript $\overline{rsum}$ denotes the operator that calculates the mean row sum of the non-diagonal elements.

The total impact measures the impact of a unit change in variable x_k on HPI in all cities. It can be divided into direct effect and indirect effect. Direct effect measures the direct impact of the same unit change in variable x_k in city i on HPI in city i averaged over all cities, while the indirect effects measures the impact of the same unit change in variable x_k in city i on HPI in other cities.

Chapter 4: Research Findings

4.1 What are the patterns of regional housing price dynamics in terms of "ripple effect" in cities within GBA?

4.1.1 Non-parametric testing of housing price volatility

Price volatility is one of the basic features of housing market dynamic. In terms of the ripple effect hypothesis, Drake (1995) suggested that the identification of areas where housing price "change more extensively" than others should be included as one of the conditions. Although it remains debateable whether it is the defining feature of ripple effects, it is necessary to take this aspect into consideration at the first place. To some extent, it represents the potential scale and magnitude of any underlying spatial correlation and causality for each region, and may further be related to the explanation of spatial influence and vulnerability for the following analyses.

To take this into consideration, we adopted Friedman's non-parametric test of ranking, which was first employed by Cook (2003) to examine the ripple effect in UK. Firstly, as is shown in table 000, it is clear that Zhaoqing and Hong Kong are the two cities that exhibit greatest volatility, while the housing price in Dongguan and Guangzhou are more stable compared to other cities. Secondly, to further examine whether the difference in volatility across cities is significant or not, the Fr statistic are calculated according to the Formula:

$$\text{Fr} = \left[\frac{12}{T(k)(k+1)}\sum_{j=1}^{k} s_j^2\right] - 3T(k+1)$$

The calculated Fr statistics is 16.7102 with a p-value of 0.081. It provided significant evidence to reject the null hypothesis that there is equal volatility of housing price across cities.

Table 3: Sum of ranks

City	DG	ZS	ZH	HK	JM	GZ	ZQ	HZ	FS	SZ	MC
$\boldsymbol{S_j}$	239	199	188	157	204	214	155	189	199	194	174

Figure 2: Sum of ranks

However, although the conclusion is reached that the volatility of housing price is not evenly distributed among locations, the spatial patterns of geographical agglomeration in housing price volatility is not very clear and precise yet. As is shown at Figure2, Zhaoqing and Hong Kong, the two most volatile cities, are located at the northwest and southeast corner respectively, while the middle region seems to be more stable. Compared to the findings of Cook and Thomas (2003), which examined the quarterly housing price changes from 1973:4 to 2003:1 of 11 regions of the UK, there is no single dominating area in the GBA as the south east of England. Therefore, it would be necessary to further explore this complicated distribution of HPI in geographical context.

4.1.2 Spatial correlation tests with Moran's I method

Starting from the volatility analysis above, this part incorporates geographic background to the distribution of HPI. According to Tobler's First Law of Geography, geographical attributes are related to each other in spatial distribution (Miller, 2004). Following this logic, the global and local spatial autocorrelation analysis of housing price are adopted based on geographical contiguity.

a. Global Moran's I

Global Moran's I indices of the housing price index in the 11cities of the GBA from 2011:1 to 2018:4 were calculated based on Queen Adjacency weight matrix. Table 4 shows that generally, there is no statistically significant spatial aggregation of housing price index among cities from 2011:1 to 2018:4. The spatial autocorrelation can only be observed in 5 quarters: 2011:4, 2012:3, 2014:2, 2015:1 and 2017:1. Therefore, the null hypothesis that "there is no spatial autocorrelation of the housing price index in terms of geographical adjacency" cannot be rejected in most of the periods from 2011 to 2018.

Table 4: Moran's I indices of HPI on Queen Adjacency weight matrix

Quarter	Moran's I	P-Value	Quarter	Moran's I	P-Value
2011Q1	-0.325	0.345	**2015Q1**	0.349	0.042**
2011Q2	0.195	0.195	**2015Q2**	0.288	0.088*
2011Q3	-0.273	0.478	**2015Q3**	0.062	0.296
2011Q4	0.317	0.091*	**2015Q4**	-0.4	0.218
2012Q1	0.202	0.122	**2016Q1**	-0.423	0.195
2012Q2	-0.209	0.597	**2016Q2**	-0.245	0.574
2012Q3	-0.448	0.075*	**2016Q3**	-0.336	0.339

2012Q4	-0.174	0.768	**2016Q4**	-0.311	0.409
2013Q1	-0.273	0.478	**2017Q1**	0.535	0.012**
2013Q2	-0.501	0.116	**2017Q2**	0.29	0.096*
2013Q3	0.226	0.194	**2017Q3**	0.053	0.335
2013Q4	-0.185	0.623	**2017Q4**	0.046	0.301
2014Q1	-0.101	0.995	**2018Q1**	0.011	0.542
2014Q2	0.317	0.091*	**2018Q2**	-0.136	0.871
2014Q3	0.089	0.406	**2018Q3**	-0.019	0.526
2014Q4	0.058	0.517	**2018Q4**	-0.049	0.762

b. Local Moran's I

To further reveal the specific and local spatial pattern of housing price autocorrelation, local Moran's I method was employed. Theoretically, Anselin's LISA map indicates four types of spatial agglomeration among neighbouring areas, namely high-high, low-low, low-high and high-low.

As is shown in Table 5(appendix), except for the low-high agglomeration, the other three types can be observed in different cities from 2011 to 2018. The areas showing high -high agglomeration type are the areas that not only experience a high housing price rising during the year, but also have positive effect on the surrounding areas. A typical example for this is Foshan in 2017. As the opposite of high-high agglomeration, low-low agglomeration indicates the areas with low housing price increases, and also affect its neighbourhood negatively. This pattern is relatively common in this case, the examples of which includes: Foshan in 2011 and 2014, Dongguan, Huizhou and Shenzhen in 2017 and 2018, Guangzhou in 2018. The high-low pattern only shows two times: Guangzhou in 2013 and Hong Kong 2017. It implies that while there is a considerable housing price rising in these two cities during the year respectively, the housing price of its neighbourhood are negatively affected.

These results can be compared to generalize two main findings in the spatiotemporal aggregation pattern of housing price. Vertically, the spatial agglomeration of HPI has become more evident since 2017, with more cities began to be included as the significant areas in LISA cluster map. Considering the constancy of geographical adjacency, it implies the possibility that other dynamic geographical attributes may also play a role in this spatial structure. To link it with the ripple effect hypothesis, this finding supports the suggestion that ripple effect is not bounded within neighbouring housing market, but can also happen among cites with other forms of linkages (Meen, 1996, Pollakowski and Ray, 1997). Horizontally, there is no single or several leading or most influential cities in housing price fluctuations through all periods. Compared to the results from volatility test, there is no apparent clue that cites with most changeable housing prices, that is Zhaoqing and Hong Kong, also play a prominent role in spatial agglomeration. Another common hypothesis that housing price ripple from developed areas to periphery areas, which has been suggested in several empirical studies (Stevenson, 2004, Oikarinen and Peltola, 2006, Buyst and Helgers, 2013, Balcilar, Beyene, et al., 2013, Wu, J. and Deng, Y. 2015) are not well supported in the GBA during the past 8 years neither. The three first-tier cities: Guangzhou, Shenzhen and Hong Kong only show significant evidence of regional influence in 2013,2017 and 2018, and even negative influence in some years. To sum up, the housing price agglomeration and diffusion in the GBA is not a one-way process dominated by specific geographic location, but a multidirectional network with effects varying over space and time.

4.1.3 Toda-Yamamoto Granger causality test for spatial leading-lag relationships

The spatial correlation analysis of Moran's I only indicates a general and inconclusive spatiotemporal pattern of regional housing price dynamic. Therefore, it is important to introduce further exploration into the 'spatial causality' in the interurban housing markets. To be more specific, to what extent can the historical house price information in one market be used to predict the current house prices in other markets? Considering the different integration orders in the time series data of HPI, the Toda-Yamamoto (TY) Granger causality test is employed to examine the spatial leading-lag relationships of paired cities.

a. Unit root test

The analysis started with identifying the integration orders of 11 HPI series. It is used to determine the m (maximum integration order) of the VAR (m+p) system in the TY procedure. As is shown in table 6, both the level and the first difference series are been tested by various unit root test methods.

For Augmented Dickey-Fuller test (Dickey and Fuller, 1979), the null hypothesis of unit root for level variables of Zhuhai and Hong Kong is rejected at 10% and 5% significance level respectively. As for the first difference series, all series are stationary, excepted for Huizhou. Based on this test, the HPI of 8 out of 11 cities are unit root processes and are integrated of order one.

However, the ADF test has its limitations. It cannot distinguish I (0) alternatives that are close to being I (1), and it has lower power when deterministic trend is added in the test regression. Therefore, with the same null hypothesis, we also conducted the Dickey-Fuller generalized least square (DF-GLS) test proposed by Elliott et al. (1995). Most of the results are consistent with the ADF test, except for the level of Zhuhai is a unit root process, and the first difference series of Huizhou is stationary.

We also conducted the KPSS test (Kwiatkowski, Phillips, et al., 1992) with null hypothesis of stationary. It shows that all levels and first differences are stationary series, except for the level of Dongguan HPI. This result seems contradicted to the last two tests. However, considering the 10% critical value of 0.119 and the results of the two unit root tests before, it is reasonable to assume the HPI process of Hong Kong is I (0), and the rest of 10 cities are I (1). It is evident that not all HPI series are integrated in the same order. Therefore, the m of VAR system in YT granger causality test is 0, while for the rest of the pairs is 1.

Table 6: Unit root test

	Level			1st difference		
	ADF	**DF-GLS**	**KPSS**	**ADF**	**DF-GLS**	**KPSS**
Dongguan	-1.891(4)	-1.024(4)	0.138(0) *	-4.755(3) ***	-3.990(3) ***	0.016(0)
Foshan	-1.913(1)	-1.987(1)	0.068(4)	-6.423(0) ***	-5.898(0) ***	0.086(3)
Guangzhou	-2.220(1)	-2.340(1)	0.052(4)	-5.082(0) ***	-4.896(0) ***	0.054(3)
Hong Kong	-3.532(2) *	-3.505(2) **	0.049(1)	-3.852(1) **	-3.982(1) ***	0.067(0)
Huizhou	-2.690(3)	-2.558(3)	0.078(4)	-2.986(2)	-2.957(2) *	0.077(3)
Jiangmen	-2.206(1)	-2.249(1)	0.087(4)	-6.028(0) ***	-6.177(0) ***	0.067(3)
Macao	-2.832(1)	-2.922*(1)	0.086(4)	-7.393(0) ***	-7.659(0) ***	0.070(3)
Shenzhen	-1.842(1)	-1.937(1)	0.107(4)	-6.479(0) ***	-6.710(0) ***	0.049(3)
Zhaoqing	-2.672(1)	-2.625(1)	0.091(4)	-6.638(0) ***	-6.848(0) ***	0.081(3)
Zhongshan	-2.896(1)	-2.764(1)	0.080(4)	-5.821(0) ***	-5.984(0) ***	0.103(3)
Zhuhai	-3.897(1) **	-2.845(1)	0.090(4)	-5.062(0) ***	-5.192(0) ***	0.111(3)

Note: All the models include a constant and a linear trend. Numbers shown in parentheses are the lag length or bandwidth. For the Augmented Dickey-Fuller (ADF) test, the lag length for level variables is chosen by Bayesian information Criterion (BIC), and the maximum lag length being set to 9 based on methods of Schwert. G. W. (1989). DF-GLS unit root tests adopted the same lag length chosen for ADF test. For KPSS test, the bandwidth is selected by Newey-West method. In all the cases, the lag length for first difference variables is the lag length for level variables minus one. The null hypothesis for ADF and DF-GLS tests is having a unit root, but stationary for the KPSS test.

* Indicates significance at 10% level.

** Indicates significance at 5% level.

*** Indicates significance at 1% level

b. Leading-lag relationship

The results of Toda-Yamamoto Granger causality tests are reported in table000 and Figure3. Generally, all cites in GBA are involved in at least one leading- lag relations with other cities, and the causality pattern forms a complex network. The causality relationships are not bounded within neighbouring cities as claimed by Clapp et al. (1995) and Chen et al.(2011). In other words, geographical adjacency is not a necessary or sufficient condition for leading- lag relationship in ripple effect. The leading-lag relationship can be detected even in relatively distanced cities pairs like Huizhou and Zhuhai, Huizhou and Zhuhai, Shenzhen and Foshan. Yet, Guangzhou is a typical example that does not have leading-led relationships with its neighbouring cities of Huizhou, Foshan and Dongguan.

Besides, the roles of first tier cities are different. Macao and Guangzhou only receive and react to the price signal from one or two other cities, while Shenzhen are the most active signal senders. Hong Kong are both the sender and receiver of the market fluctuations.

Figure 3: Toda-Yamamoto (TY) Granger causality

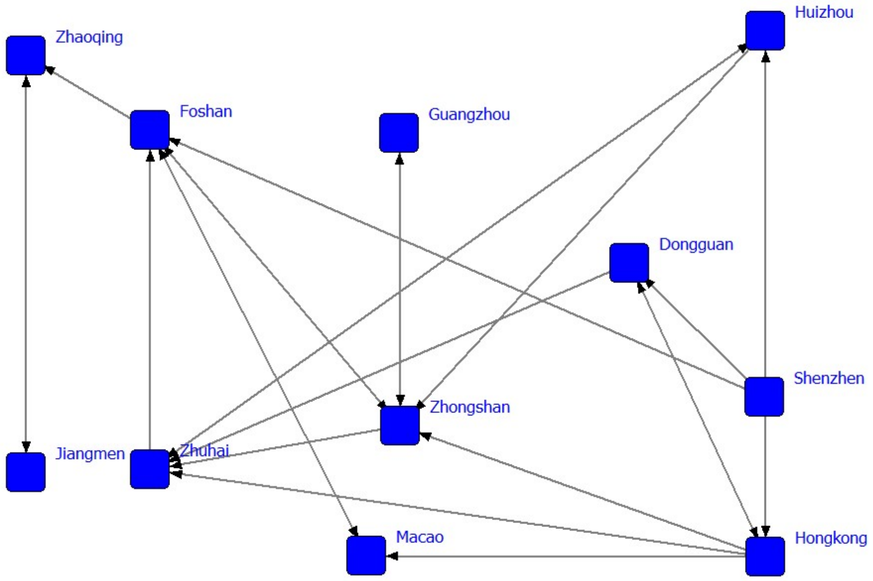


Table.7: Toda-Yamamoto Granger causality test

	Dongguan	Foshan	Guangzhou	Hong Kong	Huizhou	Jiangmen	Macao	Shenzhen	Zhongshan	Zhaoqing	Zhuhai
Dongguan		1.49 (0.222）	0.23 (0.632)	33.55*** (0.000)	0.08 (0.778)	0.63 (0.426)	0.34 (0.846)	5.03 (0.412)	1.17 (0.280)	0.06 (0.801)	14.21*** (0.000)
Foshan	0.009 (0.969）		1.78 (0.183)	0.83 (0.362)	0.50 (0.478)	1.61 (0.204）	17.79*** (0.003)	7.83 (0.166)	5.93** (0.025)	3.04* (0.081)	0.53 (0.467)
Guangzhou	0.91 (0.340)	0.85 (0.358)		0.76 (0.385)	0.42 (0.516)	0.02 (0.895)	0.75 (0.387)	4.52 (0.104)	42.1*** (0.000)	1.82 (0.178）	0.19 (0.664)
Hong Kong	9.13* (0.058)	0.41 (0.522)	0.42 (0.519)		1.05 (0.305)	2.08 (0.721)	9.05** (0.029)	0.06 (0.806)	3.39* (0.066)	0.12 (0.730)	6.00** (0.014)
Huizhou	0.12 (0.728)	1.59 (0.208)	0.67 (0.412)	1.79 (0.181)		0.02 (0.891)	0.04 (0.836)	2.10 (0.148)	9.56** (0.049)	0.43 (0.512)	24.15*** (0.000)
Jiangmen	0.30 (0.587)	0.05 (0.825）	0.14 (0.709)	6.53 (0.164)	0.12 (0.734)		0.13 (0.716)	0.07 (0.795)	0.00 (0.989)	8.38*** (0.004)	0.29 (0.592)
Macao	1.45 (0.484)	13.41** (0.020)	0.09 (0.767)	0.36 (0.948)	0.00 (0.952)	0.85 (0.357)		1.00 (0.318)	0.85 (0.356)	0.02 (0.886)	1.91 (0.385)
Shenzhen	14.84** (0.011)	12.03** (0.031)	0.80 (0.670)	3.18* (0.075)	12.66*** (0.000)	0.03 (0.869)	0.00 (0.949)		0.80 (0.370)	1.23 (0.2680	0.70 (0.404)
Zhongshan	0.54 (0.463)	6.21** (0.013)	12.43* (0.053)	0.01 (0.914)	0.69 (0.953)	1.55 (0.214)	0.04 (0.833)	0.28 (0.597)		1.03 (0.312)	8.43*** (0.004)
Zhaoqing	0.28 (0.597)	0.01 (0.942)	0.62 (0.430)	0.02 (0.899)	0.47 (0.493)	6.35** (0.012)	0.41 （0.523）	0.11 (0.744)	0.56 (0.456)		0.51 (0.475)
Zhuhai	0.19 (0.662)	5.99** (0.014)	2.41 (0.120)	0.29 (0.589)	6.13** (0.013)	2.48 (0.116)	1.97 (0/374)	0.50 (0.481)	0.67 (0.414)	0.64 (0.425)	

Note: the null hypothesis is that cities on the column do not granger cause cities on the row.
∗ Indicates significance at 10% level.

∗∗ Indicates significance at 5% level.

∗∗∗ Indicates significance at 1% level

4.2 What are the patterns of regional integration as transmission channels of ripple effect in cities within GBA?

The regional integration can be embodied in various transmission networks. In this part, we adopt the Social Network Analysis (SNA) method to explore the patterns of these related but inherently different aspects of regional integration. Two questions are answered in this part. Firstly, is the degree of regional integration evenly distributed in the GBA? If not, what are the spatial patterns for each dimension of integration? Secondly, is there any similarity and correlation between these networks? In other words, if there is a strong interaction between two particular cities in one integrating setting, is there likely to be a strong interaction between them in another integration? Furthermore, the result of T-Y Granger causality test is transformed into an undirected binary matrix to represent the spatial relation of housing price. These results provided preliminary evidence for the identification of transmission channel of housing price.

4.2.1 Spatial patterns of multiple regional integration

To answer the first question, we compare the degree centrality (DC) of each city and their ranks in each integration. The DC quantifies the strength of tie a node has to other nodes in the network, thus represents the activity of actors or the accessibility of locations. In both cases, it refers to the level of engagement of the city in the process of regional integration. Thus, it is a proper indicator for the spatial distribution of regional integration. As for the calculation, it varies between binary matrices and continues matrix. For the three binary matrices: geographical adjacency, institution and granger causality, the DC of each node is the sum of edges attached to it. In the other three weighted matrices, it is calculated as the sum of each continues values in each tie correspondingly.

As is shown in Figure4, the size of node indicates the degree centrality of a city, and the width of edge indicates the strength of tie in each relation. It is evident that the distribution of size and width of edges are varied both within and across different matrices. For example, Guangzhou and Shenzhen have a high degree of transportation accessibility, but in terms of information transmission, their density is much lower than Jiangmen and Huizhou. Considering the index construction method, it is because people in Guangzhou and Shenzhen are not so active in searing housing information of neighbouring cities through Baidu, and/or these two cities are not so popular for non-local citizens. Then if we shift the focus to economic gravity, Guangzhou and Shenzhen return to their prestigious position again. This disparity is more intuitive if we rank the cities by their degree centrality in each network, which is shown in Figure5.

To sum up, for each dimension of integration network included in the analysis there is no spatial balanced integration pattern in the GBA. But there is no unified spatial pattern of integration among different dimensions of integration networks either.

Figure 4: Five types of regional integration

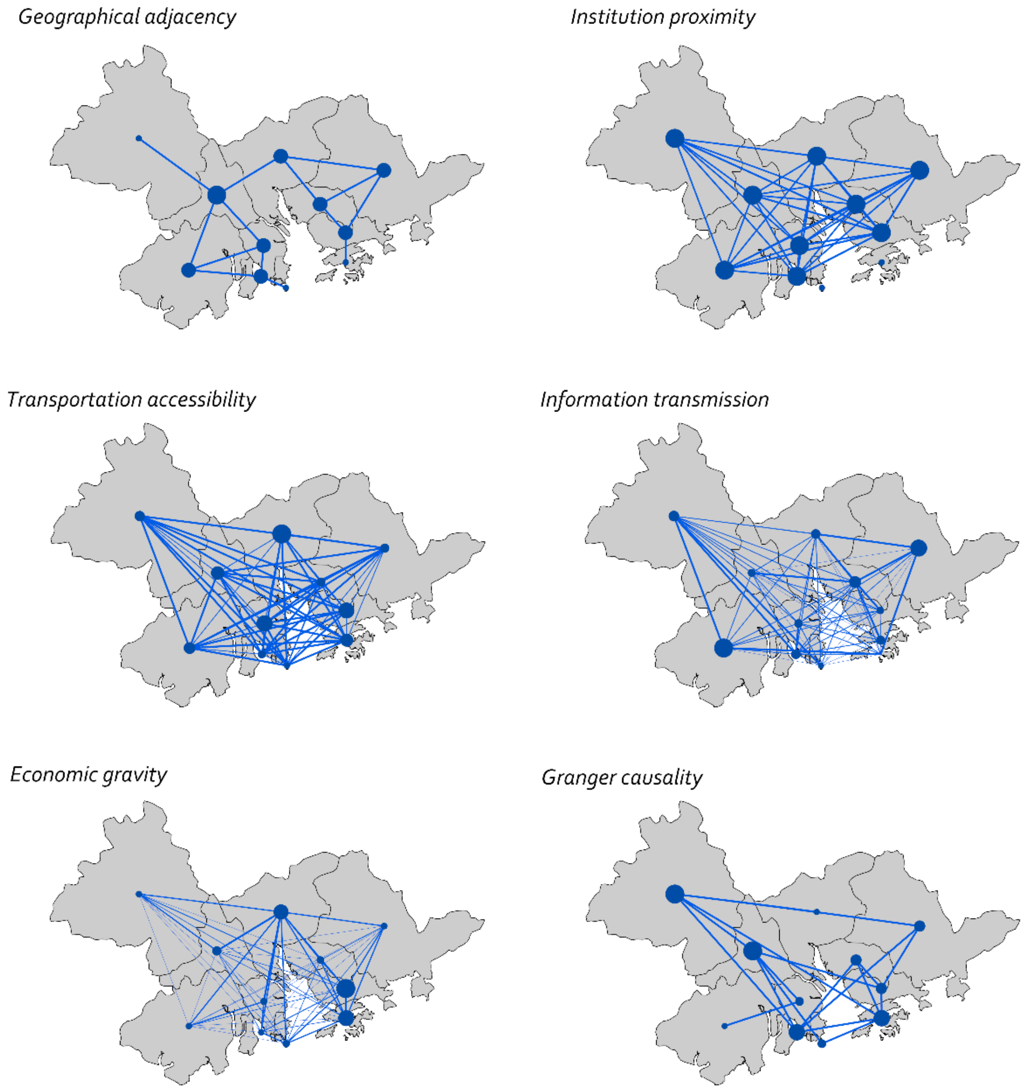
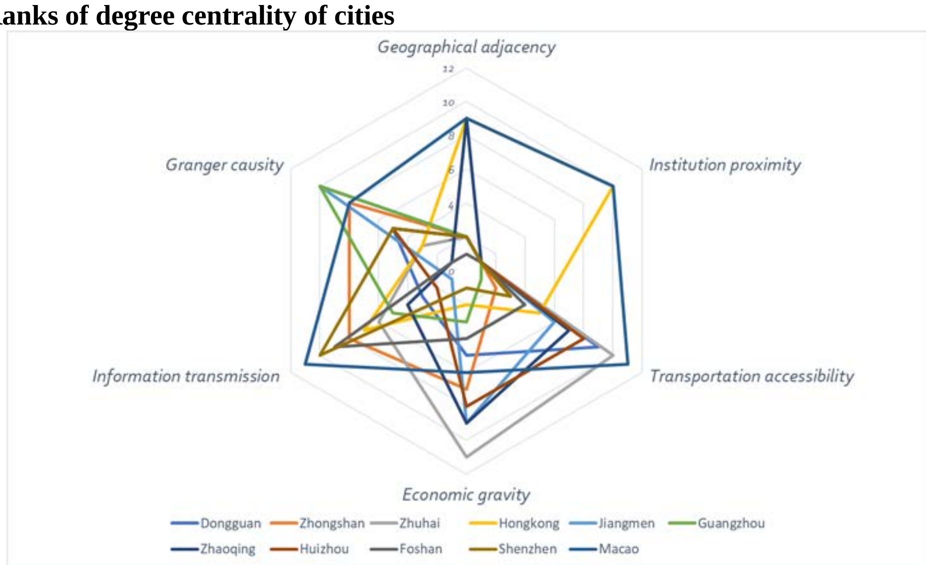


Figure 5: Ranks of degree centrality of cities



4.2.2 Networks correlation analysis

My analysis started from the physical network of geographical adjacency, which is the location canvas for other interactions to take place. As is shown at the first row of the table000, there is a moderate positive association between geographical adjacency matrix and three regional integration matrices: institutional proximity, transportation accessibility and economic gravity, with all Pearson's r above 0.25 under 1% significance level (Pearson's r between Institution proximity and geographical adjacency is 0.249, which is very close to the critical value of 0.25 for moderate association). Considering that the matrices of geographical adjacency and institutional proximity are composed with binary values, the correlation is apparent: the two SARs, which are located on the south coast of the GBA, have very limited spatial contiguity to the nine main land cities, and they do not neighbour each other neither. The only two neighbouring city-pairs with different institutions are Hong Kong-Shenzhen and Macao-Zhuhai, while the nine cities in Guangdong province sharing the same institutions also have a high frequency of neighbouring location. As for the geographical contiguity and transportation proximity, although transportation development has reduced the overall travelling time across cities in the GBA, the difference of travel time between cites is still restricted to their physical distance. The reason why there is a high Pearson's r of 0.564 in this case. Also, there is no surprise to find that economic gravity is positively associated the geographical adjacency. Because the effect of physical distance affects the economic gravity indirectly through travelling time, which is combined with economic factors (GDP and population) in the economic gravity measurement as denomination.

However, it is interesting that geographical adjacency is not significantly correlated with information transmission. That is to say, the presence of geographical contiguity may not necessarily promote the circulation density of information and sentiment between housing markets. To make it more concrete, one interpretation is that people do not simply regard the neighbouring cities as comparable housing markets to their own city. Instead, other relationships between cities may also affect their location choices, and this pattern of spatial preference can be observed by their searching behaviour on Internet.

In fact, as is shown at the fifth row, information transmission is also positively correlated with institutional networks. It is reasonable that the institutional boundary between mainland China and two Special Administrative Regions may hinder the information transmission. To some extent, the differences of politic and economic institutions are so distinct and influential that the submarkets from one side could hardly be perceived as the alternative for the one from the others. As a result, public attention and market sentiment tend to be concentrated and accumulated within the institutional boundary.

Besides, there is a negative association between information circulation and economic gravity, indicating that the strength of information networks is weaker between cities with higher economic gravity. It appears to be contradictory to the common judgement that cities with larger economic and population scale and closer travelling distance tend to generate higher density of information and emotional diffusion in housing market. To explain the "exceptional" case of GBA, it may be helpful to combine the effects of economic gravity with institutional factors. As discussed above, the boundary of institution is related to the boundary of sentiment diffusion. In this case, Hong Kong and Macao, two of the most developed cities in the GBA, are also happen to be the two cities that are institutional bounded. Therefore, although they may have high "potential" of economic gravity with other cities, this potential is not fully "realized" in their information networks because of institutional friction. Yet, except for the city pair of Guangzhou and Shenzhen, the economic gravity among other cities in Guangdong province are less prominent, but still maintain a high density and vibrant sentiment network, probably because they share similar institutional backgrounds and city tiers.

Similar to the analysis for networks between multiple regional integration and Granger causality, no significant and robust correlation evidence could be found. Based on the result of T-Y Granger causality test, two granger causality matrices are employed in this part. The first one is a binary matrix, where 0 is allocated to city pairs that fail to reject the null hypothesis of "no Granger causality" at 10% significance level, otherwise, the value is 1. To specify the probability of granger causality, we use the 1-p-values as the continuous variables of the second granger causality matrix. It is evident that these two matrices are correlated with each other, with a Pearson's r of 0.389 under 1% significance level. The results are consistent for geographical adjacency, institution proximity and economic gravity, which indicate no significant correlation. However, for transportation accessibility and information transmission, the results are contradictory. Transportation accessibility is moderately correlated with the binary Granger causality matrix, with the Pearson's r of 0.259 under 1% significant level. However, when the binary granger causality matrix is replaced by the continuous Granger causality matrix, we fail to reject the null hypothesis that there is no correlation between these two matrices under any critical significance level. Similarly, the negative correlation between information transmission and Granger causality does not hold for the robust test. Therefore, no single aspect of regional integration can generate direct prediction for the spatial leading-lag relationship of housing price.

Table 7: Pearson's r of QAP correlation test

	Geographical adjacency	Institution proximity	Transportation accessibility	Economic gravity	Information transmission	Granger causality	Granger causality (1-p-value)
Geographical adjacency		0.249* (0.055)	0.564*** (0.000)	0.257* (0.056)	0.099 (0.196)	0.096 (0.271)	0.098 (0.153)
Institutional proximity	0.249* (0.055)		0.152 (0.175)	-0.127 (0.268)	0.326** (0.081)	0.013 (0.538)	0.120 (0.143)
Transportation accessibility	0.564*** (0.000)	0.152 (0.175)		0.541*** (0.005)	-0.104 (0.269)	0.259** (0.015)	0.097 (0.170)
Economic gravity	0.257* (0.056)	-0.127 (0.268)	0.541*** (0.005)		-0.233** (0.031)	0.032 (0.320)	0.041 (0.349)
Information transmission	0.099 (0.196)	0.326** (0.081)	-0.104 (0.269)	-0.233** (0.031)		-0.131* (0.098)	-0.132 (0.137)
Granger causality	0.096 (0.271)	0.013 (0.538)	0.259** (0.015)	0.032 (0.320)	-0.131* (0.098)		0.389*** (0.000)
Granger causality (1-p-value)	0.098 (0.153)	0.120 (0.143)	0.097 (0.170)	0.041 (0.349)	-0.132 (0.137)	0.389*** (0.000)	

Note: Numbers shown in parentheses are the p-value. Number of permutations is 5000.
* Indicates significance at 10% level.
** Indicates significance at 5% level.
*** Indicates significance at 1% level.

4.3 Impact of regional integration on ripple effects on housing price

4.3.1 Description of variables

Table 8.reports the basic descriptive statistics of model variables used in the regression models. As mentioned in the methodology part, the quarterly HPI in city level is the independent variable, which ranges from -7.69% to 16.66% from 2010:1 to 2018:4. For the flow data of GDP, industry and FDI, the data are collected quarterly. For the stock of population, urbanization, hospital and road, we adopted the annually statistics. For monetary data, GDP are modified by inflation rate, while the unified currency of FDI is USD.

Table 8: Descriptive statistics

Variables	Variable meaning	Minimum	Median	Maximum	Mean	Standard Deviation
HPI	Housing price index (quarterly, %)	-7.69	1.05	16.66	2.01	3.96
GDP	GDP per capita (quarterly, 10,000 CHY)	0.54	2.38	17.76	3.64	3.72
Industry	Tertiary industry proportion (quarterly, %)	30.10	48.17	94.22	55.27	19.28
Pop	Population (annually, million)	1.57	7.23	14.90	6.90	3.27
Urban	Urban population proportion (annually, %)	42.45	89.26	100	84.42	17.26
FDI	Actual use of foreign capital (quarterly, 100,000,000 USD)	0.04	2.24	164.69	13.78	36.37
Hospital	Number of hospitals (annually, number)	4	86	243	89.256	58.63
Road	Total length of city roads per million persons (annually, kilometre)	56.13	296.12	2953.183	626.15	739.64

4.3.2 Results from the spatial panel model

In the spatial panel model, different weight matrices and variables are included to estimates the ripple effects of housing prices in GBA.

a. Model selection based on static fixed-effects SDM

The first focus is about fixed effects and random effects. Theoretically, as the 11 cities represents the complete population of the GBA, rather than a random sample drawn from the population, fixed-effects models are more suitable in this case. Empirically, fixed-effects models proved to be better by the Hausman test and R squared. Except for the economic gravity matrix model, the other four static random-effects specifications were rejected by the Hausman test. Furthermore, the large differences between within and between R squared also confirmed the significance of fixed-effects that were related to variables not specified in the analysis. Besides, common factors are another important issue in this part. According to Lee and Yu's (2010&), the local spatial interaction effects among the regions may be overestimated if common effects are not separated from the model. However, when common factor of average regional HPI are added, the results from the Hausman test showed that random-effects models were better than fixed-effect models for the transportation accessibility and institutional proximity matrices. Considering the comparability of models with different matrices, although the evidence was not completely consistent, fixed-effects models are adopted for all matrices afterwards.

The second consideration is the model specification among SDM, SAR and SEM. Starting from SDM model, we employed the Wald test for two null hypotheses respectively: $\theta = 0$ for SAR and $\theta = -\rho * \beta$ for SEM. For the static fixed-effect model without common factors, the matrices of economic gravity, institutional proximity and information transmission failed to rejected both null hypotheses. While for the common factors model, except for institution proximity, the other four matrices all indicated a better performance of SDM.

Based on the analysis above, in the static case, it is reasonable to suggest a fixed-effects SDM. The next specification is the distinction between static and dynamic models. As is shown in table 000, besides the spatial lag ($\boldsymbol{\rho}$), the time lag ($\boldsymbol{\tau}$) and the spatial and time lag term ($\boldsymbol{\varphi}$) are included in the fixed-effects SDM model. In this case, time lag ($\boldsymbol{\tau}$) represents the impact of HPI of the cities per se in the last term on contemporary housing price, while the spatial and time lag term (φ) indicates the impact of neighbouring cities. The testing of these two time lag terms are important for understanding the ripple effect as a spatial-temporal pattern of housing price dynamic in the GBA.

Table 9: static fixed-effects SDM models for HPI

Variables	Static SDM					Static SDM with common factors				
	Geography	**Transportation**	**Economy**	**Institution**	**Information**	**Geography**	**Transportation**	**Economy**	**Institution**	**Information**
Independent variables (β)										
GDP	0.656* (0.340)	0.115 (0.344)	0.104 (0.363)	-0.621** (0.271)	-0.558 (0.374)	0.334 (0.301)	0.0237 (0.292)	0.157 (0.318)	-0.569** (0.251)	-0.0727 (0.322)
industry	0.139* (0.0745)	0.155** (0.0762)	0.150** (0.0765)	0.186** (0.0744)	0.251*** (0.0748)	0.160** (0.0655)	0.194*** (0.0648)	0.184*** (0.0670)	0.222*** (0.0688)	0.232*** (0.0636)
pop	0.869 (0.931)	1.287 (0.912)	1.648 (1.024)	-2.411** (0.958)	-0.540 (0.719)	-0.192 (0.824)	0.461 (0.779)	0.658 (0.902)	-0.873 (0.924)	-0.221 (0.612)
urban	-0.0785 (0.242)	0.283 (0.242)	0.124 (0.232)	0.359 (0.249)	0.332 (0.244)	0.0456 (0.213)	0.304 (0.205)	0.354* (0.204)	0.220 (0.232)	0.256 (0.207)
FDI	-0.0140 (0.0392)	-0.0236 (0.0317)	-0.0151 (0.0299)	0.0246 (0.0281)	0.0276 (0.0278)	0.0305 (0.0347)	-0.00666 (0.0271)	0.0216 (0.0264)	0.0235 (0.0259)	0.0337 (0.0236)
hospital	-0.0289 (0.0462)	0.0117 (0.0481)	-0.0427 (0.0488)	0.0184 (0.0481)	0.0546 (0.0484)	-0.0157 (0.0406)	0.0305 (0.0409)	0.00908 (0.0430)	-0.0349 (0.0450)	0.0201 (0.0413)
Road	0.00366 (0.00246)	0.00288 (0.00248)	0.00301 (0.00248)	0.00164 (0.00236)	0.00189 (0.00243)	0.00304 (0.00217)	0.00231 (0.00211)	0.00271 (0.00217)	0.00223 (0.00219)	0.00117 (0.00207)
Spatial lagged independent variables (θ)										
*W*GDP*	-1.738*** (0.561)	-0.583 (0.696)	-1.138** (0.564)	0.594 (0.828)	0.126 (0.862)	-1.424*** (0.494)	-0.474 (0.591)	-0.948* (0.494)	0.897 (0.765)	0.495 (0.736)
*W*industry*	0.0243 (0.108)	-0.144 (0.157)	-0.0451 (0.109)	-0.191 (0.186)	-0.422** (0.190)	0.0989 (0.095)	0.0384 (0.134)	0.108 (0.097)	-0.0382 (0.173)	-0.162 (0.164)
*W*pop*	-0.860 (0.947)	1.878 (1.650)	-1.158 (0.929)	-3.619 (3.148)	4.040 (3.251)	-2.303*** (0.844)	-1.213 (1.432)	-2.302*** (0.822)	0.550 (3.032)	2.689 (2.836)
*W*urban*	-0.507 (0.437)	-0.920 (0.581)	-0.414* (0.216)	0.806 (1.016)	-1.957 (1.349)	-0.409 (0.384)	-0.698 (0.494)	-0.223 (0.190)	0.188 (0.950)	-1.006 (1.161)
*W*FDI*	-0.00247	-0.382***	-0.155**	-5.342***	-0.773**	0.054 (0.091)	-0.297** (0.121)	-0.109*	-0.996 (1.863)	-0.068 (0.347)

	(0.103)	(0.142)	(0.066)	(1.809)	(0.390)			(0.058)		
*W*hospital*	0.191*** (0.058)	0.134* (0.082)	0.106* (0.059)	0.133 (0.143)	0.435* (0.233)	0.154*** (0.051)	0.114 (0.070)	0.0567 (0.052)	-0.0793 (0.136)	-0.0105 (0.204)
*W*road*	-0.0149*** (0.00292)	-0.0109 (0.0106)	-0.176** (0.0787)	0.0115 (0.00756)	-0.00281 (0.00753)	-0.0119*** (0.00258)	-0.00378 (0.00902)	-0.0854 (0.0695)	0.0148** (0.00718)	0.00545 (0.00659)
Autoregressive terms (ρ)										
*W*HPI* ($\boldsymbol{\rho}$)	0.174*** (0.0527)	0.256*** (0.0763)	0.132** (0.0664)	0.289*** (0.0943)	0.352*** (0.0812)	-0.162*** (0.0609)	-0.708*** (0.129)	-0.313*** (0.0759)	-0.255* (0.144)	-1.250*** (0.228)
Common factors										
average HPI						1.157*** (0.113)	1.447*** (0.179)	1.250*** (0.124)	1.182*** (0.154)	2.234*** (0.245)
Log-lik	-829.0877	-829.0877	-816.1021	-1018.472	-824.4585	-829.0877	-829.0877	-816.1021	-1018.4720	-824.4585
Obs	352	352	352	352	352	352	352	352	352	352
R_w^2	0.1458	0.3567	0.1468	0.1569	0.1195	0.3567	0.1339	0.2915	0.2767	0.2799
R_b^2	0.0836	0.0097	0.0133	0.2773	0.0920	0.0097	0.0122	0.0040	0.0121	0.1256
R_o^2	0.0003	0.0441	0.0001	0.0071	0.0094	0.0441	0.0007	0.0072	0.0663	0.0223
Hausman	29.03***	25.65***	6.22	23.99***	17.95**	25.65***	9.45	19.04**	-5.17	68.04***
AIC	1916.17	1927.157	1927.47	1921.486	1926.584	1826.092	1833.285	1841.381	1865.428	1834.962
BIC	1977.988	1988.288	1989.288	1983.404	1988.402	1891.773	1898.966	1907.063	1931.11	1900.644
Wald test -SAR (θ = 0)	25.44***	31.54***	24.53***	9.60	24.36***	31.54***	15.25**	38.80***	8.90	14.04*
Wald test -SEM (θ=-ρ*β)	25.53***	30.72***	24.44***	10.00	24.05***	30.72***	15.64**	36.12***	8.62	14.29**

b. Regression results in dynamic fixed-effects SDM models

The coefficients in regression results can be approached in two ways: different variables within one certain matrix and certain variables across different matrices. First of all, the autoregressive variables are the key indicators for spatial interaction of HPI. For example, in the geographical contingency matrix model, the spatial lag ($\boldsymbol{\rho}$) and time lag ($\boldsymbol{\tau}$) were 0.0960 and 0.492 respectively, indicating a significant positive impact of spatial lag and time lag on housing price. However, the spatial and time lag term ($\boldsymbol{\varphi}$) was -0.141, which means that HPI of neighbouring cities in the last term has a negative impact on contemporary housing price. Among all five matrices, the information transmission matrix had the highest coefficients in the three autoregressive terms, and it was the best model according to the AIC and BIC. This result not only confirmed the existence of ripple effect as a spatial-temporal diffusion of housing price, but more importantly, it provided a more specific description of its forms: the contemporary impact of ripple effect was positive, but the time lagged impact was negative.

That is to say, the high HPI of one city is related to a high HPI to relevant cities in the same quarter, but may lead to lower HPI in the next quarter. Besides, the comparison of the coefficients across matrices also revealed the relevance and importance of different types of regional integration as channels of price diffusion.

For the spatial lagged independent variables, some variables were much more significant in certain matrices than others. The coefficient of W*GDP was only positive and significant in models with the information transmission matrix, indicating that economic spillovers strongly influence house prices in cities with strong information association. As for the coefficients of W*POP, it was negative in all matrices except for information transmission, suggesting a significant but negative influence of population on HPI transmitted through the channels of geographic adjacency, transportation accessibility, economic gravity matrices and institutional proximity. Thus, cities with strong links to densely populated cities tended to face less upward pressure of housing prices. In other words, these densely populated cities played an important role in buffering and absorbing the pressure of rising prices from related cities. For the W*Hospitals variable, the coefficients in geography and transportation were positive and significant in both SDM models. As the effect of local hospitals were controlled, this result actually provided a possibility for extending the values of amenity in hedonic modelling with a broader space scale and social-economic context. To be more specific, the scope and intensity of the influence of medical facilities on housing price is not confined by administrative boundaries, but related to physical accessibility like location and transportation distance.

For common factors, the results support the hypothesis that spatial dependence of housing price is not limited to the social-economic fundamentals of individual cities, like GDP and population mentioned above, but also structured by the regional housing price, which captures the general market situation that defines the spatial-temporal context of ripple effects. For coefficients estimation, these two types of impact are separated by introducing common factors to the SDM models, as is shown in the coefficients of average HPI and the variation of other coefficients with and without common factor. The coefficients of average HPI were all positive and significant in different matrices, but the magnitude varied, from 0.888 in geography adjacency matrix to 3.919 in information transmission model. But the adding of common factors also caused the changes in spatial lagged independent variables and autoregressive terms. The impact level of W*Pop in geography, economy and information are higher when common factors were included, but are lower for W*hospitals in general. For autoregressive terms, the spatial lag ($\boldsymbol{\rho}$) are more prominent in transportation, economy and information matrices and less prominent in geography. The coefficients of time lag ($\boldsymbol{\tau}$) are higher in information matrix and lower in the other. The spatial and time lag terms ($\boldsymbol{\varphi}$) only began to show its negative effect on HPI in the dynamic SDM model with common factors. Actually, the models with common factors also had better estimation performance in terms of R squared within groups, AIC and BIC statistics.

Table10: Estimation results of fixed effect SDM under integration matrices

Variables	Dynamic SDM					Dynamic SDM with common factors				
	Geography	**Transportation**	**Economy**	**Institution**	**Information**	**Geography**	**Transportation**	**Economy**	**Institution**	**Information**
Independent variables (β)										
GDP	0.179 (0.160)	-0.0731 (0.132)	-0.00401 (0.125)	-0.438*** (0.0638)	-0.445 (0.347)	-0.0806 (0.233)	-0.100 (0.191)	0.00946 (0.214)	-0.514*** (0.0881)	0.0777 (0.341)

industry	0.0416 (0.0684)	0.0496 (0.0668)	0.0490 (0.0712)	0.0750 (0.0733)	0.109* (0.0664)	0.0698 (0.0571)	0.0957* (0.0506)	0.0846 (0.0583)	0.107* (0.0603)	0.0373 (0.0550)
pop	0.0707 (0.584)	0.200 (0.977)	0.694 (1.386)	-1.177 (0.966)	-0.493 (0.552)	-0.407 (0.651)	0.346 (0.957)	0.439 (1.222)	-0.416 (1.099)	2.629*** (0.547)
urban	0.0638 (0.0896)	0.190*** (0.0726)	0.0997 (0.113)	0.211*** (0.0790)	0.219* (0.116)	0.122 (0.0958)	0.198* (0.116)	0.288* (0.152)	0.154** (0.0758)	0.189 (0.129)
FDI	0.0212 (0.0172)	0.00716 (0.0205)	0.00231 (0.0179)	0.0145 (0.0129)	0.00714 (0.0189)	0.0442** (0.0187)	-0.00811 (0.0184)	0.0253 (0.0175)	0.0129 (0.0124)	0.0428** (0.0173)
hospital	-0.0216 (0.0326)	0.00285 (0.0393)	-0.0200 (0.0404)	0.00913 (0.0395)	0.0301 (0.0330)	-0.0163 (0.0364)	0.0138 (0.0368)	0.00493 (0.0400)	-0.0307 (0.0437)	-0.117*** (0.0360)
Road	0.00237*** (0.000590)	0.00124 (0.000828)	0.00186** (0.000878)	0.000401 (0.00122)	0.000613 (0.00128)	0.00201*** (0.000627)	0.00171** (0.000821)	0.00230** (0.000903)	0.00178 (0.00109)	0.00363** (0.00161)
Spatial lagged independent variables (θ)										
*W*GDP*	-0.911** (0.451)	-0.460 (0.560)	-0.713 (0.513)	0.384 (0.721)	-0.160 (0.963)	-0.773 (0.535)	-0.304 (0.561)	-0.675 (0.588)	0.644 (0.699)	1.709* (0.887)
*W*industry*	0.0847 (0.109)	-0.0330 (0.116)	-0.00484 (0.0725)	-0.0722 (0.114)	-0.228* (0.138)	0.141 (0.105)	0.112 (0.0938)	0.131 (0.0813)	0.0550 (0.107)	0.0725 (0.113)
*W*pop*	-1.244** (0.600)	-1.299 (1.405)	-1.343** (0.644)	-3.822 (3.186)	-2.691 (3.493)	-2.151*** (0.655)	-1.878 (1.293)	-1.912*** (0.580)	-0.983 (3.486)	47.00*** (2.879)
*W*urban*	0.218 (0.248)	0.131 (0.466)	0.0187 (0.136)	0.567 (0.902)	-0.709 (0.890)	0.134 (0.335)	-0.252 (0.475)	-0.0106 (0.131)	0.329 (0.904)	1.265 (0.802)
*W*FDI*	0.0113 (0.0301)	-0.121 (0.140)	-0.0845 (0.0692)	-1.892 (1.284)	-0.419 (0.524)	0.0265 (0.0362)	-0.213 (0.137)	-0.0718 (0.0698)	-0.618 (1.621)	-0.566 (0.473)
*W*hospital*	0.0996** (0.0441)	0.141* (0.0776)	0.127** (0.0564)	0.148 (0.0908)	0.414*** (0.142)	0.0832*** (0.0309)	0.0998** (0.0505)	0.0704 (0.0512)	-0.0341 (0.0962)	-1.600*** (0.161)
*W*road*	-0.00883*** (0.00192)	-0.0150 (0.0128)	-0.0650 (0.0750)	-0.000267 (0.00587)	-0.00827 (0.0107)	-0.00677*** (0.00232)	-0.00006 (0.0106)	-0.00428 (0.0714)	0.0105* (0.00556)	0.0333*** (0.00839)
Autoregressive terms (ρ, τ, φ)										
*W*HPI* (**ρ**)	0.106** (0.0532)	0.184*** (0.0480)	0.105* (0.0603)	0.245*** (0.0414)	0.230*** (0.0505)	0.0960*** (0.0339)	0.563*** (0.0876)	0.160*** (0.0580)	0.189 (0.119)	2.368*** (0.204)
L.HPI (**τ**)	0.582***	0.599*** (0.0595)	0.601***	0.595***	0.601***	0.492***	0.499*** (0.0457)	0.504***	0.546***	0.667***

	(0.0646)		(0.0594)	(0.0362)	(0.0497)	(0.0589)		(0.0529)	(0.0313)	(0.0583)
*W*L.HPI* (*φ*)	0.0145 (0.0756)	-0.00776 (0.0791)	0.0110 (0.0881)	-0.102 (0.123)	-0.0523 (0.120)	-0.141* (0.0749)	-0.346*** (0.0971)	-0.185 (0.113)	-0.326*** (0.119)	-1.521*** (0.126)
Common factor										
average HPI						0.888*** (0.113)	1.447*** (0.179)	0.948*** (0.184)	1.003*** (0.156)	3.919*** (0.229)
Log-lik	-849.8474	-852.0508	-850.9547	-853.7675	-850.6653	-819.3264	-816.1021	-824.4585	-829.0877	-1018.4720
Obs	341	341	341	341	341	341	341	341	341	341
R_w^2	0.4259	0.4174	0.4256	0.4096	0.4205	0.5206	0.4983	0.5015	0.4905	0.3347
R_b^2	0.0378	0.0106	0.0296	0.2464	0.0780	0.1283	0.0000	0.0028	0.2169	0.0267
R_o^2	0.1180	0.1471	0.0533	0.0004	0.0949	0.1681	0.0787	0.0847	0.0417	0.0770
AIC	1717.282	1722.721	1720.512	1726.171	1719.959	1657.549	1650.599	1669.473	1676.952	1643.222
BIC	1755.601	1761.04	1758.831	1764.49	1758.278	1695.868	1688.918	1711.624	1715.271	1681.541
Wald test -SAR (θ = 0)	129.35***	16.34**	11.72	4.76	54.14	115.38***	12.95**	14.95**	8.15	1177.84***
Wald test -SEM (θ=-ρ*β)	124.69***	26.58***	9.91	6.32	60.74	95.67***	32.19***	18.44**	8.04	535.06***

Note: Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

c. Direct and indirect effects

Based on the definition by Elhorst (2014), six types of effects under different matrix settings are compared in this part to estimate the marginal effects.

The results showed that GDP influenced the local housing markets as direct effect in the institutional proximity matrix model, and the direction was positive in the short run but negative in the long run. As the diffusing effects of GDP were separated, the local housing prices were more likely to rise in cities with higher GDP in the short term, but fall for the long term; for the proportion of the tertiary industry, the direct effects are positive in all cases, which is consistent with the coefficients from table000. But the directions of indirect effects are insignificant and mixed, negative in transformation accessibility and information transmission matrices, and positive in others. Therefore, the higher proportion of industry structure was associated with the upward price trend in local housing market, but the diffusion direction and transmission channels remained unclear.

For the population, the direct effects were negative in the short-run for the information transmission matrix model, and the indirect effects were also negative for both long-run and short-run in geographical contiguity and economic gravity matrices, but only for the short-run in the information transmission matrix. These results confirm the complicated role of population in influencing the local and regional housing markets through different paths under different time spans. Besides the general “buffering” and “absorbing” function for housing prices in neighbouring and economic related cities, the populated cities helps to "spread" the public attention across the region and "redirect" the market sentiment in the short term. For the urbanization, the diffusion effect was not well supported, as none of the indirect effects were significant in any model. But the positive direct effect can be found in the economic gravity matrix for both long- and short-run, and in transportation accessibility and institutional proximity matrices for the short-run. Hence, the high level of urbanization may only push up the local housing price, but make little contribution to the ripple effect across region. This conclusion is applicable to FDI as well. For hospitals, the existence of positive diffusion effect proved to explain the ripple effect across neighbouring housing markets in both the short- and long-run, but the negative diffusion effect was confined to within the short term through the information transmission channel; the marginal effect of road, as the variable for inner city transportation, was not significant in neither direct effect nor indirect effect models; As for the average HPI, the total effects were positive among all models, indicating a self-reinforcing mechanism of regional housing price through various paths.

Table 11.Direct, indirect and total effects-dynamic SDM with common factors

	Geography	Transportation	Economy	Institution	Information
Long-run direct effects					
GDP	0.104	0.169	0.352	-1.283***	3.933
Industry	0.092	0.225	0.136	0.247	0.468
Pop	-0.121	3.312	1.829	-0.893	2.560
Urban	0.224	0.941	0.683*	0.322	0.129
FDI	0.084	0.150	0.084	0.128	0.200
Hospital	-0.062	-0.033	-0.013	-0.070	-0.198
Road	0.007	0.015	0.018	0.004	-0.002
Average HPI	1.906***	5.236**	2.192***	2.407***	29.878
Long-run indirect effects					
GDP	-1.294	-0.460	-1.152	1.151	-3.515
Industry	0.202	-0.074	0.122	-0.059	-0.439
Pop	-3.337**	-4.350	-3.591**	-0.436	9.291
Urban	0.101	-0.987	-0.356	0.179	0.223
FDI	0.009	-0.306	-0.140	-0.609	-0.318
Hospital	0.152**	0.108	0.102	-0.008	-0.213
Road	-0.138	-0.014	-0.022	0.007	-0.010
Average HPI	-0.709***	-4.210*	-1.067***	-1.146***	-28.95
Long-run total effects					
GDP	-1.190**	-0.291	-0.799*	-0.131	0.419**
Industry	0.295**	-0.151**	0.257**	-0.188	0.029
Pop	-3.458**	-1.043	-1.762	-1.328	11.851***
Urban	0.325	-0.046	0.327**	0.501	0.352*
FDI	0.0984	-0.156	-0.056	-0.481	-0.118
Hospital	0.090	-0.075	0.089	-0.078	-0.410***
Road	0.007	0.000	-0.005	0.010	0.009**
Average HPI	1.197***	1.026***	1.125***	1.262***	0.930***
Short-run direct effects					
GDP	-0.050	-0.064	0.045	0.518***	-0.056
Industry	0.065	0.090	0.079	0.107*	0.038

Pop	-3.444	0.537	0.534	-0.413	-1.941**
Urban	0.120	0.231*	0.297**	0.150*	0.094
FDI	0.043**	0.007	0.028	0.027	0.114***
Hospital	-0.018	0.005	0.002	-0.032	0.033
Road	0.002	0.003	0.006	0.002	0.002
Average HPI	0.893***	1.517***	0.959***	1.018***	4.969***
Short-run indirect effects					
GDP	-0.755	-0.199	-0.629	0.486	0.582
Industry	0.135	-0.047	0.108	0.030	-0.003
Pop	-2.004**	-1.490	-1.811***	-0.608	16.838***
Urban	0.101	-0.273	-0.059	-0.231	0.348
FDI	0.020	-0.148	-0.0 68	-0.427	-0.264
Hospital	0.080**	-0.063	0.062	-0.026	-0.549***
Road	-0.007	-0.002	-0.009	0.006	0.009
Average HPI	-0.080**	-0.591***	-0.143**	-0.139	-3.801***
Short-run total effects					
GDP	-0.806**	-0.264	-0.584*	-0.033	0.526***
Industry	0.200**	0.137**	0.187**	0.138	0.036
Pop	-2.349**	-0.942	-1.277	-1.021	14.897***
Urban	0.221	-0.041	0.238**	0.382	0.442*
FDI	0.064	-0.140	-0.040	-0.399	-0.149
Hospital	0.061	0.068	0.064	-0.058	-0.515***
Road	-0.005	0.000	-0.004	0.008	0.011**
Average HPI	0.813***	0.926***	0.816***	0.879***	1.168***

Note: *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Chapter 5: Conclusions and recommendations

5.1 Introduction

Regional integration and urbanization are the two intertwining trends that are shaping the economic geography landscape of cities. During this process, the dynamic intercity relationships within urban clusters has important impacts on regional housing markets. In the case of GBA, various types of spatial interaction have been forming a network structure, which provided possibilities for close linkages across housing markets. Therefore, the spatial-temporal patterns of ripple effects are potentially one of the most significant characteristics in understanding the regional housing markets and urban agglomeration as a whole.

The thesis adopts the GBA as a case to examine the ripple effects from the different channels of regional integration, and tests how the interface of intra-city socio-economic fundamentals and inter-city relationships function in ripple effects, that is influencing the housing price of cities itself as well as the spill-over effect. Based on the conceptual framework in chapter 2, the analysis of the thesis was developed in three aspects.

- Firstly, it evaluated the characteristics of ripple effect in terms of short-term volatility, spatial aggregation and diffusion, and spatial lead-lag relationships. This is the fundamental validation of ripple effects as spatial-temporal patterns of housing prices across markets.
- Secondly, it described the patterns and compared relationships of multi-dimensional regional integration as the potential transmission channels of ripple effect. The five facets

of regional integration are geographical contiguity, transportation accessibility, economic gravity, institutional proximity and information transmission.

- The last part explores the mechanisms of how multi-dimensional integration functions as the transmission channels of the ripple effect by estimation in dynamic spatial models.

5.2 Interpretation of the main research questions

5.2.1 Spatial-temporal patterns of ripple effect

For the short-term volatility, the fluctuation of housing prices is neither evenly distributed nor concentrated in one single spatial area. The two most volatile cities, Zhaoqing and Hongkong are located at the northwest and southeast corner of the GBA, while the relatively stable cities are in the middle region. The results from Global Moran's I and LISA also support the conclusion that instead of being dominated by one or more certain cities hierarchically, the spatial agglomeration and diffusion structure of HPI is closer to that of a spatial-temporal specified network, which has been strengthened during the past years. The detailed leading-lag relationships in ripple effects among 11 cities were further depicted by the pairwise Toda-Yamamoto Granger causality tests, confirming that geographical adjacency is not necessarily associated with spatial diffusion of housing price. To sum up, although geographical distance has always been regarded as the primary entry point for spatial analysis, it is neither the necessary not the sufficient condition for spatial agglomeration or diffusion of HPI in our case. Due to its limited explanatory power, spatial linkages other than physical distance should also be considered as structuring elements in the spatial framework for ripple effects.

5.2.2 Regional integration network

Based on the social network analysis, the significant disparity in degree centrality of each city in different networks indicated that there is no balanced spatial distribution of integration. To be more specific, Guangzhou and Shenzhen held the superior positions within GBA in terms of transportation accessibility and economic gravity, but Jiangmen and Huizhou were at the centre of public attention and market sentiment when it comes to information transmission. Meanwhile, the networks correlation analysis show that geographical adjacency is positively associated with all other networks to some extent, but the economic gravity is negatively related to institutional proximity and information transmission networks. The former part of the conclusion verified that geographical distance is still the physical condition that influences the formation of other spatial linkages. But its role has becoming more and more indirect and subtle, as it is not the single determination for spatial leading-lag relationships. For the latter, Hongkong and Macao may be the key factors underlying this conclusion, two cities that possess large economic gravity but still face a lack of integration in institutional and market attention.

5.2.3 Impacts of regional integration on ripple effect

According to the regression results of dynamic Spatial Durbin Models, the general direction of ripple effects is threefold: positive spatial diffusion effects, positive time lag effects and negative spatial-temporal diffusion effects. However, the magnitudes are different across matrices. Information transmission is the most prominent channel for spatial diffusion and time lag effects, while transportation accessibility is more significant for the negative spatial-temporal diffusion effects.

It is worth noting that the inclusion of common factors reveals the role of general market situations as the spatial-temporal context for ripple effects. The impact level of "population-based" diffusion in geography, economy and information are higher when common factors were included, but lower for "hospital-based" diffusion. Generally, the models with common factors had better estimation performance.

When considering the marginal effects of each socio-economic fundamental, the direct and indirect effect in both the short- and long- run are calculated and compared. The “GDP-based” effect is limited to the local level, with more rising price pressure for economically developed cities in the short run but relative stable in the long run. Similarly, the diffusion of “industry-based”, “urbanization-based” and “FDI-based” effects remained unclear, but the higher proportion of tertiary industry, urbanization rate and FDI do associate with the upward price trend in the local housing market regardless the time span. The “population-based” effect is more complicated, its impact is varied by transmission paths and time span. It takes the functions of “buffering” and “absorbing” price rising pressure from neighbouring and economically related cities in both period terms, and also helps to “spread” the public attention across the region and “redirect” the market sentiment in the short term; the high level of urbanization may only push up the local housing price, but make little contribution to the ripple effect across urban regions. This conclusion is applicable to FDI as well; the positive “hospital-based” diffusion effect is driven by geographical adjacency in both short-and long-run, but the negative effect is confined to within short term through the information transmission channel. Among all factors, the marginal effect of road, as the variable for inner city transportation, was not significant in neither direct effects nor in indirect effect models.

5.3 Reflections on the model

Most studies analysed ripple effect by introducing the specific socio-economic factors into either mechanism of “spatial dependence” or “coefficient heterogeneity”. This thesis adopts a combined perspective of these two classical mechanisms. More concretely, the dynamic SDM model in this study specifies the socio-economic factors as “coefficient heterogeneity” and the indirect effect as “spatial dependence”. Following this logic, the ripple effect is not a one-way leading-lag relationship between paired cities, but rather a multi-spatial dynamic network characterized by the nodes itself and the flows between them. However, the weakness lies in the mismatch of the time span between explanatory variables and HPI. As the socio-economic fundamentals in this case are developing in an incremental process, it is not completely consistent with the original meaning of “coefficient heterogeneity”, which emphasizes the different response of housing market under the same shock.

The second consideration is about the comparison of models with different regional integration matrices. It enables a statistical generation of mechanisms about different interface of intra-city socio-economic fundamentals and inter-city relationships in ripple effects. However, the risk of this approach not only comes from the matrix specification method as mentioned in chapter 3, but also related to the matrix comparison and reality relevance. Although all matrices are row standardized before entering model, the scale and its practical meaning are still quite different, making the interpretation and comparison of the coefficients confusing and not very intuitive to policy makers and regulators. On the one hand, the matrices for geographical contiguity and institutional proximity are binary, while the economic gravity, transportation accessibility and information transmission matrices are all continuous variables. Therefore, one can hardly compare the magnitude of marginal effects between matrices directly. On the other hand, the coefficient for every lag term is defined by the specific interaction of matrix and socio-economic variable. Correspondingly, the comparison of coefficient within and across models should take both factors into consideration. To avoid confusion, the matrix is termed as “path” or “channel”, and the socio-economic variable as “base”. Still, it is complicated to identify the one to one correspondence between economic model and current realities for every coefficient.

5.4 Recommendations

5.4.1 Research agenda

As has been clarified in section 1.6, there is no universally accepted definition for ripple effects or regional integration. Therefore, it leaves the possibility open that these two notions are opted to be conceptualized and operationalized depending on different research foci. This thesis emphasized on examining the role of different types of regional integration as transmission channel in the spatial-temporal diffusion of housing prices. In this sense, the defining characteristics of ripple effect are "n-n" diffusion relationships specified by both space and time. In further studies, it will be meaningful to research on the "1-n" ripple effect, that is to what extent does the housing price of pre-determined leading areas spread out to other areas. And certain time points and period can be specified based on business cycles or exogenous shocks in the short term.

Besides, for the types of regional integration, in order to balance between theoretical coherence and data availability, it is inevitably to be highly abstracted and strictly selective. For further investigation, both theoretical and empirical research are needed to understand how the local fundamentals interact with the regional integration as channels. For example, information transmission is used as one of the matrices to represent the regional integration from cognitive aspects. The theory basis is sentiment literature in behaviour economics, which emphasizes the irrational and psychological elements in market behaviour. However, it still remains to be explored more thoroughly about how these cognitive elements relate to the physical aspects of socio-economic fundamentals.

In addition, it will be meaningful to conduct research about ripple effect in urban agglomeration with different regional urban structures. As argued in sector 1.6, with nine cities of PRD in mainland China and two special administration districts, the case of GBA allows for the examination of institution difference. But as a case study, the conclusion drawn from this study can only with difficulty be generalized to broader population. Comparable research can be conducted in the Beijing-Tianjin-Hebei area and Yangtze River Delta, where the different urban agglomeration conditions may affect regional integration and housing markets in different ways.

5.4.2 Policy recommendations

It might be risky to put forward policy recommendations based on this study. Aiming at analysing the transmission channels of housing market interaction from the perspective of regional integration, this thesis is an explanatory and exploratory study. Besides, with several extensions based on the classical framework of static non-spatial models of housing price determination, the dynamic spatial model developed in this thesis is still far from mature both theoretically and empirically. Furthermore, the policy arrangements in GBA involve a complex political context, with nine cities in mainland China and two Special Administrative Regions. As discussed above, the institutional factor is one of the important channels that influence the formation of ripple effects. But simply acknowledging this fact is still far from fostering scientific policy-making. Actually, the institutional gap is also the key consideration in the making and implementing process of regional policy (Ash and Kueh, 1993, CHEUNG, CHINN, et al., 2003,Chan, Huxley, et al., 2016), which calls for further analysis from the view of public policy and governance. However, this thesis contributes to policy in promoting regional integration and maintaining the stability of regional housing market.

The first recommendation for regional integration policy is to look beyond the static geographical border. The study results have illustrated that the agglomeration and diffusion of housing price does not completely follow any physical spatial structure, but rather are influenced by other intercity relationships like transportation infrastructure, economic relatedness and institutional proximity and information transmission. Therefore, the general regional integration policy and specific sector policy under the regional framework should consider the multi-dimensions relationships in a comprehensive and dynamic way.

The second recommendation concerns the repositioning of city's role in a regional context. This entails special attention to the comprehensive and dynamic understanding of regional integration from various perspectives: geography, transportation, population, economy, information, and how does it interact with specific local socio-economic factors. The research results show that without a single leading city in the housing market of GBA, there is a complicated matrix of interface between the characteristics of the city and the interaction across cities, which impacts on local and regional housing markets in the short and long run. One of the typical examples in this case is the transportation infrastructure, which intensifies the unbalanced housing price pressure across cities with different population profile. Therefore, to promote the healthy and orderly development of real estate in GBA, it is important for each city to reconsider its general and sector strategy under the framework of regional development.

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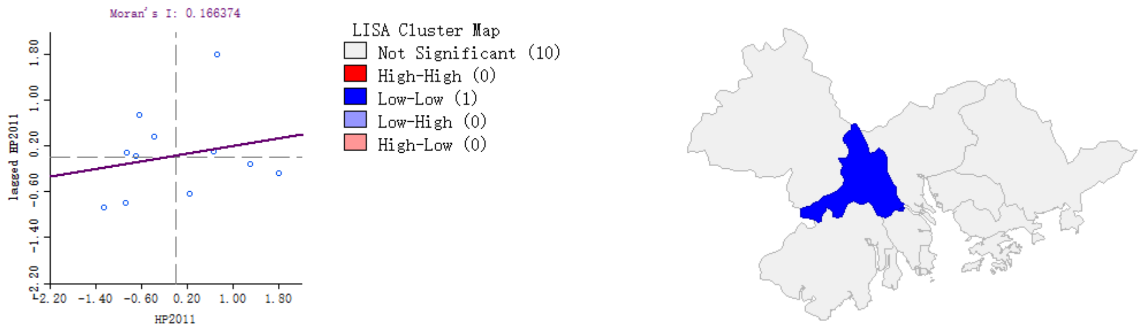
ANNIX1: Table 5 LISA cluster maps of HPI from 2011 to 2018

2011



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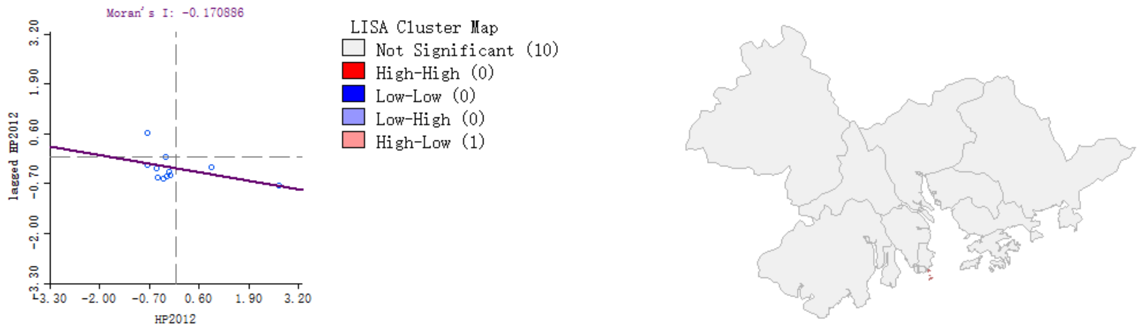

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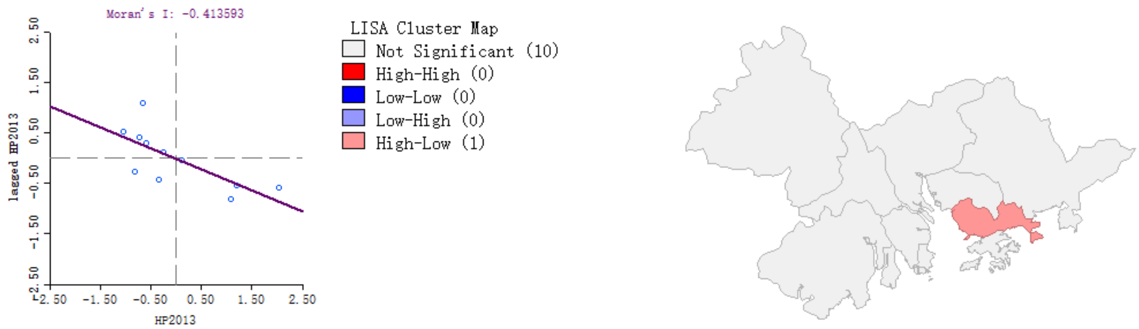

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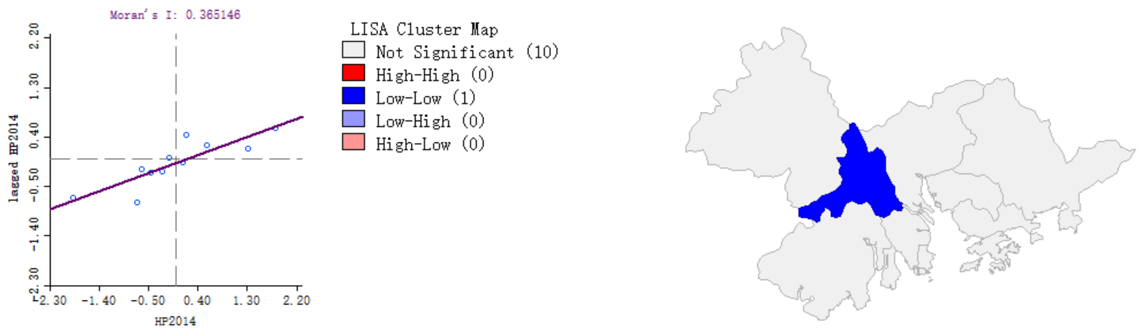

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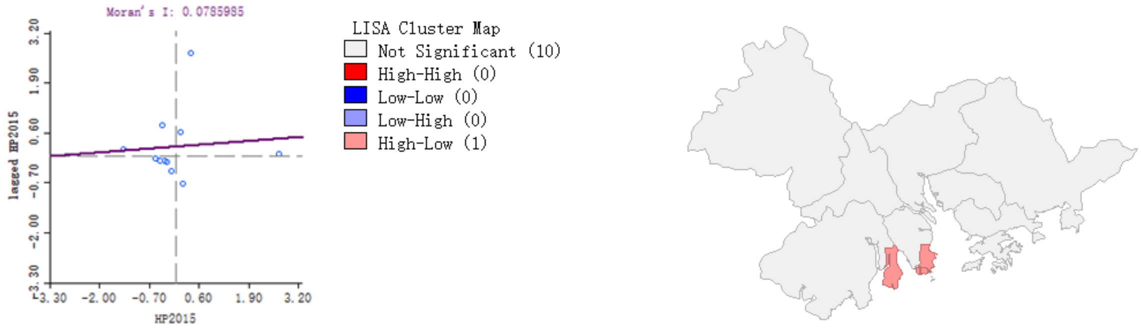

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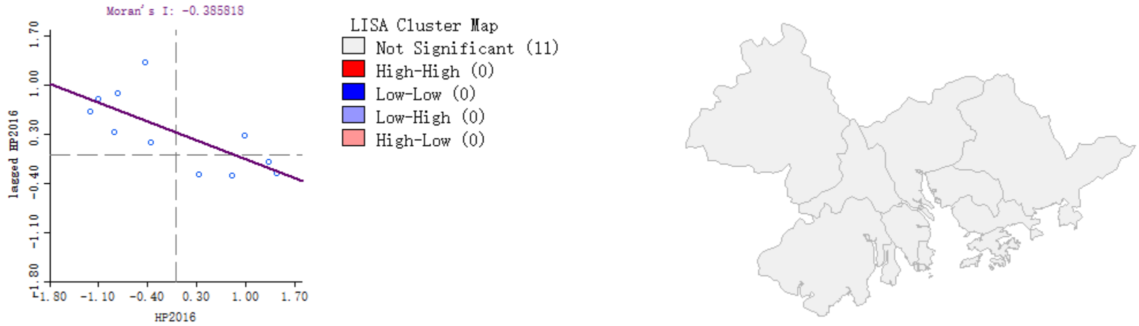

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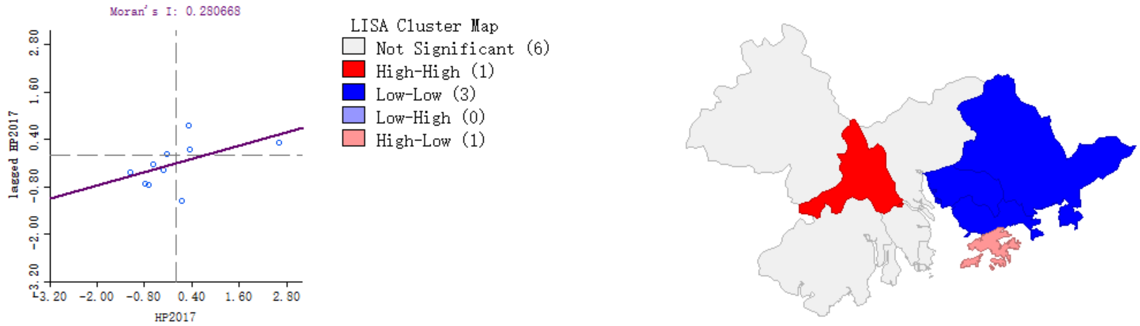
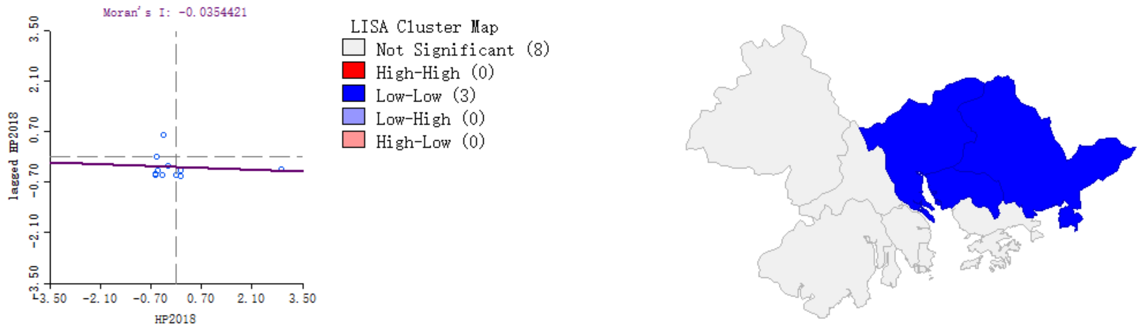


2018



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