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Intercity relationships within urban agglomeration and their impacts on urban economic development in the case of Guangdong-Hong Kong-Macau Greater Bay Area, China

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Summary

Urban agglomerations are the results of flows of production factors and industrial division of labour among cities within a specific geographic area. In the context of economic globalization and regional integration, urban agglomerations have become important spatial units that represent a country's participation in international competition and complementarity. The development of urban agglomerations should be conducive to the optimal allocation of resources within the region. However, cities mostly ignore the interests of the other cities to attract capital, business, talent and investment, thus promoting their own economic development. This often leads to regional problems such as industry contradiction, function duplication, and uneven development levels among cities. Therefore, how to understand cities' positions within urban agglomeration, and how to promote economic development through complementarity-ness is a significant or worthwhile research subject.

This study uses 11 cities from Guangdong-Hong Kong-Greater Bay Area, one of the most developed urban agglomerations in China, to explore above questions. These 11 cities show a clear hierarchy in terms of political positions, economic development levels, comparative advantages and industrial characteristics. Since 1980s, based on their own comparative advantages, a strong network of competition and complementarity has formed among these cities. However, several factors have also led to fierce disorderly competition and unscientific complementary behaviors among these cities. First, due to the fact that Hong Kong, Macau, and PRD's mainland cities enjoy three different administrative, currency and economic systems, the complementary obstacles between these three regions always exist. Second, due to the lack of scientific regional development guidance, cities tend to develop similar high-valued industries, even in the case they do not have the comparative advantages. This leads to geographic and functional niche overlaps among cities.

In this context, research set out to find out how cities within GBA can develop their economies by dealing well with the competition and complementary relationships with each other. Starting from analyzing the overall characteristics of intercity relationships, this thesis analyzed the economic spatial distribution of GBA, urban economic network among cities, and the industrial division of labour. After the description of the overall characteristics of intercity relationships, in the second section, intercity relationships were defined as three types: competition, complementary, and non-relation. Based on results of D-S model, each two cities were evaluated as one of the three intercity relationships in terms of three sectors of industries, either competition, complementary, or non-relation. Finally, intercity competition and complementary relationships were considered as one of the factors influencing urban economic development to analyze the impacts of intercity relationships on urban economy.

In terms of policy recommendations, it is important to design a regional management mechanism that considers the integrity of GBA. Also, it is crucial to establish a benefit sharing and compensation mechanism, as well as a cooperative incentive system for the better development of the less developed regions. What is more, multiple parties should be encouraged to participate in urban complementarity relationships. It not only provides opportunities for small private enterprises, it also stimulates the motivation of multi-participators to participate in cross-regional cooperation.

Keywords

Urban agglomeration, competitive, complementarity, urban economic development, impacts

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Abbreviations

APS	Advanced producer service
CV	Total cargo volume
D-S	Dendrinos-Sonis model
EC	Engel coefficient
ER	Employment rate
FDI	Foreign direct investment
GBA	Guangdong-Hong Kong-Macau Greater Bay Area
GDP	Gross domestic production
GIS	Geographic Information System
GWC	World Cities Study Group and Network
IHS	Institute for Housing and Urban Development
LR	Labour resource
MIDT	Marketing information data transfer
NGOs	Non-governmental organization
OLS	Ordinary least squares
PGDP	Gross domestic production per capita
PRD	The Pearl River Delta
SDM	Spatial Durbin model
SUR	Seemingly unrelated regression
UR	Urbanization rate

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Chapter 1: Introduction

This chapter introduces the background of the research, the practical problems and theoretical research gaps, research objectives, research questions, as well as the research limitation and scope.

1.1 Background

Economic globalization has formed a global production network. It characterizes urban space with division of industries, integration and restructuring of value chains as well as developing capabilities of urban clusters (Keil, 1998). Urban agglomerations are increasingly becoming new spatial units for global economic competition. The urban clusters are an essential phenomenon of regional urbanization (Soja, 2016). Different industries have become concentrated in different urban centers, and geography is no longer as important in most industries as in the past. The hierarchical urban system of an industrialized megacity has become a multi-centered and balanced urban network, where rapid social and economic development processes are taking place within a larger scale (Kloosterman and Musterd, 2001; Meijers, 2007). Cities are no longer confined by territorial delineations. Instead they are defined by interaction patterns (Friedmann, 1986a).

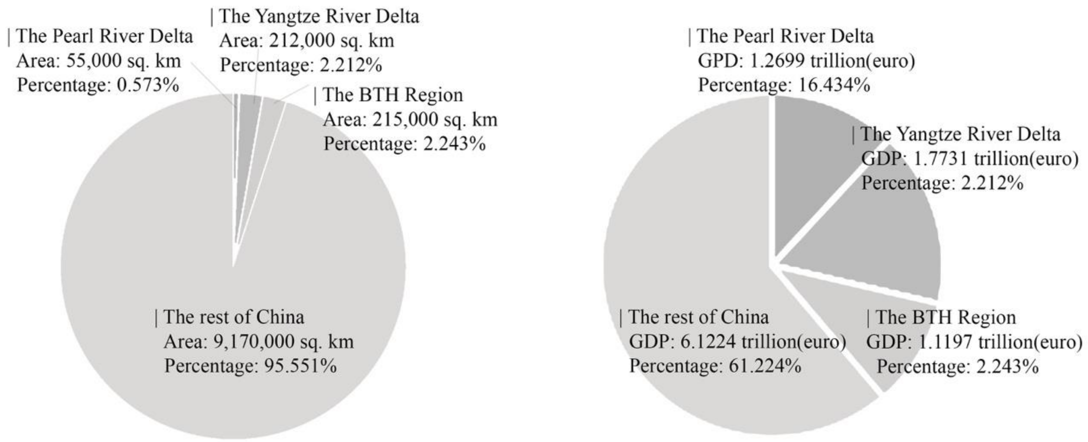
Urban spatial evolution is a process of continuous reorganization and integration of urban value chains. During the process the spillover effect is the main performance of urban agglomeration effects and scale efficiency (Frenken and Boschma, 2007). The poles within urban clusters hold the functions of both accumulation and diffusion (Bogart, 1998). The development of urban agglomerations cannot be separated from the process of industrial upgrading and transformation of the poles, which also optimize synergy mechanism among cities within the group by maximizing recourse efficiency, and thus promote the development of each city by taking use of the overall advantage of the group (Meijers, 2005). Although cities within a group differ in urban functions and industrial divisions because of different urban hierarchies and economic development levels, during the development of urban agglomerations, intercity competitive and complementary relationships between cities always exist. These relationships make great influences on both the development of cities themselves as well as urban agglomeration as a whole (Warner, 2011).

The world city development report “Reshaping World Economic Geography” proposes a three-dimensional analysis framework of density, distance and segmentation, depicting the economic geographic of world from different geographical scales (World Bank, 2009). Since the beginning of 21st century, China’s economic and social development has been characterized by high agglomeration as well as proximity of factors of production. The process of specialization and regional integration in China has been gradually accelerating. The collaborating structures integrating different levels of cities are reshaping competition units. As shown in Figure 1, China’s three most developed urban agglomerations, the Pearl River Delta (PRD), the Beijing-Tianjin-Hebei Region and the Yangtze River Delta (XiaoJiang, 2008), are home to 20% of total population , but create nearly 40% of GDP on only 5% of country’s land area in 2017.

Located in south China and geographically connected to Hong Kong and Macau, the PRD is the economic core of Guangdong Province, as well as one of three economic cores of China. The concept of Guangdong-Hong Kong- Macau Greater Bay (GBA), first introduced in 2015, composes of 9 Chinese municipalities (Guangzhou, Shenzhen, Foshan, Dongguan, Huizhou, Zhuhai, Zhongshan, Jiangmen and Zhaoqing) in PRD of mainland China as well as two special administrative regions of Hong Kong and Macau. The official government document “Framework Agreement on Deepening Guangdong - Hong Kong - Macao Cooperation in the

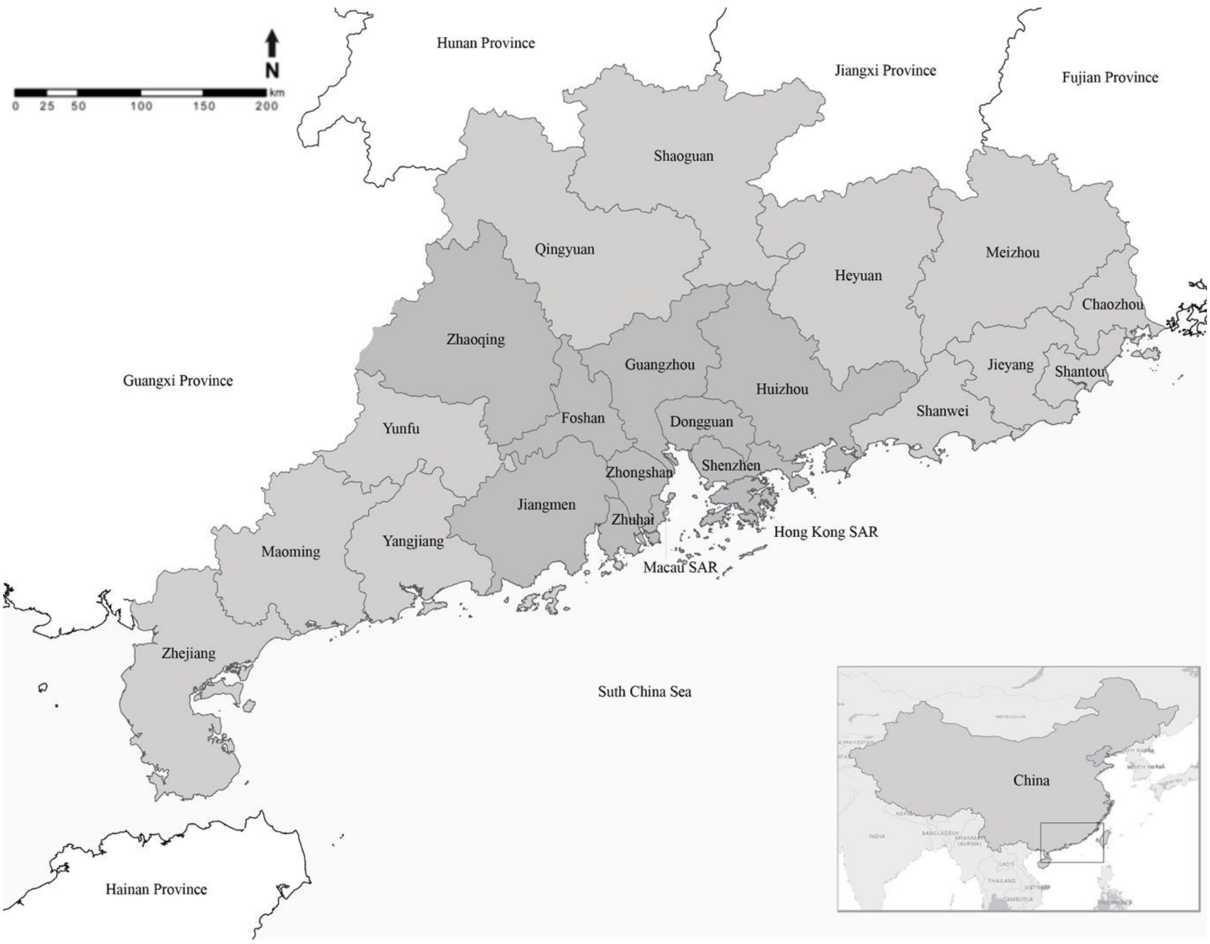
Development of the Bay Area" was proposed by national governments and is symbolic at the national strategic level. Although these 11 cities show a clear hierarchy in terms of political position, economic development level, comparative advantages and industrial characteristics., they create a strong urban network by competing with and complementing each other.

Figure 1 The percentages of land area and GDP of China's three most developed urban agglomerations



Source: Author, based on China Statistical Yearbook (2017), 2018.

Figure 2 Location of Guangdong-Hong Kong-Macau Greater Bay Area



Source: Author, based on China Statistical Yearbook (2016), 2018.

The development phases of GBA’s economy and urban relationships among cities can be divided into two phases: a) the formation of ‘Front Shop, Back Factory’ (1995-2000) and b) from ‘Front Shop, Back Factory’ to multi-competition (2000 – to date).

At the first stage, due to Chinese reform and opening policies since 1978, cities in PRD attracted foreign technology and investment from Hong Kong and Taiwan because of the comparative advantages such as cheap labour, land and geographical proximity. Within the division of labour framework, Hong Kong services as the headquarters (front shop), creating international connectivity between the world and PRD, while PRD serving as local branch plant (back factory) (Sit, 1998). The close cooperation among Guangdong, Hong Kong and Macau led to rapid growth in the regional economy. Over this time, foreign-funded enterprises had gradually transferred low-value-added and high-intensive production processes to PRD, forming a cross-regional industrial division system. The cooperation between cheap labour and low-land price in PRD, on the one hand, and Hong Kong’s manufacturing advantages, on the other, has spawned ‘Front Shop, back Factory’ model to facilitate great economic development of the region(Zhang and Kloosterman, 2016). By the mid-1990s, about 80% of manufacturing companies in Hong Kong had set up factories in PRD. This kind of division of labour and cooperation has fully taken advantage of cheap labour and land potential in PRD as well as convenient trading network and leading service capacities of Hong Kong and Macau. Some scholars argued that the pattern of regional economic productions have transformed global value chains. It not only promoted the establishment of Hong Kong’s functions as a financial, trading and shipping center, but also contributed to the transformation of PRD into a world-famous manufacturing base.

At the second stage, the economic integration between Hong Kong/Macau and Mainland China has increasingly intensified, especially after Hong Kong’s and Macau’s political returns to China in in 1997 and 1999, respectively (Enright, Scott, et al., 2005). Also, the implementation of the ‘Closer Economic Partnership Arrangement’ (CEPA) signed in 2011 increased personnel and goods flows between Hong Kong/Macau and PRD (Jiang, 2011). By post-2000, factors, such as industrial transferring and increasing costs of production endowments, have changed the economic relationships from hierarchical structure, which was anchored by Hong Kong and Macau, to network structure, where multi-centers exist. Under the industrial adjustment policies, the main industries in PRD has developed rapidly and successfully transferred from light industry which feature as labour intensive to heavy industry, technologic industry and service industry. The percentage of GDP produced by tertiary industry has surpassed the figure of secondary industry since 2013. In the meanwhile, after year-by-year industrial transformation and upgrading policies, the supporting industries of Hong Kong have transformed into modern service industries such as finance and logistics since the early 21st century (Liao and Chan, 2011).

Giving full play to respective comparative advantages and seeking common interests based on market values have always been the driving force for changing and promoting intercity relations among cities within GBA. Also, dynamic change in comparative advantages and common interest niches has characterized deep complementarity and multi-competition among cities as the most distinctive intercity relations in GBA. With the concept of “Greater Bay Area” and the idea on “Study on the Development of Guangdong-Hong Kong- Macau Greater Bay Area Urban Agglomeration” mentioned in Government documents, the development of GBA officially rose from regional strategic level to national strategic level (National Development and Reform Commission, 2015).

1.2 Problem statement

The phenomena of intercity competition and complementarity exist among any neighboring cities within an urban agglomeration (Porter, 2000). However, in practical, Matthew effects[1] also exist within most urban agglomeration. Each city has its own industrial shadow area, whose scope expands with the geographical spread of population and economic development. The expansion of shaded areas of respective neighboring city lead to overlap of shaded areas of two cities, which previously separated from each other. Unscientific division of labour among central cities, duplicated infrastructure and similar industrial structure, unscientific urban positioning and coordination mechanism has caused vicious competition among cities. As fierce competition for resources among neighboring cities appears. Further interest-driven actions, disorderly competition appears in regional contention for resources and economic frictions, which lead to a series of negative effects.

Disorderly competition is manifested in two aspects: geographic niche overlap (market area) and functional niche overlap (activities) (Wall, 2009).

Firstly, cities tend to compete when they serve the same geographic market. Many cities within GBA mistake their competitors in terms of city positioning and serving markets. For instance, Shenzhen and Hong Kong may share the same financial hinterland, but their functional linkages to the rest of the world are different. While Shenzhen is connected more to the Mainland China, Hong Kong should be a major role as it is more connected to the international market.

Secondly, cities tend to compete when they provide similar service within their urban systems. However, due to the limited regional organizing capacity, both sectoral niche overlap and organizational niche overlap exist among cities within GBA. In terms of functional overlapping, it can be manifested in three aspects: *repeated infrastructure construction, industrial homogenization* and *vicious competition for attracting investment*. First, the phenomenon of *unreasonable duplication of construction* is concentrated in certain industries with large profit potential and infrastructure areas such as seaports and airports, which are characterized by large quantity, inefficient usages of resources, and lack of coordination. For example, seven airports exist within an area of 150 square kilometers. Second, since 1980s, cities in PRD had implemented economic policies that are only aimed at increasing economies, such as 'catch-up strategy' and 'reverse development strategy'. This, in turn, led investments to focus on fast-profit-oriented small ranges of similar industries. These policies have led to high *industrial homogenization* among cities and caused intense irrational competition in the region. Third, *vicious competition* among regional governments in attracting investments by implementing irrational policies commonly exists in GBA. City governments tend to compete with each other to attract investments for high-level services and high-technological industries, professional workers, tourists, and even a marketable image, even in irrational ways that limit another cities' development. In this sense, "city wars" has taken place for a long among cities within GBA.

The lack of systemic strategic planning can be also due to the prevailing political imperative. Compared with other Chinese urban agglomerations, such as the Yangtze River Delta, a distinctive feature of GBA is 'One Country, Two Systems'. While implementing a socialist system in Mainland China, Hong Kong and Macau have adopted a capital system (Yang, 2006).

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[1] Matthew effect: The social phenomenon often linked to the idea that 'the rich get richer and the poor get poorer'. Here it refers to that the more developed cities are placed in situations where they have more chances to get develop, while those of less developed have less chances.

The rigid institutional constraints and administrative differences in the GBA are major obstacles to the development of bottlenecks in cooperation and slow process. Apart from the different administrative systems, Hong Kong, Macau and PRD have different economic systems, financial systems, currency systems, civil liberties as well as economic development planning making processes. In addition, the custom jurisdictions of free-trade-zone of each city within GBA are independent of each other. Thus, it creates much inefficient work for goods and services flow among each city. What's more, with the development of China's other urban agglomeration and the rise of manufacturing industries in Southeast Asia, GBA are facing difficulties in attracting talents and investments (Zhang, Lin, et al., 2017).

The key to the development of urban agglomeration and increasing of economic integration lies in the optimization of the internal structure, the division of labour, and collaboration between urban functional complementarities and economic linkages (Mera, 1973). However, the existence of the above challenges has led to the decline in the overall attraction of GBA, inevitably leading to its gradual fall behind the other urban agglomerations in terms of some economic development indicators.

Under the background of globalization and information, western scholars have revealed the multi-centered, networked, and equalized spatial evolution characteristics of global city-regions and mega-urban regions from the perspectives of labour division cooperation and urban networks (Scott and Storper, 2003; Hall and Pain, 2006). However, studies in western academic world are mostly based on the market economy conditions of developed countries as research background. The analysis paradigms and research hypotheses are always put forward on the basis of western countries' background. These theories are inconsistent with China's rapid urbanization development, and especially with the development of GBA, where two different social systems exist. In addition, most of research works on intercity competition and complementarity are in qualitative way, rather than quantitative way, which leads to the lack of theoretical basis for policy makers. Due to the gaps between academic theories in terms of intercity competition and complementarity and practice in GBA, policy-makers cannot make decision scientifically. Thus, unequal competitions exist in different levels of government. Therefore, in the end, Matthew effect intensifies uneven development between cities within GBA.

1.3 Research objective

This thesis takes GBA as a case to analyze intercity relationships among cities, as well as measure the impacts of intercity competition and complementarity on urban economic development. The specific objectives were:

a. To analyze the influencing paths of intercity relationships on urban economic development from three perspectives: spatial economic distribution, urban economic network, and industrial division of labour.
b. To measure to what extent which city compete or complement with each other in terms of three sectors of industries.
c. To examine and evaluate the impacts of intercity competition and complementarity on urban economic development.
d. To propose policy recommendations on dealing with intercity relationships for policy-makers.

1.4 Research question

Main research question:

What are the characteristics of intercity relationships among cities within urban agglomeration and their impacts on urban economic development in the case of Guangdong-Hong Kong-Macau Greater Bay?

Sub-research questions

a. What are the influencing paths of intercity relationships on urban economic development in cities within GBA?
b. To what extent do cities compete or complement with each other in terms of three sectors of industries within GBA?
c. What is the impacts between intercity competitive/complementary relationships and urban economic development within GBA?

1.5 Significance of the study

This thesis contributes to academic research and policy recommendations to GBA as well as the other urban agglomerations.

As for scientific significance, it researches intercity geo-economic relationships, thus contributing to theoretical development in economic geography. In focusing on urban agglomerations that play increasingly significant role in promoting national and regional economic development as well as competitiveness, this study offers new insights to measure the extent of intercity competition and complementarity. As a whole, urban agglomerations have gradually become the main form by which a country participates in international competition and integrates into global urban system. However, most researches on urban development are considered based on a single city and the intercity relationships within group and their impacts on urban development of urban clusters are less concerned. In the case of GBA, disorder competition led by local government has ignored the role of linkages between cities on urban economic development. This study goes beyond the existing qualitative studies and focus on quantitatively measuring the extent of intercity competitive and complementarity relationship in a systematic and objective manner. It measures urban economic relationships by, firstly measuring the existing intercity competitive and complementary relationships among cities; and secondly, based on preceding findings, it evaluates whether preceding findings on intercity relationships have a significant or insignificant impact on urban economic development.

As for policy relevance, the evaluation of geo-economic relationships, which may have influencing effects on urban economic development, contributes necessary ingredients needed for appropriate economic strategies. Acknowledging that division of labour and the quality of cooperation among cities have an effect on the development of urban agglomeration and urban competitiveness, means that investigating linkages among cities and enhancing regional competitiveness is paramount. This line of research is particularly useful for a region such as Guangzhou-Hong Kong-Macau Greater Bar Area, where there are intercity relationships-based competitive and complementarity relations, but are less understood. Furthermore, lessons learnt from studying Guangzhou-Hong Kong-Macau Greater Bar Area are possibly useful for Chinese other urban agglomeration, where statistics, for instance, show that by 2012, the production capacity of crude steel, electrolytic aluminum, cement and flat glass in China accounted for 40% to 60% of the total global production capacity, but the utilization rate was only about 70%. With such low utilization rate it is scary that 21 of the 39 industries in China are lower 75% utilization rate. These events have led to disorder competition among Chinese cities (Roberts, 2013).

1.6 Scope and limitations

1.6.1 Definition scope

The conclusions of this thesis were based on two hypothesises: first, in sub-questions 2 and 3, intercity relationships were defined as three types, respectively competition, complementarity, and non-relationship. Each two cites was assigned to one of the three types of relationships. Second, cities within GBA would not be affected by cities out of GBA. But in practice, intercity relationships between two cities are not only of one of the three relationships, and cities within GBA are parts of urban systems at larger geographical scale.

In terms of indicators, PGDP was chosen to represent the level of urban economic development. However, urban economic performance could not be simply represented by only one indicator. In addition, the percentage of FDI to GDP was used to replace intercity competitive relationship, while the percentage of total cargo volume to GDP was applied to replace intercity complementary relationships. However, they could only partly represent intercity relationships. These may lead to the decrease of accuracy of the outcomes. An evaluation framework should be constructed to show comprehensive urban economic performance, as well as intercity competition/complementarity, but it was not done due to time limitation.

1.6.2 Geographical scope and data accessible limitation:

Nine cities in PRD from Mainland China and two special administration cities, which consist Guangdong-Hong Kong-Macau Greater Bay Area, are chosen as the research sample.

However, first of all, the sampling sizes lead to the data limitation. Complete databases based on same indicators in all 11 cities with two different administrative systems are difficult to reach. Some data between mainland cities and Hong Kong/Macau adapts different calculating indicator system, which may lead to invalidity of the results. Also, the access to district data was limited. The data used in this thesis is multi-level. For example, in order to get more convincing results when researching economic spatial distribution by Moran's *I*, PGDP data at district-level was used. However, governments of Hong Kong and Macau do not calculate district, which led to that when data of mainland cities was at district level, data of Hong Kong and Macau was at city level. What's more, the selected empirical research object GBA is a typical polycentric urban region, where two totally different administrative and economic systems exist. This situation is rare in China and even other parts of the world. But due to tie limitation, it is difficult to analyse all typical types of urban agglomerations. Therefore, to some extent, this decreases the accuracy of the research results, and also limits the replication of the outcomes.

Chapter 2: Literature review

This chapter consists of four major sections, focusing on theoretical and empirical literature, where applicable. The first section reviews literature on urban agglomerations, spatial industrial division of labour, spatial economic aggregation and diffusion effects, and city economic network. It focuses on explaining the mechanisms of economic agglomeration and the influencing paths of these characteristics on urban development. The second section reviews theories on intercity competition and complementarity, and their impacts on urban economic development. The third section reviews the quantitative methods used for measuring intercity competitive and complementary relationships. Lastly, the chapter summarizes the research gaps on intercity relationships research, as well as the conceptual frameworks of this research.

2.1 Urban agglomeration and influencing paths

2.1.1 Urban agglomeration

a. Definition of urban agglomeration

Howard (1898) first studied urban spatial issue based on concept of garden city, which he noted could be useful in solving the problems of excessive expansion of big cities (Howard, 1898). Gottman (1957) first proposed the concept of urban agglomeration and believed that urban agglomerations developed along three continuous spatial phases: from city, to metropolitan, and to urban agglomeration (Gottmann, 1957). These three phases were the spatial types that appeared at different stages of urbanization. Obvious logical relationships among cities exist in terms of geographical scope, scale and spatial structure within urban agglomerations. To be specific, during the first stage, city has one core; whereas in the second stage, new cities' cores are formed around the surrounding areas of the original core. These new cores are both connected to and partly independent to the metropolis. At the third stage, urban agglomerations are formed due to the division of labour and more frequent flows appear between neighbouring cities. These urban agglomerations are characterized by high-density, the lowest threshold of population size, and huge urban system. McGee (1991) proposed the concept of urban-rural integration area after studying the dense urban areas of the developing countries in Southeast Asia. He described the state of agriculture and non-agricultural activities that extend along the traffic corridors between the cores of large cities as highly mixed (McGee, 1991).

Central place theory, proposed by Christaller (1933), defines hierarchical relationships between cities based on the standard of goods and services they provide to other cities. He emphasized one-sided hierarchical relationship between cities. With increasingly specialized urban functions, cities at lower class are dependent on cities at higher level, thus vertical hierarchical relationships form. However, he also stressed that horizontal relationships do not exist among cities at the same class which provide the same urban service. The central place theory emphasizes 'centrality, scale dependence, primary trend, dominant position of one-way flow, and a fixed number of spatial scale'. Urban economic functions increase with the increase of the scale, also population is uneven geographical distributed within the urban agglomeration (Meijers, 2007).

Core-periphery theory, proposed by Friedman, explains the evolution of spatial organization along with different stages of urban economic integration (Friedman and Braunwald, 1966). The 'core-areas' refer to the urban areas where industries, capital, and population are concentrated densely; while the 'periphery-areas' are not only geographically far from the cores, but also economically lags behind the cores. Core-periphery proposes that regional economic growth is accompanied by the following changes of spatial organization structure:

- Pre-industrialization stage, where few flows of regional resources exist and a small number of towns distribute in a decentralized state. Towns are isolated with each other and the spatial structure is discrete.
- Initial stage of industrialization, where a single developed economic pole appears, thus leads to 'core-periphery' regional spatial pattern. The resources and capitals of marginal areas flow into the core. The cores continues developing fast due to the increasing agglomeration capacity.
- Industrialization stage, where resources and capitals spread from the cores to the peripheral areas. This contributes to the appearance of peripheral core cities and the reduction of marginal areas.
- Post-industrialization stage, where resources and capitals continue to flow within urban agglomeration. Urban networks are formed, space is integrated, and core-periphery features are continuously disappeared. At this stage, regional spatial structure is balanced (Borgatti and Everett, 2000). This theory reveals the basic laws of the development of urban agglomeration spatial structure.

b. Mechanisms of urban agglomeration

In terms of the mechanism of urban agglomeration, J. Ravetz (2000) proposed the concept of city-region, which indicates the urban cluster is essentially a 'city-hinterland' system. Cities within this system enjoy a frequent flow of capitals, commuting and a complete division of labour, under which gradually formed a functional area (Ravetz, 2000). These functional areas expand outwards on the spatial territory. In the meanwhile, cities within the city-region show a close relationship in terms of spatial economic connections. Based on the analysis of the relationship between wages and city size, Tabuchi Yoshida's (2001) found that doubling city size increased 10% nominal wage, which was contributed by improving productivity; and in the meanwhile, it decreased 7-12% of real wage, which is the benefits from product variety minus the costs of congestion. Yoshida concludes that the wage rate is the driving factor for the development of urban agglomeration. He concluded that the wage rate was the driving factor for the development of urban agglomeration. Fan (2003) believes the formation of urban agglomeration is attributable to increasing interactions between various regions with the context of globalization. The more frequent flows of production factors between cities arise intercity relationships. Increasing intercity synergy gradually forms an urban agglomeration network. Accompanied by the emergence of urban spatial structure, the network is composed of a central city and several hinterlands or several adjacent central cities. Bertinelli and Black (2004) believe industrial division of labour, which causes production and trading activities between cities, are the essence of the formation of urban agglomerations (Bertinelli and Black, 2004). Production and trading activities not only provide markets for manufacturers but also promote the consumption and transaction, as well as the flows and transmission of a variety of information.

From the respective of urban economies, many scholars believe that profit maximization is the essential factor for the formation of agglomeration, while localized external economies of scale are the cohesive force of cities. On the basis of Alonso's urban internal structure model, Henderson (1974) established a static model to explain the formation of the urban system. The model emphasizes the role of the local governments in contributing to the formation urban agglomeration (Henderson, 1974). Abdel-Rahman (1990) introduced the concept of non-tradable goods, the externalities and the scope economy between industrial sectors into urban studies (Abdel-Rahman and Fujita, 1990). He believed that these factors characterized the urban as specialized and diverse. Anas and Xiong (2003) proposed that the diversity and specialization of cities are the productions of the cost of trade and urban location (Anas and Xiong, 2003). Duranton and Puga (2004) simulated the process of the formation of diversified cities from the perspective of knowledge spillover. He proposed the microscopic mechanism of the coexistence of specialized cities and diverse cities (Duranton and Puga, 2004).

From the respective of new geographic economy, scholars proposed that the formation of urban agglomeration is a process of natural organization based on microeconomic models which involve the concepts of increasing returns and transportation cost. Fujita and Krugman (1996) analyzed the mechanism of urban agglomeration based on single-center space economic model. They believed that the formation of cities and urban clusters were the production of force of attraction and decentralization. Decentralization refers to the transportation costs between cities and their hinterlands. They argued that once the population exceeded the critical value, a single city system would expand outwards and create links with other cities (Fujita and Krugman, 2004). Fujita (1999) believed enterprises obtain positive externalities from spatial agglomeration of economic activities. This is contributed by the intra-industry and inter-industry agglomeration of economic activities. The theory of Endogenous Growth, which is based on monopolistic competition and increasing returns to scale, believes that human capital and knowledge are the driving forces for the continuous expansion of city scale (Aghion, Howitt, et al., 1998). Based on bifurcation theory, Fujita and Krugman (1999) introduced the dynamic adjustment of economic space into previous model, thereby further expanding it into a multi-city model (Fujita and Krugman, 1999).

2.1.2 Aggregation and diffusion effects

Aggregation can be considered as the centralization of economic activities. It is a process that economic activities gather in a particular region to obtain maximum economic benefits. Spatial aggregation and diffusion phenomenon are the general rules of regional economic development. They obey certain sequences during the developing process. Generally speaking, aggregation plays a priority role in the process of regional economic development. When aggregation is developed to a certain degree, the diffusion effect will be produced. Also, the aggregation effect is always stronger than the diffusion effect. Under this circumstance, the core cities in urban agglomerations would drive the development of the surrounding cities.

Marshall (1965) first paid attention to the mechanism of aggregation economy. He expounded the causes of economic aggregation by explaining the concept of the externality of scale economy. He believed that the aggregated economy was manifested in two forms, namely urbanization economy and local economy. Technology spillover, sharing of intermediate products and sharing of the professional labour market were the manifestations of externalities. Industrial agglomeration referred to the concentration of the same types of industry or different types of related industries to a specified area, thereby achieving higher economic benefits.

Krugman (1991) introduced concepts of increasing returns to scale, monopoly competition and transportation cost to research the aggregated phenomenon at different spatial scales (Krugman, 1991). Based on the Dixit-Stiglitz monopolistic competition model, a spatial econometric model of the new economic geography area was established to simulate spatial economic aggregation phenomenon. By analyzing the interactions between economic aggregation force and the centrifugal force, the model explained the spatial aggregated phenomenon of economic activities and the formation of the “central- periphery” regional spatial organization structure. However, some scholars have criticized this model since it neglected the crowding effect and technology spillover effect caused by agglomeration.

Based on these research, study on economic aggregation and diffusion has gradually formed the growth pole theory, cumulative causation theory, core-periphery theory and new economic theory.

- The growth pole theory, proposed by Perroux (1970) emphasizes the role of regional growth poles in promoting regional economic growth under the influence of polarization and diffusion effects. He believed that when economic growth pole reaches a certain level, it will proceed to the surrounding areas through a serious of diffusion behaviours, thus driving the economic development of the surrounding areas (Perroux, 1970). However, this theory neglects the negative effects of growth poles on the development of other regions.
- Cumulative causation theory, proposed by Kaldor and developed by Nicholas and Dickson (1981), holds the idea that when the economic development of core cities has reached a certain level, a regional dualistic structure would be formed between economically developed core cities and economically less developed cities. It would hinder the coordinated economic and social development of the region (Kaldor, 1981). However, due to the emergence of urban problems in core cities, some of the production factors in core cities would drive the development of underdeveloped surrounding areas by industrial transfers.
- Core-periphery theory emphasizes the trickle-down effect[2] of core cities on undeveloped areas. This theory believes that economically developed regions will bring advanced technology, management methods and concepts to project investments in underdeveloped regions, thus promoting the overall strength of these areas (Borgatti and Everett, 2000).
- The theory of geographic economies combines aggregation proliferation with the development of the urban areas, pointing out that the spatial growth of population and economy has brought about the increase in city scale. During the process of continuous agglomeration, in big cities, advantages created by economic scales would be gradually replaced by crowded consumption. Since then, the diffusion effects occur, accompanied with a new pattern of urban spatial structure.

Friedmann established an evolution model of regional spatial organization based on economic development stage theory proposed by Rostow and growth pole theory proposed by Perroux. He believed that with the development of regional economies, the evolution of regional spatial structure would always had two contradictions, namely polarization effect and diffusion effect. These effects expanded regional economic space, and they also made the industrial spatial combination increasingly diversified and complicated (Friedmann, 1986a).

Based on the above theories, this thesis studied the spatial economic distribution of GBA, and measured the diffusion effect of the core cities of the urban agglomeration on other cities to examine the role of core cities on other cities within the urban agglomeration.

2.1.3 City economic network: from hierarchy to spatial flows

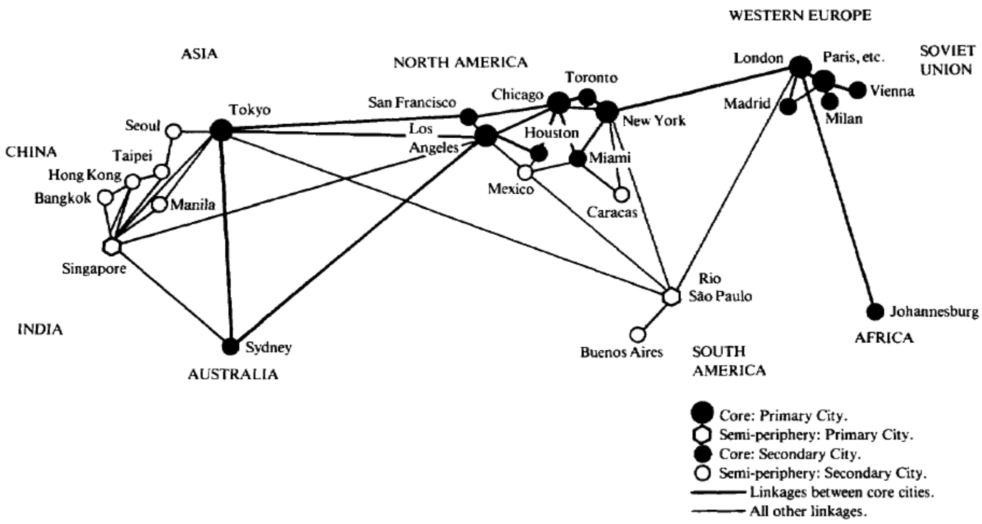
Network cities refer to a city system where diverse cities within a specific area are connected by fast and efficient transportation and communication facilities. These cities are independent of each other, but they have potential functional complementary trend (Campbell, 2013).

Friedmann (1986) proposed the links between urbanization processes and international division of labour forces in his publication *The World City Hypothesis* (Friedmann, 1986b). Friedmann argued that at the age of globalization, cities have surpassed the limitation of administrative

[2] Trickle-down effect refers to an economic growth trend in an uneven society to benefit the population as a whole, via the eventual downward percolation of wealth to the lowest strata (Source?).

geography to be a position in international investment and trade networks. He believed a city was not only a place for enterprises to carry out production, but also a base for formulating and implementing market occupation. After fully considering the functions of cities and taking advantages of other cities, a city hierarchy system would be formed (Figure 3). Structural changes in cities would find themselves related to the extent they integrate with the global economic system. In this sense, linkages created by cities' certain 'global capital' arranged cities into a 'complex spatial hierarchy' as four levels: a. core: primary city; b. semi-periphery: primary city; c. core: secondary city; d. semi-periphery: secondary city. These global capitals including the concentration of corporate headquarters, international finance, global transportation/ communications, business services, manufacturing centers, as well as population size.

Figure 3 The hierarchy of world cities



Source: Friedmann ,1986.

In publication *The Global City*, Saskia Sassen (2005) argued that cities were increasingly dependent on global cities such as London, New York and Tokyo due to the increasing influence and power of technology and telecommunications innovation (Sassen, 2005). She indicated that global cities were key locations for fresh forms of financial and producer services, which were often complex and require highly specialized skills. In addition, cities are the main nodes in the system of interconnected information and currency. The wealth they capture is closely related to specialized businesses that facilitate the flows between cities. Sassen (2005) pointed out that these flows were no longer confined within geographic boundaries and restricted by systems of regulation.

However, a shift has taken place from taking cities as 'space of places' towards 'space of flows'. Castells argued that despite of different position of division of labour and distinctive city characteristics, cities could not be isolated from urban network and global industrial division. He believed the network society was fully organized in terms of flowing space. Cities' privileged position and capacity at the intersection of flows of funds, goods, people and ideas determine their global positions within complex spatial hierarchy. Esparza and Krmenec (2000) believed that although cities at different scales did not have direct links in terms of levels, they formed relationships of mutual cooperation and trade based on different demands (Esparza and Krmenec, 2000). Pred (2014) agreed that larger cities had frequent exchanges and interactions with each other. But in practice, there were often cases where smaller cities delivered products and provided service for larger cities (Pred, 2014). This was due to the fact that small cities presented a trend of specialization in economic development, and they would develop one or more advantageous products based on their comparative advantages. Economic linkages between cities at different levels thus were created by production exchanges.

2.1.4 Industrial spatial division of labour

New labour spatial division caused by changes in production organization and the resulting imbalance in regional development have caught great concerns.

Walker (1985) combined spatial division of labour with class differentiation (Walker, 1985). Frobel (1976) extended the spatial scale of labour to the global level. He pointed out that the worldwide industrial transfer of manufacturing industries was the result of capital expansion and accumulation. The use of manufacturing labour force oriented to the world market has become a recent trend of international division of labour(Frobel, Heinrichs, et al., 1976). Scott (1985) outlined the process of capitalist commodity production and showed how to form a definitive industrial organization model in the labour process. He pointed out that internal changes in production activities and systems would lead to the formation of decentralized capital unit as well as the emergence of a new international division of space. He attributed the emergence of modern cities to vertical breakdown and the resulting network of contacts (Scott, 1985). Based on the analysis of the tendency of industrial location proliferation in developed countries since 1950s, he found that when industrial enterprises spread to marginal areas, these enterprises would be new complexes and cities locally due to agglomeration economy. In the meanwhile, a 'metropolitan-hinterland' system would be formed.

After 1990s, scholars have gradually adopted the concept of spatial division of labour to study regional development and urban spatial structure.

From the perspective of regional division of labour, based on the development situation of service industries in America from 1983 to 1988, Ettinger and Clay (1991) researched the core and peripheral areas. They measured the impacts of spatial division of labour on regional development route and complementary models. Markusen and Park (1993) studied the industrial construction and spatial division of labour in Seoul Metropolitan Region of South Korea. The study focused on explaining the roles of Korean government, corporate strategy, regional characteristics, labour and capital control (Markusen and Park, 1993). Hitz et al. (1994) studied the process of urbanization of Zurich. He concluded that the economic growth brought about by the spatial division of labour contributed to the construction of Zurich to be an international control center and thus brought about the reconstruction of urban space.

Massey (1997) explained the issue of uneven development among regions by studying the related changes between UK's industrial structure and regional development. She argued that the although R&D departments were geographically separated, the direct production process still required skilled workers, as well as the assurance of automation of production, thereby reducing labour costs and increasing labour productivity. She concluded the separation of different levels of the production process was how uneven spatial development was established (Massey, 1997). Based on the theoretical model of location decision for high-tech enterprises, Bade and Nerlinger (2000) deduced and validated the empirical model. They demonstrated that the spatial distribution of high-tech enterprises in the western region of Germany had a positive spatial correlation with surrounding universities, technical colleges and R&D facilities (Bade and Nerlinger, 2000). Smith, et al. (2009) pointed out that the spatial industrial division of labour was a process that divided certain production tasks for certain economic sectors in specific geographic regions (Smith, Kapheim, et al., 2009). It provides a basis for explaining the uneven development of capitalist spatial economy and contributes to the understanding of global value chain, global production network, network value and regional development process.

Based on the above theories, this thesis studied the industrial division of labour in GBA by measuring the industrial similarity between different industries.

2.2 Intercity complementarity and competitive relationships

Research on urban intercity relationships has gradually shifted from the traditional paradigm of the urban hierarchy to the paradigm of the urban network. Cities within an agglomeration with similar assets and investment profiles are set in competitive relations, while those with dissimilar economic profiles are supposed to complement (Meijers, 2007). This section reviewed the results of recent literature on intercity competition and complementarity, as well as their impact on urban development.

2.2.1 Intercity complementarity relationship

Hague and Kirk (2003) defined complementarity as a situation where different cities or agglomerations overcome difficulties during cooperation process while exerting their comparative advantages. They believed complementarity could explain the cooperation of economic activities and all interurban functional cooperation. These economic activities were essentially an intercity economic division of labour based on economic activities and functions (Hague and Kirk, 2003). First, to a certain extent, city should differ from each other in terms of urban functions or production activities; while second, geographical overlapping (market areas) for those urban functions or activities should be partly exist. For instance, within an urban agglomeration, based on comparative advantages, two cities create intercity complementarity while one specializes in finance and the other specializes in production and logistics. Also, in the meanwhile both of them provide services for the others (Meijers, 2006). Wall (2009) established an analytical framework for competition and cooperation relations among cities based on geographical factors and economic activities. The framework indicates that within a geographical scope, the more dissimilar the economic activities and functions of cities, the greater degree of cooperation and complementarity between cities in city network (Wall, 2009).

2.2.2 Impacts of intercity complementary relationship on urban economic development

The experience of regional economic development in various countries shows that the effective governance of cross-regional public issues urgently requires complementarity among cities. Especially in the optimization and adjustment of regional industrial structure, the construction of road transportation and other public infrastructure, and the protection and governance of regional environment. The coordinating roles of cities can promote the commercial flow between cities, increase the coordinated development between cities, and speed up the circulation of goods. This results in breaking the regional blockade formed by local protectionism, and greatly facilitate the coordinating model of joint governance between different regions (Feiock, 2004).

Factor endowment theory believes that the optimal allocation of resources is achieved by urban cooperation. Actual production requires two or more production factors for the basic conditions of production. The reasons for price advantage among different countries are often due to the endowment of production factors. Therefore, each city within the urban agglomeration should actively exert its own advantages according to its own characteristics. Urban complementarity contributes to the network state among cities of urban agglomeration (Hopkins, 2001).

The prisoner's dilemma in game theory argues that if governments within urban agglomerations can effectively communicate and collaborate, the negative impacts of irrational collective actions can largely be avoided. It believes that the best individual choice is only for individuals and does not show that they are the best choices for a team. Even under certain conditions, it would lead to irrationality in collective actions since the individual is too rational, which would negatively affect the collective interest (Rapoport, Chammah, et al., 1965). In addition, the club effects of intercity cooperation would promote more effective integration within regions.

The significance of complementarities among cities has also been mentioned in several national policy documents. ESDP (1999) proposed that cooperation, which aimed at enhancing intercity complementarity, played an important role in regional development. It had expanded the scope of services and promoted regional economic conditions, which increased the competitiveness of cities and regions (EU Commission, 1999). CEMAT (2000) also emphasized the advantages of complementarity. It pointed out that the complementarity relations between cities and towns can expand the scale of the urban economy, thus allowed cities to exert their comparative advantages better in urban competitions (COUNCIL, 2000). It was unrealistic for a single city to provide complete economic function unless through complementarity, which was proposed as regional externalities by Parr (Parr, 2004). Meijers (2006) concluded complementarity as 'a main synergy-generating region in polycentric urban regions' when he studied the role of complementarity in Randstad urban agglomeration. He augured that it was not necessary for each city specialized in all sectors. Instead, they could provide different specialized sectors to other cities and benefited from each other within the urban network. Under this situation of complementarity, cities could develop and improved competitiveness by exerting its own comparative advantages without compromising the interests of other cities (Meijers, 2006). Lall and Narula (2004) also agreed that cities where economic activities and urban functions were complementary would be more advantageous in terms of attracting investments (Lall and Narula, 2004).

2.2.3 Intercity competitive relationship

Cities compete for market, investment, population, tourism, firms, hallmark events and government funding with their comparative advantages to achieve a favorable position in the city network in fierce competition (Lever and Turok, 1999; Harvey, 1989). Porter (1990), Friedmann (1995) and Storper (1997) believed that in order to consolidate or strengthen competitive positions in city network, cities must compete with each other, especially those with similar or equal geographical scopes to attract company investment and talents (Porter, 1990; Friedmann, 1995; Storper, 1997). Campbell and Fainstein (2003) believed that competition occurs when the producers in different cities enjoyed overlapping market service scope within a city group (Campbell and Fainstein, 2003). To improve urban competitiveness, local government adopted different policies, such as reducing tax rates, increasing grants for projects, and promoting conditions of urban infrastructure to enhance the attractiveness of cities. Many rankings measuring the competitiveness of cities that were based on urban economic performance, creativity and innovation, access to and capacity of service as well as environmental sustainability appear. Wall (2009) pointed out that the indicators applied to evaluate the competitiveness of cities have been changed. They were shifting from 'old economy' to the 'new economy'. Attention was paid to comparative advantages of unmovable and controllable factors such as natural resources and labour costs in the former while the latter focused on competitive advantages of flows such as knowledge, unique skills and maximized network opportunities (Wall, 2009).

Popielarz and Neal (2007) first introduced niche theory into research on urban studies and regional spatial planning. They (2008) pointed out that independent cities without obvious comparative advanatges were more likely to create intercity competitive relationship (Popielarz and Neal, 2007). Wall (2009) also introduced niche theory to the study on urban competition in two aspects: geographic niche overlap and functional niche overlap. He noted that the formation of intercity competition was due to the fact that cities served the same geographic range of markets. The degree of competition was overlaid by the pattern of interaction and connection with similar cities, such as flows of people, logistics and service. Therefore, within an urban network, competition among cities was not only limited to geographical locations , but also existed at different geographical scales (Wall, 2009). For instance, Brussels, Antwerp and Ghent competed in the same markets within Flemish Diamond area , but differently in terms of the functional linkages to the other worldwide cities. In addition, functional niche overlap, including sectoral or product niche overlap and organizational niche overlap, was also a factor leading to intercity competition. Cities that lack of industrial differences with each other are more likely to compete.

2.2.4 Impacts of intercity competition on urban economic development

In terms of the positive impacts, Tiebout (1956) established a local public product supply model to analyze the impact of urban competition on supplement of public products and regional competition growth. To improve urban competitiveness, different regions provide better public production and service (Tiebout, 1956). Watson (1995) believed that the competition between regional governments had made great impacts on regional economic development. In order to increase urban competitiveness, cities often invested a great amount of financial and material resources in transportation, energy, and environmental facilities, and improved the infrastructure as much as possible. Feiock (2004) believed when cities competed with each other, governments usually focused on modifying the equipment and infrastructure of industries, which mainly built effective environment of the upper levels industries. It facilitated the cluster development of regional industries and brought related resources together, thus realized economies of scale. In the meanwhile, an industry supporting environment was created for neighboring regions to achieve economic progress within the urban agglomeration (Feiock, 2004). Brennan and Theodore (2005) believed that intercity competition created efficient and flowing capital. It contributed to the improvement of the quality of urban governance, which was beneficial to the growth of economy. Inefficient governments were less attractive to tax-paying companies. However, through competition, they can promote the innovation ability of organization. Thereby, it produced products of higher value-added and lower costs to form a virtuous cycle of improving urban competitiveness and economic growth.

On the other hand, once competition among cities for capital exceeds a certain limitation, the local tax rate, welfare provision and other aspects, would be negatively affected, where government's supplement ability would be influenced. At governance level, Treisman and Cai (2005) pointed out that disorderly competition among cities would bring great damages to constitutional order, reduce central government's ability to collect and control taxes, and thus led local governments to deceive or evade management from higher levels of governments (Cai and Treisman, 2005). Chirinko and Wilson (2011) studied regional competition based on a sample of capital tax rates of 48 states in United States. They showed that state's tax rate would get lower accompanying with the reductions of others' states tax rates (Chirinko and Wilson, 2011).

Existing literature pointed out that the negative impacts of disorder competition between cities on urban economic development mainly manifested in the following aspects. First, the waste of public goods and repeated construction, led by the expansionary investment strategies based on its own interests, was serious. Under the conditions of complete competition, repeated construction was due to the fact that government funds would trigger the investment of private capital in certain products and industries, thus interfering the market signals. In terms of the non-competitive sectors, local governments usually invested funds in some homogenized products, making many public facilities redundant, thereby wasting resources. These were not only a waste of taxpayers' money, but also directly led to oversupply and hindered technological progress, as well as the normal economic order (Marx, Singh, et al., 2010). Second, in order to protect local interests, local governments adopted various administrative means to prevent local market from foreign investment, which led to local protectionism (Bai, Du, et al., 2004). Third, long-term and inefficient competition declined the competitiveness of cities. In order to pursue greater interests, local governments adopted non-standard ways to participate in the competition, even ignoring the interest of urban agglomeration and the other cities. These actions only emphasized on competition seriously affected normal economic order and hindered the development of an urban agglomeration.

2.3 Methods of measuring intercity relationships

Based on the major achievements of the global urban and global urban system research, research of the urban network and intercity relationships connects space and networks from the perspective of relational relations. Through the analysis of relational data on transportation and communication facilities, corporate organizations and other social and cultural elements, these studies revealed the composition and formation mechanism of the world's urban networks. This section briefly reviewed the main research methods for studying global urban networks and inter-city relationships.

2.3.1 Infrastructure-based approach

Infrastructure-based approach measures urban networks based on the physical structure and data of inter-city networks. This method believes that high-end communications and transportation facilities link major cities in the global economy. The most important cities often have the highest level of airports or information networks with large-capacity remote fiber support. The physical network of intercity infrastructures is used to analyze the strategic spatial structure of the global transnational city network. Analysis method based on intercity physical infrastructure is subdivided into two categories. The first one reflects intercity linkages through the number of inter-city air travel passengers based on physical transport infrastructure (such as aerospace networks), while the other through data such as infrastructure of intercity internet and telecommunication capacity based on the data of communication facilities (such as the internet fiber optics).

An important source of information for studying intercity relationships on a global scale is passenger statistics on international flight routes. Based on intercity air passenger flows from 1977 to 1997, Smith and Timberlake analysed intercity relationships among cities at global level, and the temporal evolution characteristics of the changing process (D. A. Smith and Timberlake, 2001). Based on flight information data, Derudder and Witlox constructed a global city-affiliated matrix to make up for the deficiencies of basic data that existed in previous research (Derudder and Witlox, 2005). Mahutga, et al. analysed the relationship between global air passenger city network structure and international system of nations. He pointed out that distribution of power within the world's urban system appeared to be concentrated. It was considered to be the results of the rising status of semi-periphery regions and East-Asia region (Mahutga, Ma, et al., 2010).

The advantage of this research approach is that cities are considered as nodes and intuitively reflects the linkages between cities. However, since the data is generally divided by segments, and only few data concerns the origins and destination, it leads to overestimated statues of aviation transit cities. In addition, expect for data concerning business travellers that directly relates to the functions of the world cities, air passengers' travel data also includes travellers who take flights by personal reasons, such as traveling and vacations. This has caused interference with the analysis of the true pattern of world urban networks (Derudder and Witlox, 2005).

Telecommunication facilities approach measures the levels of cities within the global urban network based on the analysis of postal data, telephone communication data, and Internet data. Leamer and Storper (2004) applied the theory of international trade and economic geography to explore the impacts of the Internet on the locations of economic activities. They proposed that the widespread application of Internet technology would accelerate the process of spatial inhabitation and diffusion (Leamer and Storper, 2014). Malecki examined the spatial structure of infrastructure and Internet facilities He concluded that Internet network was similar to that of city levels. The global preference of Internet backbone network towards the development pattern of the world city system was obvious (Malecki, 2002). Based on data of Internet backbone bandwidth and airline passengers, Choi et al. (2006) studied the structure of internet backbone network and air traffic networks between 82 cities in 2002, and finished the significant correlation analysis between the levels of cities in terms of Internet infrastructure and the rankings in air traffic network (Choi, Barnett, et al., 2006).

2.3.2 Corporation-based approach

The locations of headquarters and branches of multinational corporations show business linkages of these firms at different cities, indicating the connection and urban network between different cities. Firm-based approach believes that multinational corporations are the real behaviors who create global network instead of cities themselves.

Corporation-based approach is divided into research on global producer services companies and research on generic multinational companies. The former is represented by a series of studies of the Globalization and World Cities Study Group and Network (GWC), while the latter is represented by the research of Alderson and Beckfield (2004).

GWC has developed a set of research methods for transnational city networks. The basic premise is that transnational APS companies will lock their cities together through the flow of information, polarization, knowledge, instructions, and suggestions among branches. This creates a global service center network. Based on this, Taylor et al. applied interlocked network models to determine the importance of cities in the global urban networks. He conducted regional strategic information on 100 APS companies in 315 cities worldwide, forming a corporate service value matrix of 315 (cities) x 100 (APS enterprises). Similarly, Alderson et al. (2007)applied social network analysis methods to analyze the geographical distribution data of 446 largest multinational corporations and their branches in 3,692 cities. Both were based on an assessment of the company's global location strategy, and they believed that the measurement of cross-border urban relations could be achieved through a broad connection between different branches of the company.

The difference between the two lies in the choice of the type of company. GWC adopts the regional strategy of APS companies, while Alderson adopts the geographical information of Fortune Global 500 multinational companies, regardless of the types of the companies, the nature of the company's economic activities (belonging to the manufacturing or service industries). However, the common problem between the two is that companies have different contact characteristics due to different industries, scales, and strategies, which may lead to biasing findings.

2.3.3 Social-cultural based approach

According to Smith's conceptual models of intercity linkages, both firm-based approach and infrastructure-based approach reflected intercity linkages only from an economic perspective. And they were not sufficient to fully reveal the performance and nature of world urban network (Smith and Timberlake, 1995). Study on world network of social-cultural based approach was driven by social factors.

Some scholars have applied interlocking network models between cities to study intercity political, social, and cultural relationships. Taylor applied data of 74 NGOs in 178 countries to analyse the structural attributes of city social network (Taylor, 2004); Scott conducted 26 semi-structured interviews with British immigrants working in Paris and 10-month Paris field work, summarizing the diversity of skilled migrant multinational communities and their social networks from six perspectives (Scott, 2004). Taylor (2004) defined three types of world city network through application of interlocking model: an inter-state urban network where national manufacturers act as network nodes, an inter-country urban network where UN organization act as network nodes, and an inter-country urban network where NGOs act as network nodes.

To sum up, there are three main methods for acquiring relational data:

- First, based on the premise of a large number of convenient infrastructures required by the world cities, the analysis of data on infrastructure networks (including intercity transportation facilities such as international flight routes and the internet);
- The second method based on the premise that the status of cities depends on the key sectors of important companies, the analysis of the data on the location selection strategy of headquarters and branches (Sevtsuk and Mekonnen, 2012). The former focuses on the entity city network connected by the cross-border infrastructure, while the latter derives from the links between the locations of headquarters and branches.
- Third, some scholars have demonstrated and analyzed the structure of the world city system from the perspective of intercity social and cultural linkages. However, the limitations of statistical collections directly affect the accuracy and depth of research.

Table 1 Main empirical approaches for intercity network research

Concept	Firms-based approach		Infrastructure-based approach		Socio-cultural approach	
Research object	APS firms network	Multi-national firms network	Transportation network	Communication facilities network	Global social culture network	Highly skilled labour, NGO network
Basic data	Locations of APS firms	Fortune 500 firms	Passenger data	Internet and telephone data	NGO office network data	Urban elites' migration data
Economet ric model	Interlocking network model	Social network analysis model	MIDT[3] etc.	Correlation analysis model	Interlocking network model	Flow space model
Focus	Control dimension of world cities	Dimension of city business service	Aviation hub city network	Internet city network	Social culture and political network	Urban network of labour migration

Source: Author,2018.

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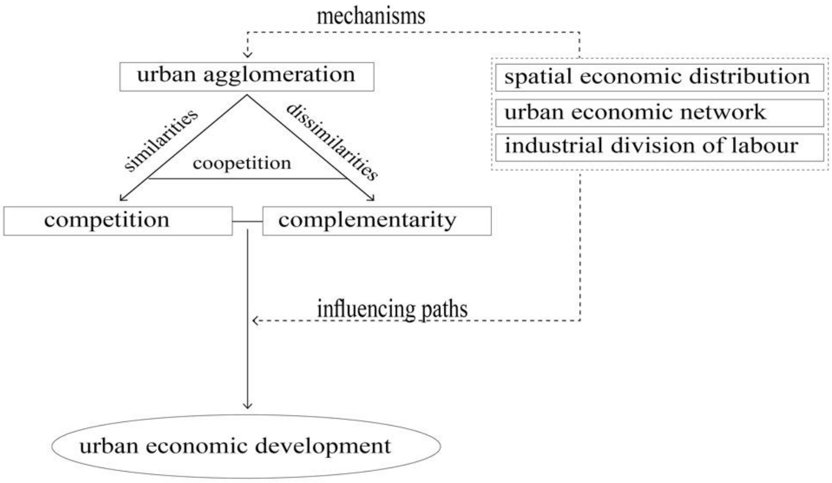
3 MIDT (marketing information data transfer) contains the details of booking and cancellation operations of all airline companies, which can not only analyze the past situation but also predict and analyze the future passenger transportation market.

2.4 Conceptual framework

Figure 4 Conceptual framework



Source: Author, 2018.

The review of theoretical and empirical research presented so far have pointed out the gaps on impacts of intercity relationships on urban economic development. The following concluding remarks can be made as follows.

First, the review of intercity relationships detailed a great deal of empirical research from the perspectives of intercity economic relations and the functional division of labour within the urban agglomeration. However, the existing research is limited and few are on judgment criteria of intercity relations.

Second, many factors affect urban economic development. Except for factors such as capital, technology, the development of surrounding cities, especially those within the same urban agglomeration, also makes a significant impact. However, only a few literatures reviewed concerned the impacts of the surrounding cities on the development of itself. Also, most of the studies on intercity competitive and complementary relationships have applied qualitative methods. Quantitative research is limited.

Third, the generation of intercity relationships and their impact on urban economic development requires paths, but there have been few relevant researches focusing on these important paths. This research gap appeal for the need to establish a new theoretical framework to understand the impacts of intercity relationships on urban economic development and more explanations on the influencing paths.

As was illustrated in the conceptual framework (see Figure 4), regional industrial labour division, urban economic network, and the aggregation and diffusion effects of core cities would contribute to the emergence of urban agglomeration. The similarities between cities would lead to the emergence of competitive relationships, while the dissimilarity between cities would cause the emergence of complementarity relationship, which was defined as 'coopetition'. The impacts of intercity relationship on urban economic development need certain paths. After reviewing the literature, this thesis believed that three factors, which promoted the formation of intercity relationships among cities, were also the influencing paths for the impact of intercity relationships on urban economic development. After this, based on the quality of urban economic development, the impact of intercity competition and complementarity on urban economic development was assessed.

Based on the conceptual framework, this thesis was implemented in three analytical steps: Part A focused on quantitative measurements of intercity competitive and complementarity relationship among cities; Part B focused on quantitative analysis and qualitative description of the influencing paths and mechanisms of intercity on urban economic development; and Part C focused on verification of whether intercity competition make influence on urban economic development.

Chapter 3: Research design and methods

This chapter gives detailed explanations of the research strategy starting with operationalization of both dependent and independent variables, data collection methods, as well as the detailed steps employed data analysis for each of the methods for each sub-question.

3.1 Revised research questions

Main research question:

What are the characteristics of intercity relationships among cities within urban agglomeration and their impacts on urban economic development in the case of Guangdong-Hong Kong-Macau Greater Bay, China?

Sub-research questions

a. What are the influencing paths of intercity relationships on urban economic development in cities within GBA?
b. To what extent do cities compete or complement with each other in terms of three sectors of industries within GBA?
c. What is the impacts of intercity competitive/complementary relationships on urban economic development within GBA?

3.2 Operationalization: Variables, indicators

The dependent variable in this research is the level of urban economic development, which is represented by PGDP of each city. Different independent variables are used to proxy the levels of intercity competitive and complementary relationships, respectively. For inter-city competition, the percentage of FDI to GDP is used as an independent variable. The percentage of cargo volume in GDP is used to proxy inter-city complementarity. Beyond these two variables being used to proxy intercity competition and complementary relationships, thus considered as influencing factors on urban economic development, several other variables (unemployment rate, urbanization rate, and Engel coefficient) were used as control variables. In addition, in order to clarify the influencing paths of intercity relationships on urban economic development, economic spatial distribution, industrial location division of labour, and urban network were analysed.

Table 2 Operationalization of sub-questions

Specific research question	Concepts	Variables	Indicators	Data collection methods and sources	Data analysis methods and software
What are the influencing paths of intercity relationships on urban economic development in cities within GBA?	Economic aggregation and diffusion	Economic spatial distribution	Global Moran' *I* (number) Local Moran' *I* (number)	Secondary data including PGDP of 121 districts in 11 cities: - Yearbooks of 11 cities	Global Morans' *I*, Abselin Local Moran's *I* at ArcGIS and GeoDa
	City economic network	The attractivenes s between cities, centralities	The degree of attractiveness of two cities (number), city centralities (number)	Secondary data including total population of 11 cities, highway distance between each two cities: -Yearbooks of 11 cities -Google Map	Urban gravity model at MathCad and Ucient
	Industrial location division of labour	Industrial structure similarities	Industrial relational degree of three sectors of 11 cities, GBA and China (%)	Secondary data including gross domestic product of three sectors of industries of 11 cities, GBA and China from 2010 to 2015: -Yearbooks of 11 cities	Location-entropy grey relational analysis at MathCad

				- Statistical beaus websites	
To what extent do cities compete or complement with each other in terms of three sectors of industries within GBA?	Regional competitive network	Percentage of GDP of three sectoral industries in GDP	Degree of intercity competition in three industrial sectors	Secondary data including add values of three sectors of industries in 11 cities from 2000 to 2016: -Yearbooks of 11 cities - Statistical beaus website	Dendrinos-Sonis model and SUR estimation at excel and Stata
	Regional complementary network		Degree of intercity complementarity in three industrial sectors		
What is the relation between intercity competitive/complementary relationships and urban economic development?	Urban economic development	The levels of urban economic development	Total value of gross domestic production per capita (number)	Secondary data including PGDP of 11 cities from 2010 to 2015: - Yearbooks of 11 cities	Panel regression models at Stata (Spatial Durbin Model)
	Competition	External investments	Percentage of FDI to GDP (%)	Secondary data including the amount of FDI and DI of 11 cities from 2010 to 2015: - Yearbooks of 11 cities - World Bank Database	
	Complementarity	Cargo capacity	Percentage of Cargo volume in GDP (%)	Secondary data including the amount of total cargo volume of 11 cities from 2010 to 2015: Website of Ministry of Transportation of China	
	Labour source	Labour source	Employment rate (%)	Secondary data of the number of employers of 11 cities, total population from 2010 to 2015: - Yearbooks of 11 cities	
	Urbanization rate	Urbanization rate	The percentage of non-agricultural population to total population (%)	Secondary data of the amount of non-agricultural population, total population of 11 cities from 2010 to 2015: - Yearbooks of 11 cities	
	Engel coefficient	Engel coefficient	The percentage of food expenditures to total consumer spending (%)	Secondary data of the amount of food expenditures from 2010 to 2015: - Yearbooks of 11 cities	

3.3 Research strategy

This is a descriptive and explanatory research in which the primary purpose is to measure intercity competitive and complementary relationships in quantitative way, as well as to test the influence of intercity relationships on urban economic development. To build the connection between intercity relationships and urban economic development, influencing paths and mechanisms were introduced. The reason for the use of quantitative research strategy was due to the availability of great amount of data, including the indicators of economic development of 11 cities, such as PGDP and FDI. Several statistical analysis methods, such as regression analysis, and various softwares (Stata, ArcGis, GeoDa) were used.

This research consists of three parts:

- The first part explored the influencing paths of intercity relations on urban economic development from three perspectives: economic spatial distribution, urban network and industrial structure. Moran's *I*, urban gravity model and location entropy grey relational model were applied in ArcGis, GeoDa, Ucient and Mathcad to figure out these three questions, respectively. Data needed here include value-added data of different industrial sectors, PGDP, distance of highway between cities, and the amount of urban population in 11 cities.

- The second part focused on calculating to what extent cities compete or complement with each other in terms of the development of primary, secondary, and tertiary industries. Value-added of primary, secondary, and tertiary industries of 11 cities were needed for the estimation Dendrinos-Sonis model in Stata.
- The third part examined whether intercity competitive and complementary relationships have impacts on urban economic development. Two econometric models were constructed for two different research objectives. SDM was estimated to analyse whether intercity competition and complementarity have an impact on urban economic development or not. Based on this, policy recommendations for modifying and enhancing intercity relations in GBA are proposed.

3.4 Data collection methods

Secondary data needed in this thesis consists of city profile statistics and intercity profile statistics for several years.

- City profile statistics of 11 cities included: GDP, gross domestic product of different sectors of industries, FDI and population,
- District-level data of 121 districts within GBA, were collected as well.

Sources of the above data consisted of statistical yearbooks from 2000 to 2016, including China Statistical Yearbook, Guangdong Statistical Yearbook, Hong Kong Annual Digest of Statistics, Macau Annual Digest of Statistics, as well as city statistical yearbooks of nine cities. Local government statistics bureaus websites were also used when some data in yearbook was missing. In addition, in order to improve the efficiency data collection, various research institution databases were used, such as All China Data Centre, China Data Online, World Bank Database. Some missing FDI data in local websites was collected from FDI market.com website.

Intercity profile statistic: distance between two cities used in measuring urban economic network in urban gravity model was measured by the author in Google map based on the shortest highway distance between cities. Data of the amount of total cargo volume, where were used to replace the variables of complementarity, were collected from the website of Ministry of Transportation of China.

3.5 Data analysis methods

The specific techniques and steps for each sub question are as follows:

Part A: What are the influencing paths of intercity relationships on urban economic development in cities within GBA?

Intercity relationships mainly affect urban economic development through three paths, namely, agglomeration and diffusion effects, urban economic linkages and regional industrial division of labour. These are also the mechanism of the formation of urban agglomerations. This section explored the characteristics of these three influencing paths and the characteristics of intercity relationships among GBA.

A1: Economic spatial distribution

Method	Data	Software	Outcome
Global Moran's *I*	PGDP of 11 cities and 121 districts	Analysis in ArcGIS and GeoDa	Economic spatial distribution
Local Moran's *I*			Spatial structure and types of economic distribution

Agglomeration is a phenomenon of the concentration of economic activities within an urban agglomeration. It is also a process in which economic activity participants gathering in specific regions for higher profits. When the agglomeration level reaches a certain level, diffusion and spillover effects will occur. It will drive the development of neighboring cities through the interaction with other cities. Global spatial autocorrelation (Moran's *I*) analysis method was applied to examine the situation of economic spatial distribution of cities within GBA, while Local Moran's *I* was used to measure the effects of the core cities on the surrounding cities.

a. Global Moran's *I*

The Moran's *I* evaluates whether economic activities are geographically clustered, dispersed, or random (Abselin, 1995). It reflects if spatial adjacent areas have similar attributes or not. The formula can be expressed as:

$$\text{Global Moran's } I = n \Big/ \sum_{i=1}^{n}\sum_{j=1}^{m} W_{ij} \cdot \sum_{i=1}^{n}\sum_{j=1}^{m} W_{ij}\,(X_i - \bar{X})(X_j - \bar{X}) \Big/ \sum_{i=1}^{n}(X_i - \bar{X})^2 \quad (1)$$

where i=1,2, 3,…,n; j=1,2,3,…,m; X_i refers to PGDP of the studied cities, X_j refers to PGDP of the adjacent area j, and $\bar{X}$ is the average of PGDP of GBA. W_{ij} is the element in the spatial weight matrix W.

The standardized statistic Z is used to test the spatial correlation significant levels. The indexes of Moran's *I* range from [-1,1]. When Moran's *I* >0, the positive correlation indicates cities with similar economic development levels have significant spatial distribution. The larger the number is, the stronger the spatial distribution correlation is; Moran's *I*<0 means negative correlation, which indicates cities with comparable properties distribute sparsely; when Moran's *I*=0, cities are randomly distributed (Guillain and Le Gallo, 2010, Zhang, Luo, et al., 2008).

b. Local Moran's *I*

Based on the outcome of spatial economic distribution created by Global Moran's *I*, Local Moran's *I* was used to identify the precise spatial structure and types of economic distribution. The formula is expressed as follows:

$$\text{Local Moran's } I = \sum_{i \neq j}^{n} W_{ij} X_i X_j \quad (2)$$

Where i=1,2, 3,…,n; j=1,2,3,…,m; x_i and X_j represent the PGDP of two cities, i and j, while the definition of W_{ij} is the same as Global Moran's *I*.

A2: Urban economic network

Method	Data	Software	Outcome
Urban gravity model	Total population of each city, highway distance between cities	Urban gravity model at Mathcad; results visualization at Ucient and Netdraw	Urban economic linkage density, centrality, outdegree and indegree

Based on macroeconomic and demographic data, urban gravity model was introduced to measure urban economic linkages to explain the magnitude of economic connections between cities within GBA. The model reflects the core city's attractiveness to affect the surrounding areas, the admittance of neighboring cities to the core city, and the degree of interaction with surrounding cities. Gu and Pang (2008) applied this method to analyze the spatial relationships, including intercity relationships and territorial relationships in the inner urban system, and classified the ranks of spatial combination areas of Chinese urban system (Chao-lin and Hai-feng, 2008). Krings et al. modified this method to analyze the inter-city telecommunication flows in Belgium (Krings, Calabrese, et al., 2009).

The model can be formulated as:

$$R_{ij} = \frac{\sqrt{P_i \cdot V_i} \cdot \sqrt{P_j \cdot V}}{D_{ij}^2} \quad (3)$$

where R_{ij} represents the degree of economic linkages between cities i and j, P_i and P_j refer to population sizes of two cities, V_i and V_j refer to economic scales of two cities, and D_{ij} represents distance between two cities. This thesis selected the population size, GDP and the highway distance between cities to reflect the scale of population, economic scale and the accessibility of cities, respectively.

However, in reality, the attraction between two cities is not equal. There is an indirection and difference in the economic attraction between cities. The attraction of more developed cities to less developed cities is greater than that of less developed cities to more developed cities. Therefore, the parameter k was introduced (GU and PANG, 2008).

The modified model is written as:

$$R_{ij} = k_{ij} \cdot \frac{\sqrt{P_i \cdot V_i} \cdot \sqrt{P_j \cdot V_j}}{{D_{ij}}^2}, \; k_{ij} = \frac{V_i}{V_i + V_j} \tag{4}$$

Where K_{ij} refers to contribution of city i to R_{ij}.

Based on urban gravity method, attractiveness index between two cities was measured. The larger the numbers are, the stronger the linkages are. This method was also used to analyze data from 2005 to 2015 in order to explain the trends of intercity economic linkages. Ucinet and Netdraw softwares were used to visualize outcomes of the economic linkages between cities.

A3: Industrial division of labour

Method	Data	Software	Outcome
Location- quotient grey relational degree analysis	Gross domestic product of each industries of 11 cities, GBA and China	Calculating at MathCad	Industrial structure similarities degree

Within an urban agglomeration, cities have established a network of cross-regional cooperation and development under an open, orderly and free flow of capitals, and have gradually formed advantageous industries. Under the deepening of competition and complementarity, a consultation mechanism for the division of labour within the industrial chain has gradually developed. It promotes the formation of common economic interests among cities, thus making cities economically closer. The location quotient grey relational analysis method was adapted to analyze the similarities and differences of industrial structure among cities.

The specific steps are as follows:

Step 1: Calculating industrial location quotient matrix

$$\mathrm{L}Q_{ik} = \frac{d_k}{\sum_{k=1}^{n} d_k} \Big/ \frac{D_k}{\sum_{k=1}^{n} D_k} \tag{5}$$

where LQ_{ik} refers to industrial location quotient, i refers to city 1,2, 3, …, n; k refers to industry 1,2, 3, …, k; d_k and D_k represent industrial GDP of city and China, respectively. According to the industrial classification in China, industries are divided into eight categories: agriculture, manufacturing, construction, transportation and storage, accommodation and catering, finance and real estate.

Step 2: Calculating the grey correlation coefficient

a. Determining comparison sequences and reference sequences

Taking national industrial structure as a reference sequence, denoted as $X_0(k)$; industrial structure data of each city and urban agglomeration as comparison sequences, denoted as $X_i(k)$, where i and k refer to different city and industry, respectively.

b. Calculating the absolute different value of each industry between comparison sequences and reference sequences (each city, GBA and China), denoted as △i=|△i(k) - X_i(k)|

c. Calculating two-level minimum difference and maximum difference, denoted as $min_i min_k$△i and $max_i miax_k$△i respectively. Where min_i△i is the first-order minimum difference, which refers to the minimum value of industry k between each city, GBA and China. And the two-level minimum difference is the minimum value among all the industrial minimum values, denoted as min_i min_k△i = min{ min △i (1) ; min △i(2) ; min △i(3) , …, min △i(n) }; meanwhile two-level maximum difference is denoted as max $_i$ max $_k$ △i = max{ max △i (1) ; max △i(2) ; max △i(3) , …, max △i(n) };

d. Calculating the grey correlation coefficient ξ_i(k)

$$\xi_i(k) = \frac{min_i min_k|X_0(\mathrm{k}) - X_i(\mathrm{k})| + \delta max_i max_k|X_0(\mathrm{k}) - X_i(\mathrm{K})|}{|X_0(\mathrm{k}) - X_i(\mathrm{k})| + \delta max_i max_k|X_0(\mathrm{k}) - X_i(\mathrm{K})|} \quad (6)$$

where δ refers to resolution factor, δ= [0,1]. δ=0.5 is generally taken according to previous researches.

e. Calculating grey relational degree

$$R_i = \frac{1}{n}\sum_{k=1}^{n} \xi_i(k) \quad (7)$$

Based on this model, the similarities of the industrial structure among cities, which leads to intercity competition, can be measured. The number ranges from 0 to 1, and the larger the number, the greater the degree of similarity between two cities in a certain industry.

Part B: To what extent do cities compete or complement with each other in terms of industries?

Method	Data	Software	Outcome
Dendrinos-Sonis model	Added value of primary, secondary, and tertiary of each city from 2000 to 2016	Excel, Stata	Industrial quantitative competitive and complementary relationship

In Part B, industrial quantitative competitive and complementary relationships were analyzed. Dendrino-Sonis model, which was first proposed by Sonis and Dendrinos in 1988, assumes that within an urban agglomeration, economic changes in each independent economy would affect the economic changes of other economies (Dendrinos and Sonis, 1988). If the economic growth of city i has positive impact on city j, then these two cities are complementing; otherwise, they are competing (Nazara and Hewings, et al., 2006). The developing situation of three industrial sectors of each city within GBA were chosen to measure the competition or complementarity between cities.

The specific steps are:

Step 1: Defining y_i (t) as the industrial share of city i of GBA at time t, the distribution of industrial shares of GBA can be written as:

The formula above can be seen as a discrete dynamic model. The relative discrete socio-spatial dynamics is given by:

$$y_i(t+1) = {F_i[y(t)]} \Big/ {\sum_{j=1}^{n} F_j[y(t)]}, \;\; i,j = 1,2,\dots,n; t = 1,2,\dots,T. \quad (8)$$

where $0<y_i(t)<1$, $F_i[y(t)]>0$ and $\sum_i y_i(t)=1$. The function $F_i(.)$ can take any arbitrary form as long as it satisfies the positive value property. $F_i[y(t)]$ refers to the locational and temporal comparative advantages of city i enjoyed by a set of complex flows between cites, including the flow of capital, goods, services, and government investment (Dendrinos and Sonis, 2012; Sonis and Hewings, 2000).

Step 2: Determining a reference city, denoted as $y_1(t)$. Then the comparative advantage of another city in terms of the numeraire city is:

$$G_j[y(0)] = {F_j[y(0)]}\Big/{F_1[y(0)]}, j = 1,2,3,\ldots,n. \quad (9)$$

Then equation (7) and equation (8) can be stated as the following system of equations:

$$y_i(t+1) = 1\Big/1 + \sum_{j=2}^{n} G_j[y(t)]$$
$$y_j(t+1) = y_j(t+1)G_j[y(t)] \quad (10)$$

Step 3: $G_i[y(0)]$ can be assumed to be a Gobb-Douglas function suggested by Dendrinos and Sonis as:

$$G_j[y(0)] = A_j \prod k y_{k_t}^{a_{jk}}, j = 1,2,3,\ldots,n; k = 1,2,3,\ldots,n. \quad (11)$$

Step 4: Then apply the log-linear form to get the following model:

$$lny_j(t+1) - lny_1(t+1) = ln(A_j) + \sum_{k=1}^{n} a_{jk} lny_k(t), j = 1,2,3,\ldots,n. \quad (12)$$

where a_{jk} represents the coefficient of k relative to j; when the coefficient $a_{ij}>0$, region j and region k are complementary relations, which means, every one percent increase in region k would respond to one percent growth in region j; when $a_{jk}<0$, it means that that j and k are in a competitive relationship, that is, when industrial share of k increases, industrial share of j will decrease (Hewings, Sonis, et al., 1996; Mantell, 2005).

Equation (11) was estimated using a least squares estimator in Stata. Since a system of equations we are dealing with are related in some way, Seemingly Unrelated Regression (SUR) were applied.

Part C: What is the impacts of intercity competitive/complementary relationships on urban economic development within GBA?

Method	Data	Software	Outcome
Panel regression models (Spatial Durbin Model)	FDI; percentage of total cargo volume in GDP; total number of employees; ratio of non-agricultural population to total population; percentage of food expenditures to total consumer spending	Analysis at Stata	Significant or insignificant positively or negatively impacts of intercity competitive and complementary on economic development

The percentage of FDI to GDP was used to measure intercity competitive relationship variables. Attracting FDI, on one hand, promotes local economic development; on the other hand, due to the scarcity and flows of capital, it also causes decrease investment in other cities, especially the neighboring regions. Considering the urban economic scale effect, the percentage of FDI in GDP was used.

The percentage of total cargo volume in GDP (CG) was used to measure intercity complementary relationship variables. Cargo volume consist of air, sea, road and rail cargo. Higher values of cargo volume mean better road infrastructure systems. The reduction in the time cost of cargo transportation reduces intercity trading costs, which facilitates flow of resources and thus promotes urban economic growth. And the convenience of road infrastructure systems promotes the capital flows among cities within an urban agglomeration. Minimizing the urban economic scale effect, the values of percentages of cargo volume in GDP was applied.

In addition, control variables included: labour resources (LR), reflecting the status of urban labour, measured by the total number of employees at the end of the year; urbanization rate (UR), reflecting the level of urban construction, measured by the ratio of urban non-agricultural population to the total population; and Engel coefficient (EC), reflecting urban development level from the perspective level from the consumption perspective was measured by the percentage of food expenditures to total consumer spending.

The specific steps were:

Step 1: Models construction

For intercity competition:

$$lnY_{it} = \beta_1 WY_{it} + \beta_2 FDI_{it} + \beta_3 WFDI_{it} + \beta_4 LR_{it} + \beta_5 WLR_{it} + \beta_6 UR_{it} + \beta_7 WUR_{it} + \beta_8 EC_{it} + \beta_9 WEC_{it} + \mu_i + \gamma_i + \varepsilon_i \quad (13)$$

Where Y_{it} is PGDP of city i at time t, representing level of urban economic development (y variable) ;$WlnY_{it}$ is lag of PGDP; $lnFDI_{it}$ is the percentage of FDI in GDP, $WlnFDI_{it}$ is lag of lnFDI, representing how one city influences the geographically adjacent cities; LR is urban employment rate, WLR_{it} is the lag of labour resource(employment rate); UR is urbanization rate, WUR_{it} is the lag of urbanization rate; EC is Engel coefficient, WEC_{it} is the lag of Engel Engel coefficient; μ_i is spatial fixed effect, γ_i is time fixed effect.

The coefficients of FDI(=β_1) and WFDI(=β_2) are central coefficients measuring the level of competition in this research. If β_1 is positive, it indicates that an increase of FDI in city i contributes to the urban economic development of city i; and if β_2 is positive, it indicates the increase of FDI in city i also contributes to the urban economic development of the geographically adjacent cities. On the contrary, if β_1 is negative, it indicates that an increase of FDI in city i will cause a decline in level of urban economic development; and if β_2 is negative, it means the increase of FDI in city i will cause a decline in the urban economic developing level of the surrounding cities.

For intercity complementarity:

$$lnY_{it} = \beta_1 WY_{it} + \beta_2 lnCV_{it} + \beta_3 WlnCV_{it} + \beta_4 LR_{it} + \beta_5 WLR_{it} + \beta_6 UR_{it} + \beta_7 WUR_{it} + \beta_8 EC_{it} + \beta_9 WEC_{it} + \mu_i + \gamma_i + \varepsilon_i \quad (14)$$

Where CV_{it} is the percentage of total cargo volume in GDP; $WlnCV_{it}$ is the lag of CV_{it}, representing complementarities influence of one city on other adjacent city urban economy; LR is urban employment rate, WLR_{it} is the lag of labour resource (employment rate); UR is urbanization rate, WUR_{it} is the lag of urbanization rate; EC is Engel coefficient, WEC_{it} is the lag of Engel Engel coefficient; μ_i is spatial fixed effect; while γ_i is time fixed effect.

The coefficients of CV(=β_1) and WCV(=β_2) are the central coefficients measuring the level of complementarity of this task. If β_1 is positive, it indicates that an increase of cargo volume in city i will benefit the economic development of city i; and if β_2 is positive, it indicates that an increase of cargo volume in city i will also benefit the economic development of the geographically adjacent cities. On the contrary, if β_1 is negative, it indicates that the increase of cargo volume in city i will depress the level of urban economic development of city i; and if β_2 is negative, it means that an increase of cargo volume in city i will also depress the economic developing level of the surrounding cities.

Meanwhile, logarithmic transformation is applied to variables with growth effects which are not normally distributed to avoid possible measurement errors in the dependent variable in both competition and complementarity models.

Step 2: Unit root test

In order to avoid spurious regression and ensure the validity of estimation results, before running regression model, unit root test was carried out to test the stationery of the panel data. The AR process is:

$$Y_{it-1} = p_i y_{it} - 1 + x_{it}' \delta_i + u_{it}, i = 1,2, \dots, N; t = 1,2, \dots, T_i \quad (15)$$

where X_{it} is an exogenous vector, which is involved not only the fixed influence of individual interface, but also the time trend of fixed influences. N refers to the numbers of members of the i-th individual interface, T_i refers to the numbers of observations of the i-th interface member, pi refers to the coefficient of auto-regression. If |pi|<1, it is a stationary sequence; if |pi|=1, it is a non-stationary sequence. If the unit root assumption principle was rejected during the test, the overall sequence was considered to be stationery; otherwise it was considered to be non-stationery (Bun and Sarafidis, 2013).

This thesis applied IPS (Im Pesaran & Shin W), ADF (ADF-Fisher Chi-square), PP (PP-Fisher Chi-square) and LLC (Levin, Lin&Chut) to do the unit root test.

Step 3: Spatial Durbin Model

Since this thesis focuses on spatial data relationship, the Spatial Durbin Model applied needed to use a spatial weight matrix to reflect the influence of neighboring factors on the model variables in a given city. A spatial weights matrix quantifies the spatial relationships that exist within the data. Different conceptualizations of spatial weights, including fixed distance, k-nearest neighbors, and contiguity, exist. This thesis used binary Queen Contiguity matrix, where 1 refers to a situation when a spatial unit (in this thesis a city) i is adjacent to another city j, and 0 otherwise. Conceptually the matrix has zeros in its diagonal. A row-standardized spatial Queen Contiguity weight matrix, with rows summing to 1, constructed between cities with contiguous borders and edges was used (Anselin, 2005).

Binary contiguity matrix is given as:

$$Wij = \frac{1}{0} \quad (16)$$

Where 1 refers to i is adjacent to j, 0 refers to i is not adjacent to j; i, j= [1, n], i and j the id, and n refers to the total amount of spatial units.

Panel data analysis, using Spatial Durbin Model, proceeded as follows in Stata: first, the thesis analysed the impact of competition relations on urban economic development and examined whether competition relationships have significant effect on urban economic development; and second, the thesis analysed the impact of complementary relationships on urban economic development and tested whether there was a significant effect of complementary relations on the quality of urban economic development.

Chapter 4: Research findings

This chapter presents research findings of three sub-questions explored in the thesis. First, the influencing paths of intercity relationships on urban economic development were researched based on economic spatial distribution, urban economic network, and industrial division of labour. Second, based on D-S model, intercity competitive and complementary relationships were measured in terms of three sectors of industries. In the third part, the impacts of intercity competition and complementarity were examined using Spatial Durbin Model in Stata.

4.1 Influencing paths of intercity relationships on urban economic development

4.1.1 Economic spatial distribution

Tobler's First Law of Geography believes that geographical attributes are related to each other in spatial distribution (Miller, 2004). With, per capita gross domestics product (PGDP) widely used in the study of national and regional economic development, this section considered PGDP as the main economic indicator to analyse economic spatial aggregation and diffusion effects of GBA. The thesis applied global and local spatial autocorrelation analysis in ArcGIS and GeoDa softwares.

a. Global Moran's *I*

To get a more convincing result, district-level data was applied in Moran's *I* analysis. Available data on PGDP allowed for Moran's *I* analysis for 121 districts in GBA. The thesis calculated global Moran's *I* index of 2005, 2008, 2011, 2013 and 2015 at ArcGIS software. The results are shown in Figure 5 and Figure 6. As is shown in Figure 5, there was a (statistical) significant aggregation phenomenon among cities within GBA. Figure 5 shows the index of global Moran's *I* in 2015 is 0.279 (p = 0.01) – it is positive and far from the expected value E (I) (-0.0333). The thesis therefore rejects the null hypothesis and concludes that the autocorrelation of the observed variable is significant[4].

The trend of the Moran's *I* index increases from 0.176 in 2005 to 0.279 in 2015. It indicates that in these five-year time-horizons, district-level PGDP values of GBA's regions show an upward trend and were positively correlated with each other. The more developed regions, such as Hong Kong and Shenzhen, with relatively high PGDP are concentrated, forming high-high agglomeration; while the less developed regions, such as Jiangmen and Zhaoqing, with relatively low PGDP are also concentrated, forming a low-low agglomeration.

[4] By calculating the p value of the Z statistic and comparing it to the significant level (a) can we decide whether to reject or accept the null hypothesis. Generally, a=0.05 or a=0.1 are taken into consideration. If a=0.05 is taken, then when |Z|>1.96, null hypothesis is rejected, indicating that the spatial autocorrelation of the observations is significant, and the adjacent variables are diverging to |Z|<-1.96 or converging to |Z|>1.96. Otherwise, the null hypothesis is not rejected, indicating that observations don't have significant autocorrelation feature within the research area.

Figure 5 The Moran's *I* index of PGDP in 2015

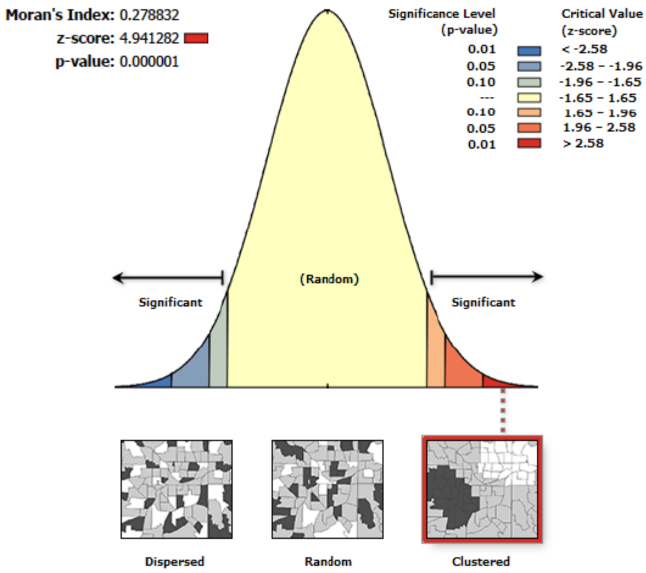
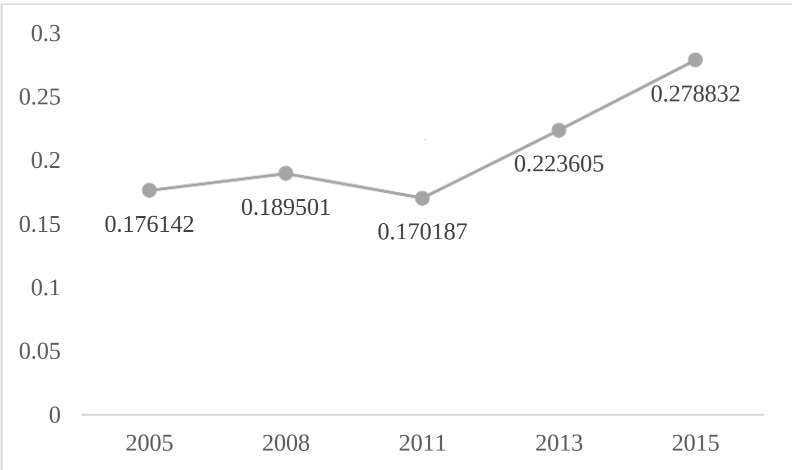


Figure 6 Trends of Moran's *I* index of PGDP from 2005 to 2015



b. Local Moran's *I*

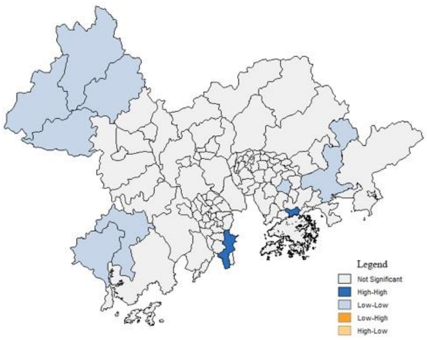
Global Moran's *I* reflects the aggregative effects between geographically adjacent or neighbouring regions, but it does not reveal the specific, localised spatial structure. After examining the global or aggregate economic spatial aggregation phenomenon in GBA, Local Moran's *I* method was applied to measure the concrete spatial distribution of neighbouring units. Conceptually when Local Moran's *I* is greater than 0, it indicates that the economic development level of the observed areas and its surrounding areas is similar, either high-high agglomeration or low-low agglomeration. In the case former case, high-high agglomeration means the economic development level of the observed region is not only more developed, but also has a positive effect on the surrounding areas. Low-low agglomeration means the economic development level of the area is low, it also negatively effects on the surrounding areas. On the contrary, when Local Moran's *I* is less than 0, it indicates that each two adjacent neighbours enjoy different economic development levels. Simply put, they belong to either high-low agglomeration or low-high agglomeration.

Figure 7 shows localised index for spatial autocorrelation (Anselin's LISA maps). The maps show clustering phenomenon in the various years, that is, 2005, 2008, 2011 and 2015. The numbers of areas which show (statistically) significant economic spatial autocorrelation have been increasing. The areas showing high-high agglomeration type are basically located around the Pearl River estuary area, while the areas belonging to the low-low agglomeration are distributed in the western and northern parts of GBA. From 2005 to 2015, in addition to the significant increasing numbers of areas showing high-high agglomeration around the Pearl River estuary area, we can also find that the areas showing low-low agglomeration also increased obviously in the south-west parts of GBA. This also shows the Matthew effect in GBA.

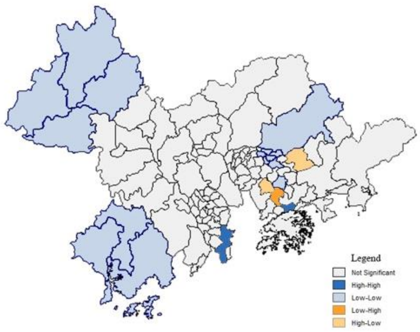
Taking the result of 2015 as an example, cities showing high-high agglomeration mainly include Hong Kong, Shenzhen, Guangzhou and some districts of Zhongshan and Zhuhai. While cities showing low-low agglomeration mainly include Jiangmen, Zhaoqing and the northern part of Huizhou. The trend from 2005 to 2015 reflects the more significant economic aggregation phenomenon among cities within GBA, but the aggregation effect mainly reflects in certain specific areas and their surroundings. Most less economically developed cities have remained relatively backward after ten years of development.

Figure 7 LISA cluster maps of PGDP in 2005, 2008, 2011 and 2015

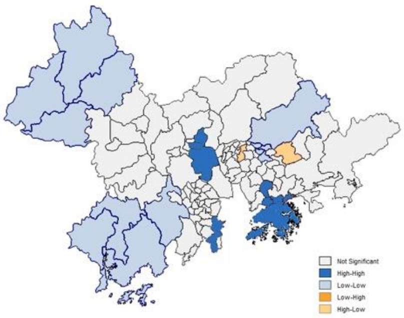
(a) 2005



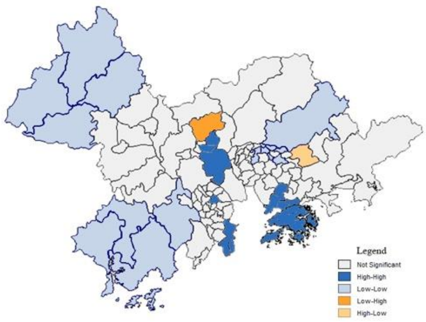
(b) 2008



(c) 2011



(d) 2015



4.1.2 Urban economic network

a. Network density analysis

Based on the detail steps explained for constricting an urban gravity model in Chapter 3, this section calculated economic strength as linkages between any two cities within GBA for 2005, 2008, 2011, 2013 and 2015 in Mathcad. Based on the outcomes, social network analysis was conducted in Ucient. Social network analysis allows the calculation and visualization of economic strength (as linkages) at different years in this case. Table 3 contains the results. The numbers refer to the degree of attractiveness of cities listed in the row to the cities listed in the column in the table.

The following economic linkage strength matrix calculated by urban gravity model was imported into Ucient and Network to generate a visual structure diagram of economic linkage network among cities within GBA. As shown in Figure 8, each node in the networked structure diagram represents each city, and the lines and arrows between each two cities represent economic linkages and directions between cities within GBA. It can be seen from the figure that the urban economic linkage network within GBA is relatively dense, and the economic connected circular network structure has been formed.

Ucient was applied to calculate the network density values of economic linkages among cities within GBA in the five individual years, and the outcomes are given in Table 4. Table 4 shows that economic density among cities within GBA increased from 2.104 in 2005 to 10.634 in 2015, which indicates that cities are more closely linked with each other. With the economic growth of each city, economic connections among cities within GBA are increasingly strong, and economic aggregation phenomenon is more significant.

Table 3 Economic linkages of each two cities of 2005, 2008, 2011, 2013 and 2015

	Hong Kong	Macau	Guangzhou	Shenzhen	Zhuhai	Foshan	Jiangmen	Zhaoqing	Huizhou	Dongguan	Zhongshan
Hong Kong	0/0/0/0/0	0.37/0.21/0.000443/0.000777/0.000708	2.96/3.13/5.75/7.79/9.50	10.9/10.9/19.6/27.2/34.2	0.29/0.15/0.27/0.37/0.47	1.44/1.19/2.13/1.26/3.17	0.41/0.18/0.34/0.42/0.32	0.13/0.06/0.14/0.21/0.57	0.59/0.29/0.64/0.98/1.18	2.25/1.66/2.67/3.46/4.07	0.42/0.28/0.44/0.62/0.72
Macau	4.32/17.32/26.21/29.73/35.84	0/0/0/0/0	4.64/8.99/16.6/20.11/24.50	3.84/7.15/13.2/16.2/20	6.98/6.68/25.51/30.64/37.65	2.98/4.96/2.75/5.64/14.30	2.43/2.23/7.39/8.46/4.58	0.78/0.54/2.73/3.38/3.75	0.99/0.95/3.43/4.29/5.13	2.81/4.37/9.09/10.7/12.6	3.47/3.63/12.86/14.4/17.1
Guangzhou	0.46/5.86/7.19/7.45/8.93	0.08/0.20/0.00035/0.000503/0.000456	0/0/0/0/0	2.3/5.12/7.78/9.6/12	0.081/0.21/0.28/0.32/0.41	5.34/13.35/19.34/9.89/24.80	0.31/0.63/0.91/0.93/0.96	0.12/0.27/0.35/0.63/0.52	0.19/0.41/0.69/0.89/1.07	2.03/4.77/6.13/6.85/7.88	0.30/0.68/1.07/1.26/1.45
Shenzhen	1.82/23.36/28.8/29.87/35.33	0.08/0.18/0.000327/0.000464/0.000409	4.38/5.87/9.14/11.13/13.23	0/0/0/0/0	0.07/0.16/0.23/0.26/0.32	0.89/2.26/3.31/1.69/4.15	0.19/0.39/0.58/0.59/0.43	0.05/0.12/0.59/0.29/0.85	0.31/0.68/1.19/1.51/1.75	1.77/4.00/5.28/5.85/6.59	0.21/0.49/0.78/0.91/1.02
Zhuhai	2.62/15.61/21.03/23.51/28.13	3.65/8.34/0.34/0.01/0.04	4.74/11.03/17.10/15.94/25.23	3.52/7.9/12.2/15/18.5	0/0/0/0/0	2.61/6.17/9.23/5.09/12.63	1.46/2.99/4.49/4.96/2.47	0.03/0.74/1.32/1.74/2.54	0.59/1.29/2.27/2.84/3.35	2.62/5.95/8.46/9.92/11.51	2.38/5.31/8.59/10.64/12.76
Foshan	0.753/6.78/8.78/9.67/11.71	0.16/0.34/0.00391/0.00113/0.00104	18.24/40.21/63.51/79.59/97.31	2.8/5.97/9.28/11.8/14.8	0.15/0.33/0.49/0.61/0.000888	0/0/0/0/0	0.83/1.52/2.26/2.52/2.22	0.27/0.55/0.56/1.45/0.93	0.62/0.61/1.14/1.51/1.82	2.38/5.09/7.02/8.38/9.82	0.62/1.25/2.07/2.62/3.08
Jiangmen	1.27/7.99/10.73/12.11/14.54	0.49/1.14/0.000713/0.00639/0.00605	6.32/14.63/22.83/28.13/34.36	3.59/8.07/12.4/15.5/19.3	0.50/1.24/1.81/2.28/2.91	4.86/11.42/17.25/9.55/24.39	0/0/0/0/0	0.50/1.14/1.18/2.81/1.95	0.54/1.18/2.02/2.72/1.59	2.61/5.95/8.32/9.98/11.85	2.15/4.78/7.69/9.71/11.57
Zhaoqing	1.04/5.66/7.55/8.41/10.14	0.29/0.64/0.00248/0.00352/0.00318	6.16/14.11/21.63/26.28/31.31	2.58/5.75/8.66/10.6/13.2	0.29/0.71/0.94/1.17/1.37	4.22/9.61/14.10/7.54/19.12	1.32/2.65/3.59/3.87/4.42	0/0/0/0/0	0.56/1.17/1.84/2.32/2.62	2.19/4.86/6.65/7.71/8.98	0.80/1.72/2.56/3.05/3.55
Huizhou	1.94/12.22/16.23/17.83/21.41	0.21/0.48/0.00146/0.00202/0.00185	3.97/9.17/14.10/17.79/20.64	6/13.4/20.3/24.8/30.8	0.21/0.52/0.71/0.82/1.02	1.95/4.56/6.69/3.54/8.97	0.57/1.15/1.62/1.75/1.95	0.22/0.50/0.87/1.05/1.27	0/0/0/0/0	3.41/7.67/10.50/11.97/13.94	0.75/1.29/1.97/2.37/2.68
Dongguan	1.28/11.34/15.12/16.61/20.04	0.16/0.36/0.000866/0.00134/0.00125	7.53/17.19/27.72/34.34/42.05	5.86/12.78/20.3/25.5/32	0.166/0.388/0.615/0.755/0.969	2.59/6.11/9.63/5.23/13.43	0.48/0.93/1.55/1.65/1.91	0.15/0.33/0.74/0.93/1.14	0.59/1.24/2.35/3.17/3.83	0/0/0/0/0	0.61/1.31/2.38/2.87/3.38
Zhongshan	1.46/9.44/12.50/13.91/16.81	0.83/1.88/0.00573/0.00849/0.00793	6.84/15.82/24.40/29.74/36.24	4.45/9.93/15.28/18.76/23.34	0.915/2.21/3.14/3.74/4.75	4.11/9.59/14.30/7.68/19.62	2.39/4.79/6.97/7.57/8.78	0.34/0.75/1.36/1.72/2.11	0.62/1.33/2.22/2.87/3.47	3.72/8.36/11.64/13.58/8.33	0/0/0/0/0

Note: Most values are rounded to two digits after the decimal, except for some extreme small values.

Figure 8 Urban economic network structure of GBA

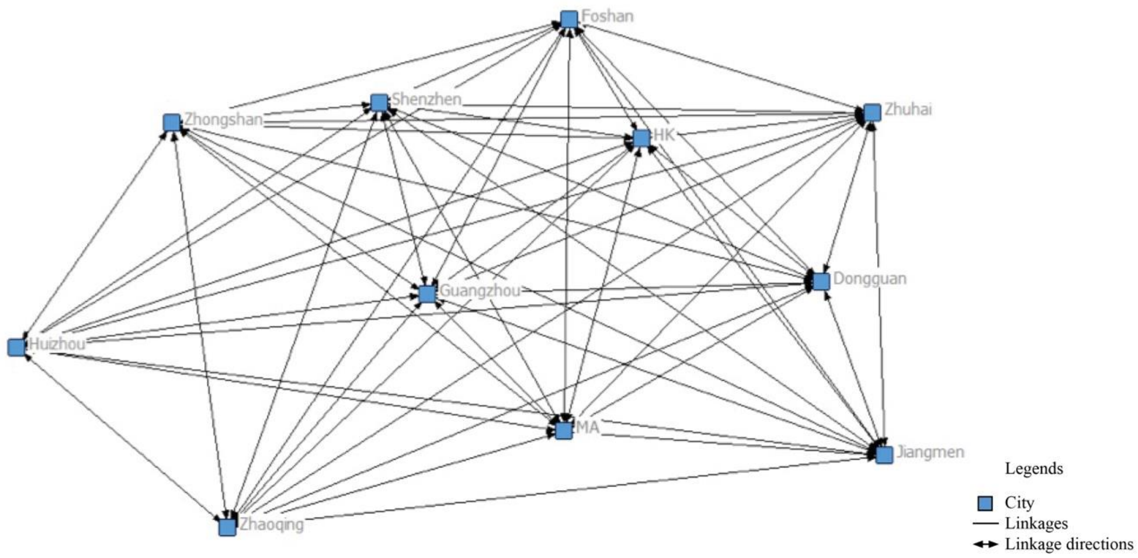


Table 4 Urban economic network density of GBA in 2005, 2008, 2011, 2013 and 2015

Year	2005	2008	2011	2013	2015
Density	2.104	4.932	7.460	8.342	10.635

b. Network centrality analysis (outdegree and indegree)

The economic inter-linkages between cities within an urban agglomeration are not equal, since in a network structure, the economic linkages between cities show directionality. Normally more developed regions are more attractive to other cities than less developed ones. This thesis measured the imbalance between cities by analysing urban centrality, which include outdegree and indegree. While indegree refers to the extent of how a city is easily affected by other cities within the network, outdegree refers to the ability of the city to influence other cities in the network. The values of outdegree and indegree of each city were calculated in Ucient and the outcomes are given in Table 5 and Table 6.

Table 5 Economic centrality degrees (outdegree)

Ranks	Outdegree				
	2005	2008	2011	2013	2015
1	Guangzhou 66.74	Guangzhou 176.34	Guangzhou 222.69	Guangzhou 298.31	Guangzhou 334.1
2	Shenzhen 45.78	Hong Kong 112.34	Hong Kong 154.02	Shenzhen 193.41	Shenzhen 218.1
3	Foshan 30.99	Shenzhen 89.45	Shenzhen 138.92	Hong Kong 181.31	Hong Kong 202.63
4	Dongguan 25.70	Dongguan 53.13	Foshan 98.64	Foshan 123.94	Foshan 144.29
5	Hong Kong 16.96	Foshan 43.45	Dongguan 75.72	Dongguan 89.41	Dongguan 95.4
6	Zhongshan 11.73	Zhongshan 23.45	Zhongshan 39.48	Zhongshan 46.31	Zhongshan 56.47
7	Jiangmen 10.38	Zhuhai 16.48	Zhuhai 33.985	Zhuhai 37.31	Zhuhai 49.82

8	Zhuhai 9.66	Jiangmen 19.31	Jiangmen 21.652	Jiangmen 25.31	Jiangmen 28.04
9	Macau 6.33	Huizhou 13.23	Huizhou 17.691	Huizhou 19.31	Huizhou 25.81
10	Huizhou 5.62	Macau 3.23	Zhaoqing 9.793	Zhaoqing 13.97	Zhaoqing 15.11
11	Zhaoqing 2.59	Zhaoqing 3.12	Macau 0.05	Macau 0.06	Macau 0.07

Note: Rounded to two digits after the decimal.

Table 6 Economic centrality degrees (indegree)

Ranks			Indegree		
	2005	2008	2011	2013	2015
1	Macau 33.24	Macau 89.31	Macau 118.89	Macau 14.31	Macau 175.36
2	Foshan 26.78	Foshan 68.31	Foshan 95.07	Foshan 124.85	Foshan 141.68
3	Zhongshan 25.68	Zhongshan 57.41	Zhongshan 91.69	Zhongshan 116.94	Zhongshan 123.348
4	Zhuhai 24.22	Zhuhai 51.97	Zhuhai 84.62	Zhuhai 93.72	Jiangmen 122.156
5	Jiangmen 22.84	Jiangmen 48.13	Jiangmen 84.12	Jiangmen 91.64	Dongguan 118.53
6	Hong Kong 19.77	Dongguan 39.83	Dongguan 80.19	Dongguan 84.90	Zhuhai 115.764
7	Zhaoqing 19.44	Huizhou 31.39	Huizhou 72.96	Huizhou 81.69	Huizhou 102.592
8	Dongguan 19.36	Zhaoqing 29.18	Zhaoqing 67.50	Zhaoqing 74.48	Zhaoqing 94.643
9	Huizhou 19.23	Hong Kong 23.85	Shenzhen 49.90	Shenzhen 55.13	Shenzhen 63.621
10	Guangzhou 11.22	Guangzhou 19.44	Guangzhou 43.70	Guangzhou 51.78	Guangzhou 58.007
11	Shenzhen 9.71	Shenzhen 19.18	Hong Kong 31.99	Hong Kong 41.49	Hong Kong 54.137

Note: Rounded to two digits after the decimal.

By comparing the numbers of centrality values of five individual years, it can be observed that, although the overall values of outdegree and indegree have changed significantly, the relative positions of most cities remained the same. Macau, Foshan and Zhongshan have had high-level indegree for all five individual years, indicating that the economic performances of these three cities are more easily affected by other cities within GBA. The degree of being affected by other cities of Jiangmen, Zhuhai, Dongguan and Foshan is slightly weaker than the former three cities. The indegree values of Guangzhou, Shenzhen and Hong Kong are lower than those of other cities, indicating that the economic performances of these three cities are less easily influenced by the other cities. It also means that the economic resilience and economic independence of Guangzhou, Shenzhen and Hong Kong is highest among cities within GBA.

In terms of outdegree values, the results of Guangzhou, Shenzhen and Hong Kong are relatively higher compared with other cities. This indicates that these three cities have greater capacity to influence the economic performance of other cities within GBA. In particular, the values of outdegree of Guangzhou are much higher than the other cities for all five individual years. The values of outdegree of Huizhou, Zhaoqing and Macau are lowest in all five individual years. It indicates that their roles in influencing other cities are relatively weak. It also illustrates that these three cities are at the edge or periphery of economic development within GBA compared with others. Even though the PGDP of Macau and Hong Kong are the highest in GBA, due to the prevailing administration and policy situation, the economic communications between these two cities and other Mainland cities in PRD are weak. Unlike Hong Kong, Macau's economy scale is small, thus leading to its weak impact capacity on other cities. This shows that the aggregation effect and diffusion effect within an urban agglomeration are not only determined by cities' economic scales, but also geographical characteristics (Schweitzer, 2003).

We can also find that the core positions of Guangzhou, Shenzhen and Hong Kong are increasingly highlighted. At these five individual years, the values of outdegree of these three cities are leading compared with others. In addition, the gaps in outdegree values are also growing, but the values of indegree have remained low. This shows that the impact capacity of these three cities (Guangzhou, Shenzhen and Hong Kong) on other cities within GBA is significantly greater than that of other cities' impacts on them. This indicates strong diffusion effects of these three cities (Guangzhou, Shenzhen and Hong Kong) on other cities within GBA. Regarding the roles of these three cities (Guangzhou, Shenzhen and Hong Kong) at different geographical scales, Guangzhou is the capital city of Guangdong province, Shenzhen is one of national special economic zones, and Hong Kong is one of global financial centres – they are, thus, the three economic poles of GBA. Through the spill-over effects of endowment factors, such as industrial transformations, technologies, capital, these three cities (Guangzhou, Shenzhen and Hong Kong) promote the economic development of other cities, thereby improving the overall economic performance of GBA.

By calculating the values of economic network centrality, the asymmetry and imbalance of urban economy among cities within GBA can be concluded. The closer the value of centrality is to 1, the stronger the concentration of the network is. As can be seen from Table 7, the value of difference of outdegree value and indegree value within GBA declined slightly from 19.64% in 2005 to 17.95% in 2015. This shows that although the influencing capacity of core cities (Guangzhou, Shenzhen and Hong Kong) is increasing, complementarity relationship among cities is also getting stronger, and the urban spatial network is gradually becoming more balanced.

Table 7 Network centralization trend (%)

Year	2005	2008	2011	2013	2015
Outdegree centralization	27.015%	24.803%	25.653%	25.760%	25.748%
Indegree centralization	7.371%	4.353%	7.672%	8.303%	7.802%
Difference	19.644%	20.450%	17.981%	17.457%	17.946%

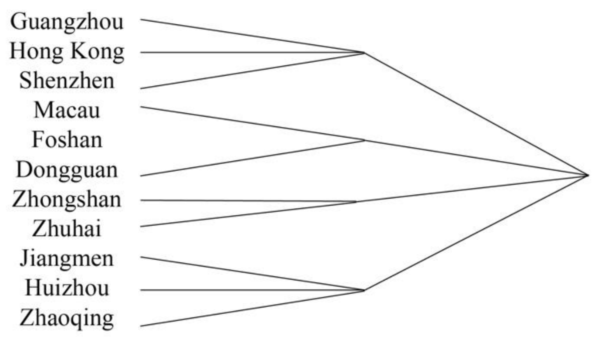
Note: Rounded to three digits after the decimal.

c. Cohesive sub-group analysis

Economic spatial linkages are the basis of the formation and development of spatial structure. Within urban network, according to the degree of connections, cities within an urban agglomeration can be divided into several sub-groups, each of which has close connections. This thesis applied Concor function in Ucient to analyse cohesive sub-group urban spatial structure of GBA. The results of cohesive sub-group of 2005, 2008, 2011, 2013 and 2015 are the same, so only the results of 2015 are shown in Figure 9. As Figure 9 shows, cities in GBA are divided into four sub-groups.

- Guangzhou, Hong Kong and Shenzhen belong to subgroup 1. These three cities are provincial capital city, national special administrative region, and special economic region, respectively. The result (Figure 9) show that the role of city matches the economic status of the city.
- Macau, Foshan and Dongguan belong to sub-group 2, mainly distributed around sub-group 1. Although the PGDP of Macau is the highest among these cities, economic scale is also an important factor in city function within an urban agglomeration.
- Sub-group 3 consists of Zhongshan and Zhuhai. Both of them are located in the west part of GBA, which is also consistent with the fact the east part of GBA develop better than the west part.
- Jiangmen, Huizhou and Zhaoqing belong to sub-group 4. This also explains the research outcome from local Moran's *I* that less economically developed cities are mainly distributed in the outer areas of the urban agglomeration.

Figure 9 Results of cohesive sub-group analysis



4.1.3 Industrial spatial division of labour

1) Macro-level industrial structure analysis

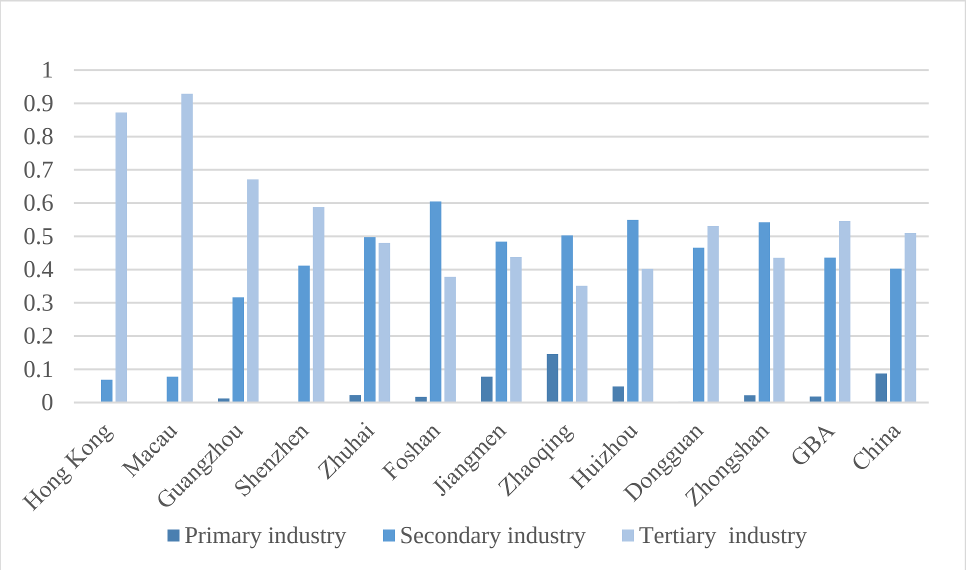
A macro-level industrial comparison of 11 cities, GBA and China was drawn according to the percentages of total industrial production values of three sectors of industries (primary, secondary, and tertiary) to GDP of each in 2015. As can be seen from Figure 10, the industrial structures of Guangzhou, Shenzhen, Hong Kong, Macau, Dongguan and GBA are similar to the one of China, all of which are "tertiary-secondary-primary" structure, while the industrial structures of the rest of the other six cities are "secondary- tertiary-primary" pattern. To be specific, in terms of primary industry, the value of Zhaoqing is the largest (14.64%) among the 11 cities, while the statistics of other 10 cities are less than 10%. There is no agricultural activity in Macau, and the proportions of Shenzhen and Hong Kong are less than 1%, which are 0.3% and 0.6%, respectively.

The secondary industry still accounts for an important economic development proportion in GBA. This is explained by the present PRD's important role in manufacturing in the world as well as due to the rapid urban construction needs, visible industries such as constructions, transportation develop rapidly. The advantages of tertiary industry in GBA are also highlighted.

With the implementation of industrial upgrading policies such as "double-transfer policy[5]" since 2008 and encouragement and guidance from local governments to tertiary industry, the proportions of tertiary industry of Macau, Hong Kong, Guangzhou, Shenzhen and Dongguan exceed national level (50.97%), which are of 92.9%, 87.26%, 67.11%, 58.78% and 53.09%, respectively.

However, the above analysis of industrial relationships at macro level is too broad to distinguish the actual situation of industrial division of labour and structural classification. Within GBA, cities represented by Guangzhou and Shenzhen are in the process of industrial upgrading and service industry deepening, while cities represented by Foshan and Dongguan are in industrialization deepening period and acceleration of service industry, which show similar macro-industrial structure. Regions at the same or similar level of development show great similarities in supply and demand structure, which further lead to similar resource structures, production functions, and demand preferences. Therefore, industrial structure at macro level must have a high degree of similarity. In order to deeply understand industrial relationships among cities within GBA, this thesis further analysed industrial structures based on Chinese industrial classification.

Figure 10 Industrial structures of 11 cities, GBA and China of 2015



Source: author, based on China Yearbook (2016), 2018.

2) Middle-level industrial location structure analysis

Based on the methods explained in chapter three, this section shows the calculating outcomes and outcomes analysis.

a. Industrial location quotient

$$\text{b.}\quad LQ_{ik} = \frac{d_k}{\sum_{k=1}^{n} d_k} \Bigg/ \frac{D_k}{\sum_{k=1}^{n} D_k}$$

where LQ_{ik} refers to industrial location quotient, i refers to city 1,2, 3...,n; k refers to industry 1,2,3,…,k; d_k and D_k represent industrial GDP of a given city and the country (China),

5 Double-transfer policy, implemented since 2008, encourages labour-intensive industries in PRD to transfer to the east and west wings and the mountains areas of northern Guangdong, which creates job opportunities for the locals; while high-skilled labours are encouraged to transfer to PRD.

respectively. According to Chinese industrial classifications, industries are divided into eight categories: agriculture, construction, transportation, warehousing and postal services, wholesale and retail, accommodation and catering, real estate, and other service industries.

Table 8 shows the outcomes of industrial location matrix. The numbers at the table reflect how concentrated a particular industry is in GBA as compared to China. It reveals what makes a particular region unique in comparison to the national average. The higher the location quotient numbers are, the more advantageous the industries are in the specific cities (Isserman, 1977).

Due to space reason, this section only analysed the results of industrial location quotient of 2015. As shown in Table 8, in addition to agriculture, Guangzhou and Shenzhen showed their comparable advantages in the other seven industries within GBA. The value of manufacturing of Hong Kong and Macau is only 0.031 and 0.016, respectively, which was much lower than the average value (0.847) of GBA. This is the consequence of their secondary industry transformation to PRD and other mainland cities. In addition, Zhaoqing's agriculture (1.398), Foshan's manufacturing (1.570), Macau's and Zhuhai's construction (0.933 and 0.861), Guangzhou's and Hong Kong's transportation and storage (1.482 and 1.299), Guangzhou's retail (3.599), Macau's accommodation and food service (2.871), Hong Kong's and Shenzhen's finance (1.842 and 1.755), Hong Kong's, Macau's and Shenzhen's real estate (0.511, 0.489 and 0.446) showed comparable advantages within GBA.

Table 8 Industrial location quotient matrix of 11 cities and GBA

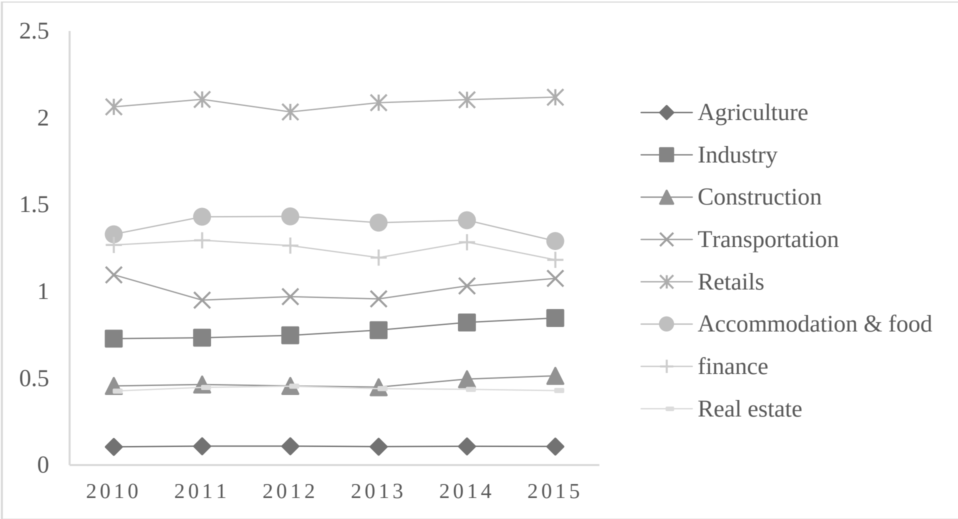
	Agriculture						Manufacturing					
	2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Hong Kong	0.003	0.003	0.003	0.003	0.004	0.004	0.037	0.024	0.037	0.035	0.033	0.031
Macau	0.000	0.000	0.000	0.000	0.000	0.000	0.013	0.011	0.011	0.010	0.011	0.016
Guangzhou	0.101	0.095	0.092	0.086	0.082	0.079	0.822	0.805	0.782	0.786	0.826	0.825
Shenzhen	0.009	0.008	0.007	0.006	0.005	0.006	1.050	1.047	1.024	1.027	1.082	1.109
Zhuhai	0.153	0.150	0.150	0.156	0.157	0.151	1.240	1.224	1.186	1.176	1.229	1.271
Foshan	0.108	0.112	0.115	0.114	0.112	0.108	1.225	1.177	1.248	1.413	1.513	1.570
Jiangmen	0.428	0.438	0.462	0.466	0.508	0.499	1.287	1.258	1.208	1.233	1.261	1.315
Zhaoqing	1.540	1.517	1.440	1.352	1.379	1.398	0.920	0.977	1.048	1.188	1.278	1.359
Huizhou	0.552	0.526	0.492	0.472	0.474	0.494	1.102	1.169	1.226	1.346	1.338	1.483
Dongguan	0.038	0.037	0.037	0.035	0.036	0.035	1.196	1.185	1.167	1.179	1.254	1.303
Zhongshan	0.269	0.265	0.251	0.243	0.251	0.237	1.652	1.359	1.247	1.154	1.166	1.225
GBA	0.105	0.109	0.109	0.106	0.108	0.107	0.728	0.733	0.747	0.777	0.821	0.847
	Construction						**Transportation**					
	2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Hong Kong	0.414	0.459	0.503	0.530	0.601	0.636	1.377	1.211	1.230	1.205	1.301	1.299
Macau	0.521	0.448	0.427	0.395	0.579	0.933	0.478	0.430	0.402	0.371	0.431	0.577
Guangzhou	0.485	0.503	0.474	0.424	0.451	0.443	1.383	1.372	1.438	1.369	1.459	1.482
Shenzhen	0.433	0.433	0.414	0.431	0.413	0.399	0.712	0.690	0.663	0.668	0.671	0.660
Zhuhai	0.514	0.509	0.523	0.662	0.776	0.861	0.419	0.387	0.378	0.418	0.418	0.491
Foshan	0.320	0.314	0.294	0.275	0.301	0.302	1.254	0.430	0.460	0.457	0.643	0.755
Jiangmen	0.362	0.345	0.352	0.341	0.386	0.403	0.811	0.735	0.749	0.787	0.784	0.820
Zhaoqing	0.601	0.559	0.509	0.458	0.442	0.452	0.737	0.638	0.619	0.580	0.659	0.616
Huizhou	0.589	0.594	0.554	0.529	0.573	0.651	0.631	0.648	0.705	0.671	0.847	0.997
Dongguan	0.417	0.393	0.320	0.307	0.472	0.492	0.358	0.459	0.539	0.561	0.680	0.655
Zhongshan	1.053	0.925	0.921	0.844	0.838	0.743	2.094	2.042	2.126	2.362	2.358	1.192

GBA	0.456	0.464	0.456	0.449	0.495	0.514	1.096	0.950	0.970	0.957	1.032	1.075
	Retail						**Accommodation and food**					
	2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Hong Kong	1.754	1.965	1.493	1.802	1.790	1.650	1.359	1.660	1.775	1.789	1.846	1.653
Macau	0.493	0.466	0.489	0.500	0.491	0.532	2.486	2.569	2.536	2.421	2.657	2.871
Guangzhou	3.698	3.657	3.774	3.679	3.599	3.723	1.362	1.405	1.434	1.394	1.420	1.162
Shenzhen	1.119	1.149	1.243	1.208	1.183	1.121	0.999	1.039	0.994	0.973	1.058	1.010
Zhuhai	1.068	1.036	1.028	1.110	1.143	0.991	1.164	1.132	1.157	1.008	1.175	1.093
Foshan	2.567	2.546	2.639	2.539	2.764	2.932	0.954	0.807	0.764	0.785	0.491	0.474
Jiangmen	0.925	0.876	0.857	0.816	0.887	0.823	1.145	1.066	0.989	1.001	0.800	0.752
Zhaoqing	2.708	2.526	2.600	2.508	2.599	2.776	1.705	1.566	1.646	1.624	1.817	1.821
Huizhou	3.135	2.956	2.841	2.753	2.836	2.999	1.458	1.592	1.507	1.457	1.544	1.663
Dongguan	0.971	0.970	0.986	1.091	1.207	1.172	1.657	1.813	1.687	1.469	1.332	1.224
Zhongshan	3.213	3.091	2.932	2.879	3.029	3.169	1.716	1.793	1.747	1.739	1.804	1.795
GBA	2.063	2.106	2.034	2.087	2.104	2.119	1.329	1.430	1.432	1.396	1.410	1.290
	Finance						**Real estate**					
	2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Hong Kong	2.012	2.116	2.131	2.046	2.074	1.842	0.536	0.598	0.621	0.548	0.557	0.511
Macau	0.565	0.527	0.504	0.506	0.576	0.682	0.354	0.243	0.250	0.375	0.438	0.489
Guangzhou	0.882	0.975	0.983	0.951	1.089	0.998	0.410	0.412	0.414	0.461	0.433	0.422
Shenzhen	1.905	1.925	1.814	1.729	1.755	1.586	0.435	0.425	0.461	0.438	0.437	0.446
Zhuhai	0.660	0.718	0.769	0.803	0.804	0.804	0.359	0.385	0.405	0.407	0.403	0.395
Foshan	0.471	0.531	0.526	0.502	0.587	0.474	0.320	0.369	0.345	0.343	0.379	0.392
Jiangmen	0.404	0.510	0.508	0.514	0.710	0.626	0.225	0.262	0.338	0.349	0.280	0.287
Zhaoqing	0.367	0.367	0.360	0.382	0.381	0.827	0.255	0.264	0.169	0.170	0.148	0.135
Huizhou	0.436	0.431	0.414	0.428	0.439	0.428	0.325	0.333	0.316	0.350	0.350	0.340
Dongguan	0.579	0.543	0.544	0.613	0.807	0.710	0.419	0.488	0.507	0.438	0.400	0.421
Zhongshan	0.535	0.511	0.562	0.060	0.648	0.590	0.292	0.350	0.327	0.315	0.306	0.306
GBA	1.268	1.295	1.264	1.195	1.284	1.182	0.426	0.447	0.454	0.440	0.436	0.429

Note: Rounded to three digits after the decimal.

In order to study the changing trend of comparative advantages of GBA from 2010 to 2015, this thesis drew the trend figure of location quotient of GBA (Figure 11) based on the location quotient matrix table. As can be summarized from the Figure 11, the values of location quotient of agriculture, real estate, and manufacturing were always less than 1. The values of agriculture and real estate slightly declined over the years, of which agriculture always accounted for the smallest proportion. The values of finance and accommodation & food service have declined slightly after 2011, but had remained at a relative high level, which were between 1 and 1.5. The values of retail and transportation & storage were at fluctuating upward, with the value of retail accounted for the largest proportion during the six years.

Figure 11 Trends of industrial location quotient of GBA from 2010 to 2015



c. Industrial structure location quotient grey correlation coefficient

As described in Chapter 3, location quotient grey correlation coefficient is calculated using the following equation.

$$\xi_i(k) = \frac{min_i min_k |X_0(\mathrm{k}) - X_i(\mathrm{k})| + \delta max_i max_k |X_0(\mathrm{k}) - X_i(\mathrm{K})|}{|X_0(\mathrm{k}) - X_i(\mathrm{k})| + \delta max_i max_k |X_0(\mathrm{k}) - X_i(\mathrm{K})|}$$

where δ refers to resolution factor, δ= [0,1], and δ=0.5 is generally taken according to previous researches.

Table 9 shows the outcomes of industrial structure location quotient grey correlation coefficient. These outcomes were used for calculating the grey correlation degree at next step.

Table 9 Industrial structure location quotation grey correlation coefficient

	Agriculture						Manufacturing					
	2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Hong Kong	0.891	0.887	0.894	0.887	0.887	0.889	0.491	0.483	0.500	0.472	0.459	0.455
Macau	0.888	0.884	0.891	0.884	0.883	0.885	0.484	0.479	0.492	0.465	0.453	0.451
Guangzhou	0.997	0.986	0.983	0.977	0.969	0.968	0.927	0.893	0.872	0.848	0.835	0.811
Shenzhen	0.897	0.892	0.897	0.889	0.888	0.891	0.838	0.855	0.888	0.893	0.895	0.901
Zhuhai	0.947	0.955	0.957	0.943	0.945	0.950	0.701	0.722	0.762	0.765	0.770	0.765
Foshan	1.000	1.000	0.995	0.993	0.997	1.000	0.711	0.753	0.723	0.623	0.606	0.599
Jiangmen	0.719	0.715	0.713	0.690	0.669	0.678	0.675	0.701	0.748	0.726	0.747	0.735
Zhaoqing	0.364	0.369	0.396	0.391	0.389	0.389	0.966	0.922	0.867	0.757	0.736	0.707
Huizhou	0.649	0.665	0.696	0.686	0.689	0.680	0.795	0.759	0.736	0.658	0.698	0.639
Dongguan	0.926	0.921	0.926	0.920	0.919	0.920	0.729	0.748	0.775	0.763	0.752	0.743
Zhongshan	0.836	0.842	0.861	0.855	0.851	0.864	0.518	0.645	0.724	0.782	0.819	0.799
	Construction						**Transportation**					
	2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Hong Kong	0.954	0.997	0.951	0.909	0.885	0.872	0.746	0.761	0.772	0.763	0.751	0.786
Macau	0.929	0.984	0.969	0.938	0.907	0.663	0.571	0.613	0.606	0.577	0.574	0.623
Guangzhou	0.968	0.957	0.982	0.972	0.950	0.921	0.743	0.662	0.652	0.660	0.655	0.669
Shenzhen	0.976	0.966	0.956	0.979	0.909	0.877	0.682	0.761	0.741	0.735	0.692	0.665
Zhuhai	0.936	0.950	0.930	0.791	0.743	0.704	0.548	0.594	0.596	0.597	0.569	0.585
Foshan	0.860	0.848	0.844	0.822	0.808	0.796	0.841	0.613	0.632	0.616	0.676	0.721

Jiangmen	0.899	0.875	0.895	0.882	0.882	0.881	0.743	0.794	0.799	0.826	0.766	0.764
Zhaoqing	0.852	0.898	0.945	0.991	0.940	0.930	0.697	0.726	0.714	0.680	0.685	0.642
Huizhou	0.862	0.865	0.900	0.910	0.912	0.858	0.639	0.733	0.768	0.737	0.815	0.915
Dongguan	0.957	0.922	0.866	0.850	0.974	0.974	0.527	0.627	0.670	0.669	0.697	0.663
Zhongshan	0.579	0.642	0.653	0.670	0.702	0.783	0.452	0.430	0.430	0.362	0.379	0.334
GBA	0.954	0.997	0.951	0.909	0.885	0.872	0.746	0.761	0.772	0.763	0.751	0.786
	Retail						**Accommodation and food**					
	2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Hong Kong	0.728	0.856	0.618	0.738	0.721	0.638	0.968	0.783	0.718	0.671	0.650	0.694
Macau	0.343	0.334	0.361	0.335	0.334	0.342	0.415	0.419	0.442	0.438	0.393	0.342
Guangzhou	0.334	0.347	0.334	0.334	0.351	0.339	0.964	0.973	1.000	1.000	0.990	0.866
Shenzhen	0.465	0.462	0.525	0.476	0.468	0.452	0.714	0.679	0.667	0.654	0.697	0.746
Zhuhai	0.452	0.435	0.465	0.450	0.457	0.422	0.835	0.735	0.762	0.674	0.776	0.807
Foshan	0.620	0.652	0.591	0.639	0.551	0.503	0.687	0.570	0.567	0.567	0.468	0.502
Jiangmen	0.419	0.401	0.426	0.386	0.399	0.388	0.819	0.694	0.664	0.670	0.570	0.605
Zhaoqing	0.560	0.663	0.607	0.655	0.620	0.556	0.687	0.860	0.804	0.779	0.665	0.608
Huizhou	0.434	0.492	0.520	0.545	0.525	0.483	0.867	0.838	0.922	0.931	0.858	0.689
Dongguan	0.429	0.420	0.455	0.445	0.474	0.465	0.716	0.683	0.775	0.917	0.914	0.926
Zhongshan	0.417	0.456	0.493	0.502	0.466	0.439	0.680	0.695	0.735	0.700	0.672	0.620
	Finance						**Real estate**					
	2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Hong Kong	0.525	0.501	0.502	0.484	0.506	0.555	0.884	0.846	0.841	0.882	0.871	0.911
Macau	0.539	0.517	0.535	0.537	0.533	0.622	0.922	0.803	0.812	0.926	0.999	0.933
Guangzhou	0.681	0.721	0.757	0.767	0.807	0.818	0.983	0.962	0.959	0.976	0.998	0.992
Shenzhen	0.564	0.567	0.614	0.600	0.632	0.671	0.992	0.977	0.994	0.999	1.000	0.981
Zhuhai	0.575	0.588	0.639	0.671	0.628	0.686	0.927	0.933	0.950	0.962	0.962	0.961
Foshan	0.508	0.519	0.542	0.536	0.537	0.538	0.887	0.916	0.891	0.893	0.935	0.958
Jiangmen	0.488	0.512	0.536	0.540	0.585	0.597	0.805	0.819	0.885	0.899	0.839	0.853
Zhaoqing	0.477	0.470	0.491	0.496	0.472	0.699	0.830	0.820	0.755	0.748	0.738	0.737
Huizhou	0.497	0.488	0.507	0.510	0.489	0.522	0.892	0.881	0.865	0.900	0.905	0.902
Dongguan	0.544	0.523	0.548	0.579	0.629	0.636	0.995	0.955	0.945	1.000	0.959	0.991
Zhongshan	0.529	0.512	0.554	0.413	0.560	0.582	0.862	0.897	0.875	0.866	0.863	0.871
GBA	0.525	0.501	0.502	0.484	0.506	0.555	0.884	0.846	0.841	0.882	0.871	0.911

Note: Rounded to three digits after the decimal.

d. Grey correlation degree

As described in Chapter 3, based on the outcomes of industrial structure location quotient grey correlation coefficient in Table 9, grey correlation degree is calculated using the following equation.

$$R_i = \frac{1}{n}\sum_{k=1}^{n} \xi_i(k)$$

According to this model, the similarities of the industrial structure among cities, which leads to intercity competition, can be measured. The results of grey correlation degree of city and industry are shown in Table 10 and Table 11. Based on Table 10 and Table 11, trends of grey correlation degree of each city and each industry from 2010 to 2015 were drawn (see, Figure

12 and Figure 13). The number ranges from 0 to 1. The closer the values are to 1, the more similar industrial development levels are.

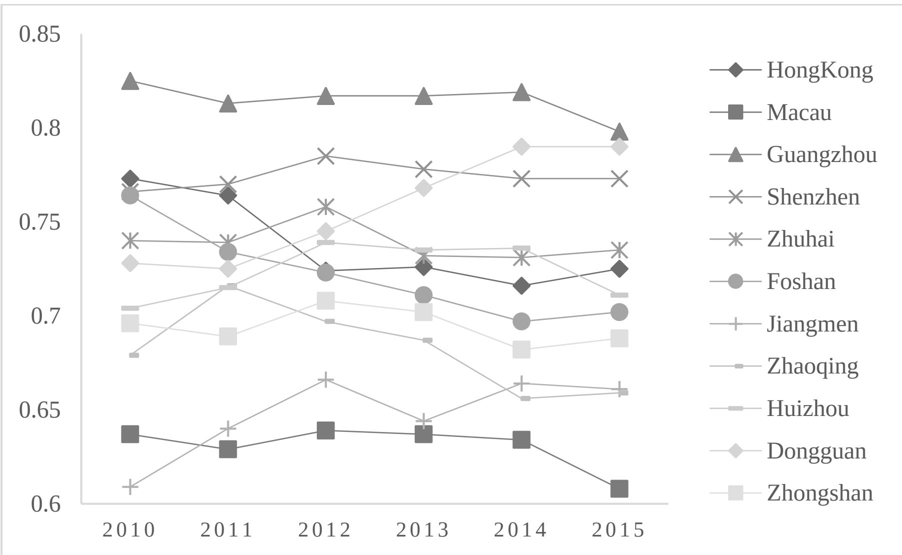
Taking GBA as reference, the descending order of grey correlation degree of industrial structure of each city (Table 10) in 2010 was Guangzhou, Hong Kong, Shenzhen, Foshan, Zhuhai, Dongguan, Zhaoqing, Jiangmen, Huizhou, Macau and Zhongshan, while in 2015 it was Guangzhou, Dongguan, Shenzhen, Zhuhai, Hong Kong, Huizhou, Foshan, Jiangmen, Zhongshan, Zhaoqing and Macau. The values of grey correlation degree of industrial structure at these two time periods (2010 and 2015) was between 0.609 and 0.825, and between 0.608 and 0.78, respectively. The values are concentrated, indicating that although geographical characteristics of industrial structures of cities existed, the industrial structural differences among cities were not obvious. When different cities provide similar functions, intercity competitive relationship appears.

Table 10 Grey correlation degree of each city from 2010 to 2015

	2010	2011	2012	2013	2014	2015
Hong Kong	0.773	0.764	0.724	0.726	0.716	0.725
Macau	0.637	0.629	0.639	0.637	0.634	0.608
Guangzhou	0.825	0.813	0.817	0.817	0.819	0.798
Shenzhen	0.766	0.770	0.785	0.778	0.773	0.773
Zhuhai	0.740	0.739	0.758	0.732	0.731	0.735
Foshan	0.764	0.734	0.723	0.711	0.697	0.702
Jiangmen	0.696	0.689	0.708	0.702	0.682	0.688
Zhaoqing	0.679	0.716	0.697	0.687	0.656	0.659
Huizhou	0.704	0.715	0.739	0.735	0.736	0.711
Dongguan	0.728	0.725	0.745	0.768	0.790	0.790
Zhongshan	0.609	0.640	0.666	0.644	0.664	0.661

Note: Rounded to three digits after the decimal.

Figure 12 Grey correlation degree of each city from 2010 to 2015



In terms of grey degree of industry, in 2015, the industry with highest value of grey correlation degree within GBA was real estate, which was of 0.917. It indicates that these cities focused on developing real estate, which led to industrial similarity and disorder competition in real estate among cities. The values of construction and retails were relatively high, both ranging from 0.8 to 0.9, which indicates that competitions on these two industries were fierce.

Industry, accommodation and food service, as well as transportation and storage shared close values 0.691, 0.673 and 0.67, respectively. The values of grey correlation degree of finance and agriculture were the smallest 0.629 and 0.457, respectively. This indicates that the developing levels of these two industries were relatively greater comparing with other six industries. We observe that financial industry was mainly distributed in Hong Kong and Shenzhen, while agricultural industry was mainly distributed in Zhaoqing.

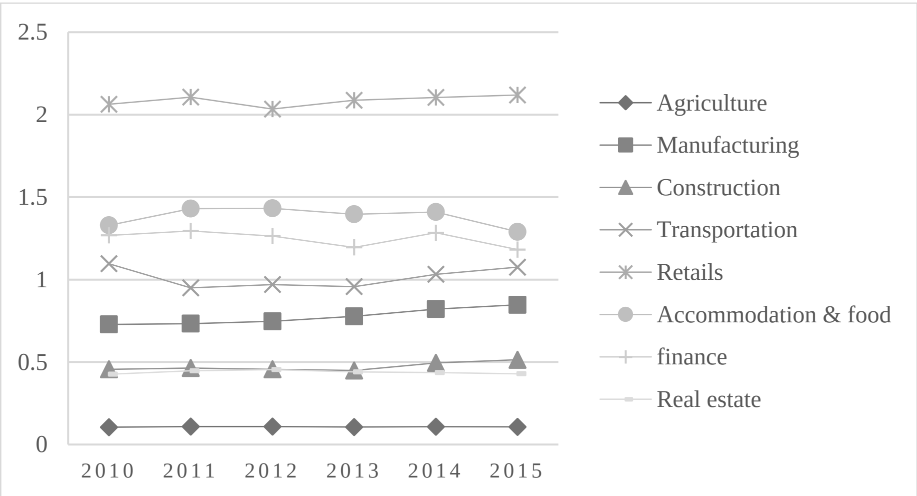
The values of real estate and construction have always been the highest during these six years. The values of real estate grew since 2012, while the values for construction have gradually declined since 2012. The values of them in 2015 were similar to transportation and storage industry, which kept steady increasing. This indicates that developing levels of these three industries were in a balanced state among 11cities, while on the other hand, it shows competitions in these three industries were fierce. The values of accommodation and food service have been decreasing year by year, and it shared similar developing trend with industries. The values of financial industry were on rising trend, growing from 0.539 in 2010 to 0.629 in 2015, indicating that although the developing gaps of finance among cities were getting smaller although still at large level. The values of agriculture, which showed a declining trend, have been the smallest during these six years.

Table 11 Grey correlation degree of each industry from 2010 to 2015

	2010	2011	2012	2013	2014	2015
Agriculture	0.829	0.829	0.837	0.829	0.826	0.829
Industry	0.712	0.724	0.735	0.705	0.706	0.691
Construction	0.888	0.900	0.899	0.883	0.874	0.842
Transportation	0.654	0.665	0.671	0.657	0.660	0.670
Retails	0.473	0.502	0.490	0.500	0.488	0.457
Accommodation and	0.759	0.721	0.732	0.727	0.696	0.673
Finance	0.539	0.538	0.566	0.558	0.580	0.629
Real estate	0.907	0.892	0.888	0.914	0.915	0.917

Note: Rounded to three digits after the decimal.

Figure 13 Grey correlation degree of each industry from 2010 to 2015



Based on the above analysis, we can conclude that:

- The overall comparative advantageous industries of GBA have not changed a lot. Retails, accommodation and food service, and financial industry occupied the largest economic share in GBA, while agriculture and construction accounted for the lowest.

- The results of the grey correlation degree of each city indicates that cities in GBA enjoy a high degree of industries similarity. In addition, the economically more developed cities are more easily to be in competitive relationships with the other cities.
- The grey correlation degree of each industry indicates that cities show a great competitive relationship with each other in terms of real estate, construction, and transportation.

4.2 Dendrinos-Sonis model

This section presents results based on the Dendrinos-Sonis model (D-S model) regarding industrial quantitative competitive and complementary relationships in the GBA.

In the D-S model, the numeraire plays a significant role in the model as it guarantees the sum of the shares of all cities within the urban agglomeration adds to one. It means that in terms of competing for economic share, city's economic growth is dependent on the shares of other cities. As the core city in PRD, Guangzhou's industrial development and transformation process is similar to that of most other cities. Taking Guangzhou as the reference city, this report simulated D-S model based on the data of the added value of three industrial categories, that is, primary, secondary, and tertiary from 2000 to 2016. The results are given in Tables 12, 13 and 14.

The cities listed in the row in each table are the independent variables, while the cities in the column are the dependent variables. A positive coefficient outcome indicates complementary relationships between two observed cities. The growth of economic share of independent city would also increase the economic share of dependent city. On the other hand, a negative coefficient result indicates competitive relationships between two cities. It means the growth of economic share of independent city would lead to the reduction of economic share of dependent city.

4.2.1 D-S model estimation of primary industry

As observed in Table 12, more than three-quarters of the estimated parameters are of the results of D-S model of primary industry are significant under 10% significance level.

Among the cities with a high proportion of primary industry, Zhaoqing, Jiangmen and Huizhou are mostly in a competitive relationship with each other. This indicates that in terms of primary industry, the growth of economic share of any one of these three cities would lead to a decline in the growth of primary industry in the other two cities. This is because as the main agricultural production export cities of GBA, in most cases, they compete against each other for first industrial product market regardless of the benefits of other two cities. In addition to their own inner city's demand for agricultural products, these cities also mainly supply their agricultural produce to cities with under supply of primary industry, especially those who are geographically adjacent. To be specific, Huizhou's agricultural products are mainly supplied to Hong Kong; Shenzhen and Dongguan, Zhaoqing's agricultural products are mainly exported to Guangzhou and Foshan, while Jiangmen's are mainly supplied to Zhuhai and Zhongshan. As detailed in Table 12, there is a positive correlation between agricultural exporting cities and the receiving cities as they mostly cooperative. Back to the D-S model, the increase in economic share of primary industry of agricultural production export cities would also drive the increase in the economic share of the primary industry of agricultural production import cities.

In terms of the other cities, the relationships between Shenzhen, Dongguan, Hong Kong and other cities are more of a competitive relationship. Even if the proportion of primary industry is low in these three cities, the development of primary industry would lead to a decline of economic share of primary industry of other cities, especially those with a high primary industrial proportion. In addition, Guangzhou, Foshan and Zhuhai show a more cooperative relationship with other cities in terms of primary industry.

Table 12 Results of D-S model estimation of primary industry

	Shen zhen	Zhuhai	Foshan	Huizhou	Dongguan	Zhong shan	Jiangmen	Zhaoqing	Hong Kong	Guangzhou
Shenzhen		-5.214 ***	8.301 **	0.983 ***	1.876 ***	-5.621 ***	-5.153 ***	7.861 ***	2.294 ***	3.23 **
Zhuhai	-0.103 ***		-0.929 *	0	-0.209 ***	0.632 ***	0.585 ***	0.869 ***	-0.249 ***	0
Foshan	0.032 ***	-0.127 *		0	0.108 ***	-0.2449 ***	0.249 **	-0.539 ***	0.109 ***	0
Huizhou	-0.312 ***	0	0		-0.042 **	0	0.136 **	-4.514 ***	0	0
Dongguan	0.516 ***	2.868 ***	5.869 ***	0		-2.353 ***	-2.04 ***	0.566 **	1.005 ***	-0.005 ***
Zhongshan	-0.091 ***	0.517 ***	0	0	-0.163 ***		0.5957 ***	0.67 *	-0.246 ***	0.012 **
Jiangmen	-0.111 ***	0.659 ***	-1.351 ***	-1.793 **	-0.174 ***	0.820 ***		-3.002 ***	-0.254 ***	
Zhaoqing	-0.052 ***	0.203 *	-0.774 **	1.219 **	-0.143 ***	0	0		-0.176 ***	0.018 *
Hong Kong	-0.369 ***	2.009 ***	3.04 *	0	0.719 ***	-2.418 ***	2.211 ***	-3.649 ***		-0.004 **

Note: t-statistics in parentheses; ***, **, * represent the outcome is significant under 1%, 5% and 10%. respectively; “0” = not significant in previous regression; the results of Macau were null since there was no primary activity in Macau; The values in the table are rounded to three digits after the decimal.

4.2.2 D-S model estimation of secondary industry

As given in Table 13, half of parameter estimations of D-S model of secondary industry are significant under 10% significance level.

Cities with higher proportions of secondary industry such as Foshan, Dongguan and Zhongshan, are mainly in complementary relationships with most of the other cities in GBA. These means that as these cities are developing their own secondary industry, they also drive the development of secondary industry of other cities. This also indicates that well-organized industrial division of labour has been formed among cities within GBA. This is due to these three cities benefiting mainly from transferred industries from Hong Kong, Guangzhou and Shenzhen in the past 30 years. In addition, the characteristics of secondary industry in these cities are significant and distinctive. For instance, the manufacturing industry of ‘the world factory’ Dongguan and the furniture manufacturing industry and the transportation industry of Foshan are highly competitive throughout South China.

In the past 30 years, due to industrial policies such as “front shop, back factories”, most of Hong Kong’s secondary industry has been transferred to other mainland cities and southeast Asian countries. However, the results show that Hong Kong is still in competitive relationships with most cities in terms of the secondary industry. This is mainly because even if cities in GBA are shifting to the tertiary industry, secondary industry is still the most important industry in most cities in PRD.

In terms of the other cities, Guangzhou and Shenzhen show a more complementary relationship with other cities, while Zhuhai and Jiangmen show a more competitive relationships. Due to the small scale of secondary industry of Macau, it participates less in secondary industrial sectors.

Table 13 Results of D-S model estimation of secondary industry

	Shenzhen	Zhuhai	Foshan	Huizhou	Dongguan	Zhongshan	Jiang-men	Zhaoqi-ng	Hong Kong	Macau	Guangzhou
Shenzhen		-7.487 **	1.837 ***	0	0	0.702 ***	-0.430 ***	0	-0.057 **	0	0.046 ***
Zhuhai	0		0	0	0	0	0	0.613 ***	0	0	0
Foshan	1.523 ***	-4.098 ***		0	0.205 **	1.258 ***	-1.465 ***	0	-0.328 ***	0	0.018 ***
Huizhou	0	0	0.282 ***		0.122 **	0.348 **	-0.669 **	0.256 ***	-0.14 ***	-0.257 **	0
Dongguan	2.017 ***	-3.609 **	0.696 ***	0		1.224 ***	-1.459 ***	-0.489 ***	-0.247 ***	0	0
Zhongshan	0.929 ***	-2.010 ***	0.439 ***	0	0.086 *		-0.875 ***	0	-0.174 ***	0	0.004 ***
Jiangmen	-0.519 ***	0.917 **	-0.181 **	-0.401 ***	0	-0.352 ***		0	0.095 ***	0.211 ***	-0.003 **
Zhaoqing	0	0	0	2.9841 ***	0.354 **		0.759 ***		-0.245 *	0	0
Hong Kong	-3.41 ***	9.663 ***	-2.122 ***	-2.261 **	-0.540 **	-3.119 ***	4.092 ***	0		0	-0.001 ***
Macau	0	2.314**	0	0	0	0	0	0	0		0

Notes: t-statistics in parentheses; ***, **, * represent the outcome is significant under 1%, 5% and 10%, respectively; “0” = not significant in previous regression; Rounded to three digits after the decimal.

4.2.3 D-S model estimation of tertiary industry

Table 14 shows that 69% parameter estimation of the results of D-S model of tertiary industry are significant under 10% significance level.

In terms of tertiary industry, Guangzhou shows a complementary relationship with all the other cities within GBA. First of all, Guangzhou is located in the centre of GBA; its convenient transportation and a large amount of population flows allows it to become the logistics centre of South China. Compared with other cities, it enjoys the highest economic linkages with cities within GBA. In the process of industrial upgrading, its industrial spill-over and diffusion effects simultaneously promote the development of tertiary industry of other cities. Moreover, due to political factors, Guangzhou, as the capital city of Guangdong Province, has taken cities under its administrative units into consideration while developing new industries by adjusting its industrial structure to promote the development of other cities.

Shenzhen, Zhuhai, Foshan and Huizhou show a more competitive relationships than a complementary relationship with most of the other cities in GBA. While each city is committed to developing its tertiary industry, it does not consider whether the industries it develops is in conflict or mutually beneficial with the others. The competition of tertiary industry is fierce among cities within GBA. For example, each city is committed to developing as a financial city, which leads to over-supplementation of financial resources.

Due to political reasons, the tertiary industry of Hong Kong and Macau mainly meets international business. Therefore, despite of the high level of development of tertiary industry, their participation level with other cities in GBA is not high. However, from the perspective of the service market, the division of labour between Hong Kong/Macau and other cities in PRD is clear. What policy needs to guide is to strengthen cooperation between Hong Kong/Macau and other mainland cities.

Table 14 Results of D-S model estimation of tertiary industry

	Shenzhen	Zhuhai	Foshan	Huizhou	Dongguan	Zhongshan	Jiangmen	Zhaoqi-ng	Hong Kong	Macau	Guangzhou
Shenzhen		-1.213 ***	-1.079 **	-1.861 **	-1.138 *	0	-0.912 **	-1.109 **	-3.508 **	0	1.023 ***
Zhuhai	-1.261 **		0	0	0	0	-0.684 *	0	0	0	0.756 ***
Foshan	-1.367 **	-1.019 **		-1.445 *	0	0	-0.784 **	0	0	0	0.788 ***
Huizhou	-1.862 ***	-1.381 ***	-1.224 **		0.549 ***	0.812***	0.413 ***	0.588 ***	1.609 ***	0.334 ***	1.314 ***
Dongguan	-1.556 **	-1.167 **	-0.931 *	-1.700 *		0	-0.938 **	-1.004 *	0	0	0.778 ***
Zhongshan	-1.787 **	-1.33 ***	-1.114 **	-1.973 **	-1.085 *		-1.019 ***	-1.161 **	-3.502 **	0	1.077 ***
Jiangmen	-1.062 *	-0.782 *	0	0	0	0		0	0	0	0.591 ***
Zhaoqing	-1.402 **	-1.042 **	0	-1.498 *	0	0	-0.792 **		0	0	0.816 ***
Hong Kong	1.071 ***	0.792 ***	0.765 ***	1.291 ***	0.798 ***	0.966***	0.598 ***	0.782 ***		0.349 *	2.39 ***
Macau	-1.681 **	-1.25 **	-1.075 **	-1.9301 **	-1.341 **		-0.852 **	-1.072 *	-4.22 **		0.409 ***

Notes: t-statistics in parentheses; ***, **, * represent the outcome is significant under 1%, 5% and 10%, respectively; “0” = not significant in previous regression.

4.3 Impacts of intercity coopetition on urban economic development

This section presents the outcomes of the SDM models.

In the models, because of the incomparability and accessibility of data from Hong Kong and Macau, these two cities were excluded in the analysis. First, for the FDI data used in the competition model, Hong Kong's and Macau's FDI data were too high compared with other cities. The mean value of the percentage of FDI in GDP of Hong Kong was 33.32%, the mean value of the percentage of Macau was 11.34, while values of the other 9 mainland cities were only 5.08%. Including the data of Hong Kong and Macau would have biased the estimated results due to outliers.

Second, for the cargo volume used in complementary models, it consisted of shipping, air, road and rail transport cargo volumes. However, since Hong Kong and Macau are two independent administrative regions compared to mainland China, the road and rail connections between Hong Kong/Macau and other cities are very weak. Thus, the governments do not calculate road and rail volume into total cargo volume. These different methods of estimation and collecting data led to the incomparability of cargo volumes. What's more, due to the fact that PRD as one of the most developed urban agglomerations in China, means a complete industrial chain and industrial division of labour have been formed. Therefore, for these reasons, in this section only PRD's impacts of intercity competition and complementarity on urban economic development were evaluated. In addition, in these models, binary contiguity matrix considering spatial effects was used.

4.3.1 Description of variables

Table 15 shows basic descriptive statistics of model variables used in the regression models.

As shown in the Table 15:

- the average value of PGDP – the dependent variable – within PRD is 64334.49, the standard error is 32448.92, the minimum value is 11890, while the maximum one is 157985. These values show that the economic development gaps among cities are obvious.
- In terms of percentage of FDI in GDP, the average value is 5.08557%, the minimum value is 2.205 %, and the maximum value is 7.29984%.
- When it comes to variables used as proxies for intercity complementarity, in order to reduce weight-induced errors or size effects, the percentage of cargo volume in GDP of each city was used instead of the total amounts of cargo volumes. In terms of the percentage of cargo volume in GDP, the mean value is 5.527%, the minimum value is 2.351%, while the maximum value is 5.992%.
- In addition, the average values of control variables, that is, urbanization rate, employment rate and Engel coefficient are 76.559%, 97.865%, and 63.114%, respectively. Since the Engel coefficient is inversely proportional to the level of urban economic development, the value of "1-Engel coefficient" is used in the model.

Table 15 Description of variables

Variable	Mean	Std. Dev.	Min	Max	Unit
PGDP	64334	32448	11890	157985	RMB/person
Percentage of FDI in GDP	5.086	4.134	2.205	7.299	%
Percentage of cargo volume in GDP	5.527	4.810	2.352	5.992	%
Employment rate	97.861	0.424	97.200	98.980	%
Urbanization rate	76.560	16.907	38.990	98.400	%
1-Engel coefficient	63.114	3.778	52.595	72.276	%

Note: Rounded to three digits after the decimal.

4.3.2 Unit root test

In order to avoid spurious regression and ensure the validity of estimation results, this thesis applied unit root test to test the stationarity of each panel data sequence before regression analysis. The methods applied for unit root test include IPS (Im Pesaran & Shin W), ADF (ADF-Fisger Chi-square), PP (PP-Fisher Chi-square) and LLC(Levin, Lin&Chut). The results are given in Table 16.

Table 16 Results of unit root test

Variable	IPS (Im Pesaran & Shin W)	ADF (ADF-Fisger Chi-square)	PP (PP-Fisher Chi-square)	LLC (Levin, Lin&Chut)
lnPGDP	-1.702 **	117.346 ***	37.013 ***	-2.621 ***
lnPercentage of FDI in GDP	1.927	87.203 ***	61.601 ***	-3.682 ***
lnPercentage of cargo volume in total population	0.513	108.804 ***	452.573 ***	-48.625***
Employment rate	-3.831***	183.292 ***	186.448 ***	-5.487 ***
Urbanization rate	-12.290***	158.165 ***	48.247 ***	-27.707***
1-Engel coefficient	-1.359 ***	183.400 ***	73.231 ***	-9.049 ***

Note: Note: Rounded to three digits after the decimal.; ***, **, * represent the outcome is significant under 1%, 5% and 10%, respectively.

Although the outcomes of stationarity of the unit sequence are not totally the same under different unit root test methods, each sequence has at least one stable situation. So, it can be considered that the variables are stationary, and they meet the requirements of panel data regression.

4.3.3 Impacts of intercity competition on urban economic development

1) Hausman test

Before running model, Hausman test was performed. As the results given in Table 17 show, the chi-square statistic of the test is 14.01 (p value= 0.007) is statistically significant. This means that the null hypothesis stating that the random effect is unrelated to the explanatory variable is rejected. That is, the test results of fixed-effect are more convincing than that of random-effect.

2) Panel data regression analysis

The fixed-effect of Spatial Durbin Model consists of time fixed-effect, spatial fixed-effect, and spatial and time fixed-effects. These three types of fixed-effects were estimated in Stata, and the estimated results shown in Table 17.

Table 17 Outcomes of impacts of intercity competition on urban economic development

Variable	Spatial fixed-effects	Time fixed-effects	Spatial and time fixed-effects
Percentage of FDI in GDP	0.0644**	0.230	0.039**
Employment rate	0.055	-0.067	0.033
Urbanization rate	0.003	0.017***	-0.0004
Engel	0.017*	0.016**	0.017**
Percentage of FDI in GDP_lag	-0.015	-0.257***	-0.049*
Employment rate_lag	-0.410***	0.030	-0.340***
Urbanization rate_;ag	0.014***	0.009**	0.007
Engel_lag	0.011**	0.020	-0.001
rho	0.764***	-0.610***	0.052
$Sigma^2$_e	0.003***	0.012***	0.003***

R^2	0.883	0.169	0.479
Hausman test		14.01 (*p*=0.0073)	

Note: Note: Rounded to three digits after the decimal.; ***, **, * represent the outcome is significant under 1%, 5% and 10%, respectively.

As can be seen from Table 17, the regression coefficient of the percentage of FDI in GDP is positive, and significant under 5% in both spatial fixed-effects and spatial and time fixed-effects. It indicates the increase of FDI in GDP in city i will promote the urban economic development of city i. Meanwhile, the regression coefficient of the lag variable of the percentage of FDI in GDP is negative and under 1% and 10% significance test in time fixed-effect and spatial fixed-effect, respectively. These results suggest that an increase of FDI in city i will hinder the economic development of the geographically adjacent cities.

In terms of the other control variables, the regression coefficient of urbanization rate is positive and significant (under 5%) in time fixed-effects model, while the regression coefficient of the lag of urbanization rate is positive and significant (under 1% in both cases) in spatial fixed-effects and spatial and time fixed-effects models. It means that as labour flows from rural to urban areas, it contributes to urban economic development of both the city itself and the surrounding cities.

Engel coefficient is statistically significant (albeit differently) in all three types of fixed-effects, while the lag of Engel coefficient is significant (under 5%) spatial fixed-effects model. Since the Engel coefficient data has been transformed essed by '1-', the results show that it is positively related to the urban economic development. That is, the improvement of urban residents' consumption level is conducive to the urban economic development.

The employment rate is statistically insignificant in all three significant test, while its lag (of employment rate) is negative and significant (under 1%) in spatial fixed-effects and spatial and time fixed-effects models. These results indicate that an increase of employment rate of city i will impact negatively the urban economic development trajectory of its surrounding cities. The results of the impacts of these three control variables (urbanization rate, employment rate, and Engel coefficient) used in the model are consistent with existing research's conclusions (see, for example, Ming-xing, Chao, et al., 2011; Domar, 1946, Gao; Wailes, et al., 1996).

4.3.4 Impacts of intercity complementarity on urban economic development

The same methods for measuring the impacts of intercity were processed for measuring the impacts of intercity complementarity.

1) Hausman test

Hausman test was performed to test the stationary of the data before regression analysis. As the results given in Table 18 show, the chi-square statistic of the test is 20.23 and significant (*p* value = 0.000). It indicates that the test results of fixed-effect are more convinced than that of random-effect.

2) Panel data regression analysis

Time fixed-effect, spatial fixed-effect, and spatial and time fixed-effects were estimated in Stata, and the estimated results shown in Table 18.

Table 18 Outcomes of impacts of intercity complementarity on urban economic development

Variable	Spatial fixed-effects	Time fixed-effects	Spatial and time fixed-effects
Percentage of cargo volume in GDP	0.954**	0.200**	0.115***
Employment rate	0.054	-0.033	-0.002
Urbanization rate	0.004**	0.019***	0.003
Engel	0.017**	0.013**	0.016**

Percentage of cargo volume in GDP_lag	0.106	0.081	0.182***
Employment rate_lag	-0.452***	-0.081	-0.463***
Urbanization rate_;ag	0.014***	0.016**	0.009***
Engel_lag	-0.133**	-0.008	-0.005
rho	0.719***	-0.762***	-0.091
$Sigma^2$_e	0.003***	0.020***	0.002***
R^2	0.897	0.486	0.719
Hausman test		20.23 (*p*=0.0004)	

Note: Note: Rounded to three digits after the decimal.; ***, **, * represent the outcome is significant under 1%, 5% and 10%, respectively.

As can be seen from Table 18, the regression coefficient of the percentage of cargo volume in GDP is positive and significant (under 5%) in spatial fixed-effect, and equally significant (under 1%) in both time fixed-effects, and spatial and time fixed-effects models. These results mean that the increase of cargo volume in city i will contribute to urban economic development of city i. Meanwhile, the estimated coefficients of the lag of the percentage of cargo volume in GDP is also positive and significant (under 1%) in spatial and time fixed-effects model. This indicates that the increase of cargo volume in city i will also contribute to urban economic development of the geographically adjacent cities.

In addition, the regression results in Table 17 and Table 18 in terms of the control variables are similar. These results are in line with theoretical expectations and existing empirical findings as noted in section 4.3.3 above.

Chapter 5: Conclusions and recommendations

This chapter presents the conclusions of the study, policy recommendations as well as possible avenues for further study.

5.1 Introduction

Urban agglomerations play an increasingly significant role in the process of regional and national participation in international labour division and competition. As the results of regression analysis in Chapter 4 show (section 4.3.3 and 4.3.4), intercity relationships within urban agglomeration has significant impacts on urban economic development of each city. In turn, determining the level of competitiveness of urban agglomeration. Over the years, due to significant policy changes (e.g., Chinese reform and opening policies, Double-transfer policy in Guangdong), GBA's spatial structure has been changed from core-edge structure to multi-core network structure, accompanied with the transformation of labour division, urban functions and changing intercity competitive and complementary relationships among its cities.

This thesis took GBA as a case to clarify the characteristics of urban relationships and their impacts on urban economic development. Based on the conceptual framework in Chapter 2, this thesis explored three aspects.

- First, it measured and analyzed the influencing paths of intercity relationships on urban economic which were based on urban aggregation and diffusion effects, urban economic network and industrial division of labour.
- Second, it then judged intercity relationship as either competition or complementarity according to the quantitative outcomes of the relationships of three industrial sectors.
- Finally, this thesis tested and evaluated the impacts of intercity competition on urban economic development.

Based on the results explained in Chapter 4, the rest of this chapter reviews the research questions and research objectives, and thereby proposes recommendations.

5.2 Interpretation of the main research question

Based on a synthesis of results in Chapter 4, answers to the three sub-research questions could be summarized as follows:

5.2.1 Economic spatial distribution

Based on the research results of economic spatial distribution, we can conclude that the economic spatial pattern within GBA is concentrated. The Global Moran's *I* index rose from 0.176 in 2005 to 0.279 in 2015. However, the outcomes of Local Moran's *I* indicates that the imbalance of economic development within GBA is obvious. It can be seen from LISA maps that the economically-developed regions are concentrated around the estuary of the Pearl River, with a tendency to expand to the surrounding areas. Economically less developed areas gather in the northern and eastern parts of GBA. This also indicates that the aggregation effect of the core cities is stronger than the diffusion effect.

5.2.2 Urban economic network

Based on the research results on the urban economic network conducted by social network analysis method, we can conclude that the economic spatial structure of GBA has gradually changed from a hierarchical structure to a multi-polar centre network. To be specific, the core cities of GBA have changed from Hong Kong and Macau to Hong Kong, Guangzhou, Shenzhen and Macau. All the numerical values of economic linkages between any two cities, calculated by urban gravity model, are increasing yearly. This indicates that the cooperative relationship among cities is constantly improving, and the urban economic linkages tend to be spatially balanced.

Meanwhile, calculated results on network centrality show that network centralization trend has slightly declined from 19.65% in 2005 to 17.95% in 2015. This indicates that, although the core cities' superior positions within GBA are still obvious, the other cities also play constantly more significant roles within the urban network. However, the results of cohesive sub-group analysis show that the urban economic network still relies too much on the diffusion effects and the betweenness functions of the core cities.

5.2.3 Industrial division of labour

The calculation of industrial location quotient indicates that retails, accommodation and food service, and financial industries contribute the largest economic share in GBA, while agriculture and construction industries accounted for the lowest. The outcomes of the grey correlation degree of each city shows that Guangzhou, Shenzhen and Dongguan enjoy a more competitive relationship with other cities, which is caused by their large economic might. The results of the grey correlation degree of industry indicate that in terms of eight sectors of industries, cities show a great competitive relationship with each other in real estate, construction, and transportation/storage industries.

5.2.4 Intercity quantitative competitive and complementary relationships

Intercity relationship is defined as being either competitive or complementary. Combined with D-S model, by using SUR method and taking Guangzhou as the reference city, this thesis measured the competitive or complementary relationships of three sectors of industries among cities. Based on the outcomes of intercity industrial relationships, the following conclusions on intercity relationships can be drawn:

- Cities with similar industrial comparative advantages are more likely to have a competitive relationship, while cities that enjoy a 'supplement-demands' relationships tend to complement each other. In terms of primary industry, the main agricultural product export cities (i.e., Zhaoqing, Jiangmen and Huizhou) compete with each other. At the same time, these three cities enjoy a complementary relationship with agricultural product import cities, such as Guangzhou and Shenzhen. Cities with more developed secondary industry, such as Dongguan, Foshan and Zhongshan, show more complementary relationships with other cities. When these cities develop their own secondary industry, they also drive the development of secondary industry of the surrounding cities. When it comes to the tertiary industry, cities show a fierce competitive relationship. In recent years, each city has implemented industrial upgrading policies and focuses on developing tertiary industry. This has resulted in industrial homogeneity among cities. Overall, the division of labour in primary industry and secondary industry among cities is clear, while the contradiction of the division of labour in tertiary industry exits obviously.
- When it comes to the core cities in GBA, Guangzhou shows a strong diffusion effect on the other cities, while Shenzhen does not. It can be observed from the results that there are industrial synergies between Guangzhou and most other cities. However, Shenzhen only shows a complementary relationship with other cities in terms of secondary industry. Especially, when it comes to the tertiary industry, Shenzhen shows competitive relationship with all the other cities except for Hong Kong. Strengthening the aggregative effects of the core cities plays a significant role in the development of urban agglomeration. But excessive unequal policy support, which neglects the development of the other regions, will perform a negative impacting role on the urban cluster in the long term. The complementary relationships between Hong Kong/Macau and the mainland cities in PRD is weak. Due to the political and economic institutional reasons, these three independent

market systems differ from each other in in terms of economic, administrative, fiscal and currency systems. As two relatively independent economies, the complementary relationship between Hong Kong/Macau and the other 9 mainland cities from PRD is much weaker than that between cities from PRD and other mainland cities. Although various policies have been proposed in promoting collaboration between Hong Kong/Macau and PRD, rigid institutional constraints and administrative differences are still the major obstacles to the cooperation bottlenecks and the slow progress of cooperation policies.

5.2.5 Impacts of intercity relationships on urban economic development

Based on the Spatial Durbin Model regression results, intercity competition and intercity complementarity, we can conclude that to an extent, intercity competitive relationship has a positive effect on local urban economic development. However, the spill-over effect on the economic development of the other cities is negative. That is, excessive intercity competition will limit the economic development of other cities. Results also show that intercity complementary relationship has a positive effect on both the local economic development and the economic development of other cities. The spill-over effect on the other cities is positive. In addition, residents' consumption level, urbanization level and employment rates also affect urban economic development to varying degrees, albeit in different ways.

5.3 Policy recommendations

With the advancement of marketization, globalization and informationization, the spatial mobility and flows of production factors has been greatly enhanced. When each city formulates its own development strategies, it should take complementary and synergistic needs of external regions into consideration, thereby jointly contributing to city economies and regional competitiveness. In terms of industrial division of labour, urban network, participation entitiesand regional cooperation, four recommendations in terms of improving regional integration of GBA are proposed.

5.3.1 To establish a regional management mechanism and to construct a high-value industrial chain spatial supporting system

The phenomenon of urban competition is essentially a resource allocation mechanism and process. Presently, different cities within GBA develop their production preferences according to the principle of maximizing their respective economic benefits. It results in a dynamic regional division of labour. Cities continue to adapt their industrial structure to cope with changing intercity competition. The establishment of the dynamic industrial division of labour requires political and social foundation. The lack of rational social foundation would lead to conflicts between urban competition and industrial division of labour, which would result in industrial structural contradictions. Intercity competition within urban agglomeration would be disorder and unequal without rational and necessary social foundation (Stockwell, Kirchner, et al., 1997). With the development of economic globalization and the integration of regional division of labour, the developing modes, which are defined by urban administrative regions, have faced great challenges.

The solution lies in formulating, policies that focus on resolving industrial structure contradictions and industrial conflicts of GBA and rebuild regional governance mechanisms on the basis of treating the GBA as one geographic, economically functioning unit. Under the regional governance system, each city will play its advantageous role during intercity complementarity. For example, Hong Kong and Shenzhen would play their roles in financial service industry in terms of different service geographical areas. Foshan and Dongguan would play their roles in manufacturing.

5.3.2 To establish a mutual benefit sharing and compensation mechanism

The mutual benefits relationship among cities within urban agglomeration is the basic point of intercity competition as well as the driving force of intercity complementarity. However, the distinguished differences in terms of economic development levels, advantageous industries, and resource endowment among cities, have led to a lack of interest sharing and compensation mechanisms among cities. It is also one of the bottlenecks for intercity coordinated development. After more than 20-year integration of GBA, even though a multi-core networks has gradually formed, Hong Kong, Guangzhou and Shenzhen, as the core cities still have much stronger control and influence capacities in terms of industries, traffic, talents and other economic development factors.

As economic and social structural systems within GBA are being reconstructed, the advantageous cities further develop and expand their market shares by relying on their own advantages. This way, cities, which are less developed, may have to abandon their original advantageous industries and reconsider their city positions within the urban agglomeration. Under this situation, the benefits would flow to the advantageous cities, while the interest of disadvantageous cities would be damaged. In this way, during complementing, dominant cities would need to compensate inferior cities, so that cities within GBA can benefit through mutual cooperation.

Without mutual cooperation damage to region-wide interest would suffer. On one hand, the regional compensation mechanism is a process of realizing the interest transfers and distribution. It is realized by governments on the basis of equality and collaboration(Cernea, 2007). On the other hand, the benefit sharing mechanism includes the means, contents, standards and implementation system of benefit compensation among cities. The key for intercity complementary relationships among cities is to achieve a win-win situation for all cities by creating a distribution system that balance the intercity benefits (Capello, 2009).

5.3.3 To implement a cooperative incentive system

An incentive system plays a guiding and guaranteeing role in social order and stable development. The key for cooperation among cities is to design an intensive system that breaks through the boundaries of urban administrative regions and overcomes self-interest-centered developing strategies. Institutional innovation can effectively alleviate the counter-motivation of intercity cooperation and avoid vicious competition. Presently, due to the role of industrial chain and market chain, cities within GBA have formed a highly functional inter-related economy. However, the existence of two different social and economic systems still cause various obstacles between Hong Kong/ Macau and cities in PRD. The economic linkages and complementarity among cities within GBA should break through the boundary restrictions of administrative regions to establish multiple-level collaborative division of labour. Judging from the developing trend of urban agglomeration, governments should seek policies which promote economic development by unified planning and coordination (Slavin, 1983). For instance, government should establish regional internal tariff elimination system to encourage enterprises to compete and complement across the borders.

In addition, according to their own advantages, cities should focus on developing their own advantageous industries. Further, during the processes of official assessment and promotion, due to the single economic amount assessment standard, most local governments would adopt local protection policies to maximize their own interest. This however lead to market segmentation within urban agglomeration. So, when assessing officials, single assessment standard, which only focus on the economic speed, should be abandoned. Instead, the evaluation system should actively guide city's main officials to be oriented to the overall interests of the entire urban agglomeration. In addition to single city economic development, more attention should be paid to the improvement of the quality of economic development of the urban agglomeration as a whole.

5.3.4 To encourage the participation of multiple parties and to establish an effective normalized urban economic cooperation mechanism

On one hand, it is important to improve cooperation mechanisms among local governments so that regional plans and policies can be implemented more comprehensively. On the other hand, it is necessary to establish a cooperative and interactive relationship between government departments and non-government departments, which means cooperation between the official and the unofficial parties. Presently, local governments are the main participating bodies of urban cooperation and they play a major role in promoting intercity complementarity. However, solely relying on government behavior would always lead to inefficient and uneven cooperative relationships. Rational decision-making by enterprises, industry associations and other NGOs are essential to achieving more fair and efficient cooperative relationships among cities.

The current situation is that local government leads the economic development of GBA. In a broader sense, NGOs are not affected by the distribution of local interest. NGOs should take advantages of their low cost and rapid effects to promote the integration of GBA in a bottom-up way. With economic development and transformation of government functions, industry associations play increasingly significant roles in economic operations. These organizations act as bridges during integration and coordination between government and society. In addition, industry associations can also promote resource integration among cities within GBA by developing industry standard development plans, while multinational corporations and cross-regional group-type enterprises can effectively break the regional blockade and realize the resource optimal allocation (Ansell, 2000).

5.4 Possible avenues for further study

As has been clarified in section 1.6 in Chapter 1, the limitation of this research mainly came from data inaccessibility and incomparability, as well as the characteristics of regional spatial structure of the study area.

First, due to the data accessibility, this thesis analysed urban economic network by using urban gravity model, which measured urban relationships based on geographical distance. However, with the development of technology, location advantage plays a less important role in intercity complementarity. In further study, it will be meaningful to research on economic spatial network based on data, which can better represent the intercity economic activities and linkages. For example, data of distribution of headquarters and branches of multinational corporations and listed companies could be useful.

In addition, when measuring the impacts of intercity competitive and complementary relationships on urban economic development, the percentage of FDI in GDP and the percentage of cargo volumes in GDP were used, respectively. However, the degree of intercity competition and complementarity are manifested in different aspects. Only considering competing for FDI and complementing by cargo connections may lead to less accurate results. Further, in this thesis, due to the incomparability of FDI data and cargo data, Hong Kong and Macau were excluded in regression models. In this case, the conclusions on the impacts of intercity competitive and complementary relationships were only based on PRD instead of GBA. In future, it will be significant to conduct research based on other comparable indicators, which can represent intercity competition and complementarity for 11 cities in GBA to get a more generalised results.

Finally, it will be interesting to conduct research about intercity relationships and their impacts on urban economic development in different and typical types of regional urban structure. For instance, comparable research can be conducted in Beijing-Tianjin-Hebei area Yangtze River Delta, where Beijing (national capital centre) and Shanghai (national economic centre) are the two extremely outstanding cities. This would boost policy suggestions in future on how to manage polycentric urban regions in China and other similar places around the world.

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