MAPPING URBAN NETWORKS IN MAINLAND CHINA THROUGH THE LENS OF CORPORATE SPATIAL ORGANIZATION

Miaoxi Zhao

UNIVERSITEIT GENT

geografie vakgroep Universiteit Gent

SEG research unit Social and Economic Geography

MAPPING URBAN NETWORKS IN MAINLAND CHINA THROUGH THE LENS OF CORPORATE SPATIAL ORGANIZATION

ACADEMISCH PROEFSCHRIFT

Aangeboden tot het behalen van de graad van

Doctor in de Wetenschappen: Geografie

door

Miaoxi Zhao

Promotor

Prof. dr. Ben Derudder

Department of Geography, Ghent University

Members of the Examination Committee

Prof. dr. Nico Vande Weghe (Chair)

Department of Geography, Ghent University

Prof. dr. Philippe De Maeyer

Department of Geography, Ghent University

Prof. dr. Frank Witlox

Department of Geography, Ghent University

Prof. dr. Bart Dessein

Department of Languages and Cultures of South and East-Asia, Ghent University

Prof. dr. Wei Shen

Confucius Institute, Lancaster University

Preface

I am profoundly grateful to my supervisor, Professor Ben Derudder, who has provided me with strong academic guidance since 2010. His insightful comments were crucial for this dissertation, and his constructive criticisms and suggestions regarding the different chapters were very helpful. Most of my publications in international journals and conference proceedings were supported by his endeavours. I should also like to thank Professor Frank Witlox of Ghent University, who has also given me help in this beautiful city.

A lot of thanks and gratefulness goes to Dr Xingjian Liu, who has been one of my academic friends ever since he started his PhD studies at Cambridge University. Both Ben and Xingjian helped me publish my paper in Urban Studies. I owe a big thank you to Dr Yanliu Lin from Utrecht University. She has given me a lot of support during my studies at Ghent. Special thanks go to Professor Martin De Jong of Delft University of Technology, with whom I discussed a lot of different academic issues in both China and in Europe. I am grateful to Dr Yimin Wang of University of London College, who gave me a lot of support when I came to Europe. I also thank Dr Kang Wu, who maintained regular academic contact with me during his stay at Harvard University.

I very much appreciate the help from Liang Dai, Galuh Syahbana and Weiyang Zhang. I would like to thank Ye Zhong, Gaofeng Xu, Zhensong Guo, Junhao Huang, Yulan Chen, Piangcheng Zhang and Rongrong Li from the South China University of Technology.

I also thank my brother Ze Zhao – who cares for my parents and also helps me with financial issues in China – my mother, my father-in-law and my dearest son, Shuping Zhao, who has been steadily growing during my time at Ghent. I feel guilty about spending so little time playing with him and will make up for it soon. Finally, I am immeasurably grateful to my wife, Shuanglin Wang, for her love, understanding and support.

Miaoxi Zhao
31-8-2016

CONTENTS

LIST OF FIGURES

Figure 4.6 Possible topology based on the CGHM for three regions...108

Figure 5.1 Location of city regions in the YRD and PRD 117

LIST OF TABLES

LIST OF ABBREVIATIONS

APS	Advanced producer service
BOC	Bank of China
BTH	Beijing–Tianjin–Heibei
CGB	Guangdong Development Bank
CGHM	Combining Geographic and Hierarchical Features
CSIC	Chinese Standard Industrial Classification
FAI	Fixed assets investments
FDI	Foreign direct investment
FTZ	Free trade zone
GaWC	Globalization and World Cities
GCR	Global city region
ICBC	Industrial and Commercial Bank of China
IDC	Indegree centrality
INM	Interlocking network model
LRM	Location recommendation model
ODC	Outdegree centrality
PMCR	Polycentric megacity region
PRD	Pearl River Delta
PS	Producer service
PUR	Polynuclear urban region
SOE	State-owned enterprise
WCN	World city network
WTO	World Trade Organization
YRD	Yangtze River Delta

Chapter 1: Introduction

This chapter provides the theoretical context for the idea of urban networks in mainland China as seen through the lens of corporate spatial organization, and introduces the resultant city network analyses that form the basis of this dissertation.

1.1 Background to the dissertation

In recent decades, the development of urbanization all over the world has been reshaped by processes of globalization. China, with the most population in the world, is increasingly being integrated into global production networks since entering the World Trade Organization (WTO) in 2001 (Wei et al., 2009). Specifically, the urbanization level in mainland China kept increasing in the period 2001–13, and the amount of foreign direct investment (FDI) rose significantly during 2001–08. This was followed by a small drop in 2008–09; the amount remained stable in 2011–13 (see Figure 1.1).

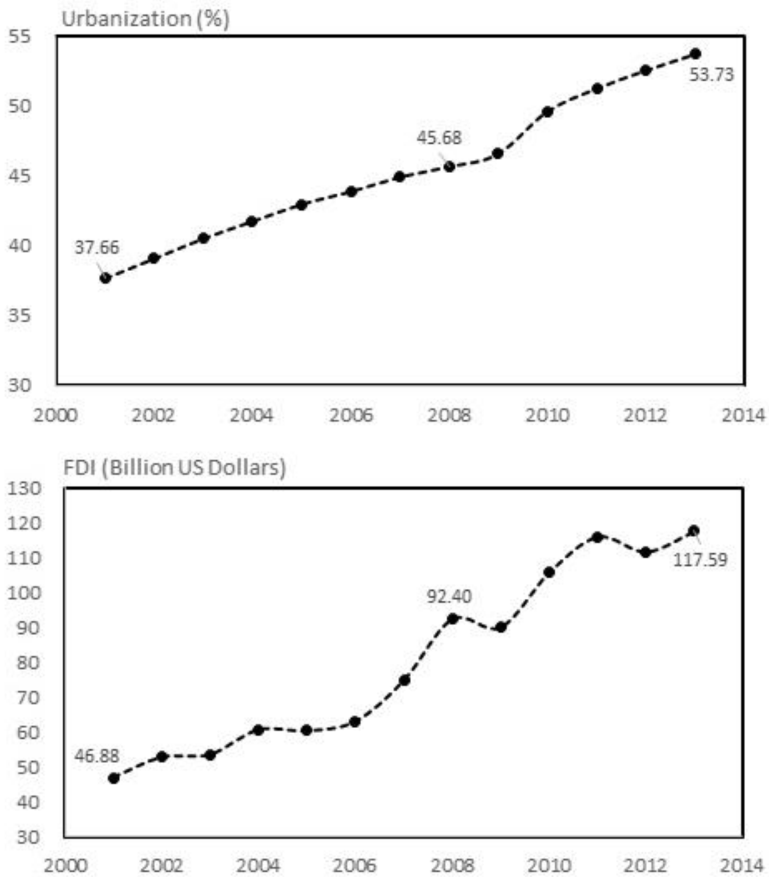

Figure 1.1 Urbanization level and amount of FDI in mainland China during 2001-13

In this process, China's urban system has been attracting widespread interest from economists, sociologists and geographers all over the world (Liu et al., 2008). A great number of studies have used network analysis methods to guide the planning of Chinese regional development (Liu, Dong & Liu, 2013; Zhen et al., 2013). However, most of these studies position major cities in the national economy, and pay limited attention to medium-size cities (Hou et al., 2015). Furthermore, inter- and intra-regional difference is an important aspect of the process of urbanization in mainland China, except for gateway cities such as Beijing and Shanghai. From this perspective, exploring city networks at different geographical scales has important implications for studies on urban China that focus on regional development (Zhao & Tang, 2010; Jin, 2010; Hou et al., 2015; Yeh, 2014; Zhang, 2015).

When studying urban networks, there are diverse types of flows between cities: actual connections (e.g. airline networks: Smith & Timberlake, 2001), virtual connections (e.g. internet backbone networks: Zook, 2001; Townsend, 2001) and indirect connections in the form of spatial corporate organizations (Pred, 1977; Taylor, 2001; Anderson & Beckfield, 2004). In the context of contemporary economic globalization, scholars tend to view leading producer service (PS) firms as the key agents of urban networks; many of them therefore explore the linkages within geographical corporate structures (Taylor, 2001). However, using spatial corporate organizations to measure urban network always faces the problem of choosing the most adequate algorithm that for measuring indirect city-dyads in the network (Taylor, 2001; Alderson & Beckfield, 2001; Zhao & Tang, 2010; Neal, 2012; Liu & Derudder, 2013; Henanman & Derudder, 2013). After all, using different methods to analyse urban networks leads to different results.

On the other hand, considering different geographical scales is of particular importance when examining spatial corporate organizations for the networks in an urban system (Taylor et al., 2009). In China, connections among cities are currently considered to be a central issue in regional development (Hou et al., 2015; Zhao et al., 2015). In China's recent planning document of 'New Path of Urbanization (2015-2020)', the central government states that it wants city regions to accommodate the majority of migrants from rural areas. And more high-speed railways will be built in the coming five years, and they will have the potential to enable more social and economic connections among cities. However, recent reports have also argued that more convenient transportation might only benefit megacities rather than medium-sized or small cities, and that this might lead to more people leaving the latter cities and thus create further regional polarization (Zhao, Liu & Chen, 2012; Wu, Fang, Zhao & Chen, 2013). This means that studying networks of city regions will be helpful for policymakers to understand the urban system in China. However, relatively few researchers have investigated the evolution of multiscale features of urban networks in China, and their results have had few spatial implications for the actual planning of urban systems (Hou et al., 2015).

To address the above-mentioned research issues, in this dissertation I juxtapose different studies of urban networks in mainland China through the lens of corporate spatial organization, using diverse methods and different geographical scales. To the best of my knowledge, this is the first systematic study of China's urban development from this perspective.

1.2 State of the art

1.2.1 External relations of cities

Research on the external relations of cities has traditionally focused on delineating, describing and theorizing urban hinterlands (Taylor & Derudder, 2015). With the immense rise in importance of central place theory in geographical scholarship from the late 1950s onwards, the city became defined by its regional and local external relations (Bunge, 1966). The first feature of the theory (Berry & Pred, 1961: 3) states that: 'the basic function of a city is to be a central place providing goods and services for a surrounding area.' But that statement contrasts with the theory of Jacobs (Taylor, 2010; Taylor & Derudder, 2015), who argued that a city does not grow by trading only with its rural hinterland (Jacobs, 1969: 35). For this contradiction, Taylor and Derudder (2015) emphasized the shift of focus from nation states to cities in globalization, whereas Bourne (1975: 14) asserts that the national urban system can be easily recognized. Within system thinking, the nearest scholars get to doubting the existence of a national urban system is when the openness of the system is discussed in the era of globalization (Taylor & Derudder, 2015).

1) Cities in globalization

The study of the inter-relations of major cities has resulted in a stream of research on world cities, global cities, global city regions, and mega-city regions (Hall, 1966; Cohen, 1981; Friedman & Wolff, 1982; Sassen, 2001; Scott, 2001; Hall & Pain, 2006).

The term 'world city', the concept used by Gottman (1989) to identify the leading culture centres of the world, can be traced back to the work of Geddes (1924). Within this range of themes, Hall (1966) revealed the role of economic functions in his study of world cities. Since then, research on world cities has led to a very large literature covering a wide range of topics and issues. Cohen (1981) was the first to link cities to a new international labour division. Following the work of Cohen, Friedman and Wolff (1982) published an influential paper containing 'the world city hypothesis'. Friedman (1986: 69) described this hypothesis as 'the spatial organization of the new international division of labor' and regarded the world city as the emergence of a limited set of 'basing points for global capital'. Three of the seven theses of the world city concern the foundation of cities in globalization, namely the functional thesis, the hierarchical thesis and the global–local thesis (Taylor & Derudder, 2015). In the 1980s, the theme of a new international labour division gave way to a more encompassing language of globalization. Following Soja et al.'s (1983) description of the 'global capitalist city', Sassen (1991) encapsulated the new thinking in her detailed study of New York, London and Tokyo as 'global cities'. For Sassen (1991), the key point is the 'combination of spatial dispersal and global integration', since the process of globalization has created a new strategic role for major cities. That is to say, dispersing production all over the world has resulted in a demand for new control and organization functions that are essential to 'global cities'.

Urban scholars continued researching global cities in the 1990s, and many of them observed that as globalization proceeds, an extensive archipelago of large city regions has been materializing (e.g. Petrella, 1995; Veltz, 1996; Sassen, 2001; Newman & Thornley, 2011). Scott (2001), for instance, coined the term 'global city regions' (GCRs) to indicate that a number of large metropolitan areas are increasingly functioning as the spatial foundations of the global economy that has been taking shape since the end of the 1970s. The ensuing challenge of describing and analysing the shifting spatial organization of GCRs resulted in a rapidly evolving urban–regional literature. From this has emerged a plethora of concepts, among which 'polycentric mega-city regions' (PMCRs, see Hall & Pain, 2006) and 'polynuclear urban regions' (PURs, see Turok & Bailey, 2004) are favoured terms. The key emphasis of this literature is the observation that heavily urbanized regions are made up of a conglomeration of cities of varying sizes and importance (Hall & Pain, 2006).

2) External relations of cities in globalization

A review of recent literature on world cities, global cities and mega-city regions shows that scholars tend to focus on the two elements that are crucial for the urban system in globalization: networks and hierarchies (Taylor & Derudder, 2015). Castells (1996) said that 'networks constitute the new social morphology of our society' in the era of information. The emergence of new enabling communication and information technologies, and new scales, scopes and intensities of networking, is 'reshaping the material basis of society' (Taylor & Derudder, 2015). However, the basic feature of networks is mutuality, which runs counter to the usual hierarchical character of urban systems when viewed from central place theoretical-perspectives. Hierarchies, unlike the mutuality of urban networks, imply competitive intercity relations. Because of this contradiction, Taylor and Derudder (2015) proposed to analyse the world city network as a 'network with a hierarchical tendency'.

Compared to Sassen's (1991) 'specific places' of New York, London and Tokyo, Castells (1996) argues that the global city phenomenon cannot be limited to a few urban cores at the top of the hierarchy. He also suggests that a 'global network' connects cities with different intensities and at different geographical scales, whereby regional and local centres within countries become integrated at the global level. For Castells (1996), global cities should be defined as a networked process: the really significant character is the network itself. Based on the idea of Sassen (1991), Castells thus provides a new context to view world cities: cities are part of a space of flows that in turn express the new network society. This results in the conversion of global cities as advanced service centres into a global network of cities (Taylor & Derudder, 2015).

3) Corporate firms as actors of urban networks

Research on intercity relations is often positioned in the context of Castells' research on a 'global spaces of flows', which is said to be constituted by three layers: infrastructural support for networked social practices, geographical network spaces formed by nodes and hubs, and the spatial organization of the managerial elite using these networks (Castells, 1996; Taylor & Derudder, 2015). The empirical studies that were initially focusing on Castells' (1996) first layer of space of flows and infra-structural patterns (Sassen, 2002; Malechi, 2002), both actual (e.g. airline networks: Smith & Timberlake, 2001) and virtual (e.g. internet backbone networks: Zook, 2001; Townsend, 2001). Although these studies provided important insights into how cities are linked within a specific city network, they did not measure the intercity social practices that created the city network (Taylor & Derudder, 2015). As Timberlake et al. (2014) argued, cities per se do not act, plot, think or scheme: they are sites of ongoing human activity and repositories of the history of this activity (Timberlake et al., 2014). Hence, urban networks should be regarded as the interaction of agents' activity among cities. In this view, spatial corporate organizations have also been used to indicate indirect flows between cities, besides the actual or virtual movements (Pred, 1977; Taylor, 2001; Anderson & Beckfield, 2001).

Among the different kinds of spatial organization, the urban dimension of producer services' provision has a long tradition in urban studies (e.g. Coffey & Bailly, 1992; Moulaert & Todtling, 1995). Over the last two decades, the literature on the nexus between urbanization and producer services (PS) has assumed a new dimension, in which the ongoing internationalization of the PS sector has created interest in its impact on the globalization of metropolitan economies in general (Sassen, 2001), and in the emergence of globalized urban networks – as epitomized by the research carried out in the context of the Globalization and World Cities research network (GaWC) – in particular (see Taylor et al., 2002).

As a consequence, empirical research on the global networking potential of cities is often explored through the lens of cities' connectivity in the office networks of PS firms (Shin & Timberlake, 2000; Smith & Timberlake, 2001; Alderson et al. 2010; Mahutga et al., 2010; Neal, 2014). The particular empirical focus on 'globalized' PS firms has been criticized as constituting only a partial approach to globalized urbanization (Robinson, 2002; Smith & Guarnizo, 1998), as this clearly involves only a small and very particular share of the multifaceted networking from, to and through cities. However, although it is indeed partial, the role of PS in economic globalization is far from cursory. Sassen (2001), for instance, argued that PS activities are at the forefront of contemporary metropolitan economic growth in the wider context of economic globalization. Although with the exception of some banks and insurance companies, firms involved in the PS sector are not among the largest capitalist enterprises in the world economy, they are interpreted as 'indicator enterprises' (Aranya & Taylor, 2008). That is, by analogy with 'indicator species' in ecology, these firms are not dominant in quantitative terms but imply the presence of 'vibrant' metropolitan economies (Dawley et al., 2014).

4) The GaWC model and its criticism of urban networks

Exploring city networks based on the locational data of enterprises in the PS sector is at the cutting edge of urban studies (Taylor, 2001). Based on the assumption that firms are key actors in the formation of cities' networks, Taylor (2001) proposed to use social network analysis to quantitatively explore the locational data of advanced PS firms forming the 'world city network' (WCN). This kind of social network, which is composed of linkages between a set of nodes representing cities and a set of nodes representing firms, is commonly called a bipartite network or two-mode network (Liu & Derudder, 2013; Neal, 2014). In general, a bipartite network is 'a set of network nodes divided into two disjoint sets so that no links are present between two nodes within the same set' (Ulusoy et al., 2015). Taylor's method (2001) – the interlocking network model (INM) – is a one-mode projection of the two-mode network: the data is transformed so that it features connections within the same set of nodes (i.e. between cities). This represents a breakthrough for studies on the WCN as it allows analysing the structure of city network through the lens of co-locations of multi-locational PS firms. The approach has also been utilized in many empirical studies with other agents producing the city-dyads, namely NGOs (Taylor, 2004), media conglomerates (Hoyler & Waston, 2013) and higher education institutes (Chow & Loo, 2015).

In recent years, a scientific discussion has emerged over the how to analyse this type of bipartite network produced by PS firms (Derudder & Parnreiter, 2014). The concept of the bipartite network, composed of cities and firms, first appeared in research on social networks (Liu & Derudder, 2013; Neal, 2014). Its principle, put forward by sociologist Simmel, is the relationship between individuals and clubs, in which individuals can make friends with each other and thus form the basis of a social network (Tichy, Tushman & Fombrun, 1979; Freeman, 2004). However, the relationship between social networks and city networks is not yet clear (Neal, 2012, 2015; Liu & Derudder, 2012). And this problem cannot be resolved by Taylor's (2001) interlocking network model (INM). For instance, Neal (2012, 2014), Henanman & Derudder (2014) have questioned the use of the INM and explored alternative/amended methods based on the probability of linkages among cities. Derudder and Liu (2013) argued that calibration approaches are needed to improve the falsifiability of modelling results. Therefore several methods are used to explore the urban networks of corporate spatial organizations in WCN research (Alderson & Beckfield, 2001; Taylor, 2001; Neal, 2013; Henanman & Derudder, 2014).

There are several arithmetic ways to explore the bipartite network projection for cities' connections: the first method is Alderson & Beckfield's (2001, 2010) algorithm on headquarters and offices, which is based on connections between any two cities that accommodate the headquarters and branch plants of an enterprise, respectively; the second method is Taylor's (2001) algorithm that transforms the matrix of bipartite network model into a one-mode network by means of the interlocking network model (Liu & Derudder, 2013); the third method, which was introduced by Neal (2013), is to set up a complementary 'sorting process' perspective in which connections are viewed as arising from the complex process through which firms are 'sorted' into cities; the fourth one, given by Henanman and Derudder (2014), considers the hierarchy of offices at different geographical scales and forms an algorithm focusing on gateway cities in sub-regions. However, there is still a need to exploit the interchangeability of different approaches and model the same set of city-by-firm data with multiple empirical models (Liu & Derudder, 2013). That will allow us to solve the issues of structurally determined results that may arise from the technicality of individual models (Neal, 2012).

1.2.2 China's urbanization process

In general, urbanization in China reflects a distinct regional disparity in both economic development and individual income. For instance, the geographic distribution of two million e-commerce sales in 2013 shows that most Chinese people with purchasing power lived in the urban areas of eastern and central China, while only a small portion of them lived in the urban areas of the western region (see Figure 1.2). The better living conditions and easier access attracts more people to the coastal areas of China. Similarly, regional differences are also reflected by firms' performance in contemporary China (Pan & Xie, 2014; Jiang & Nie, 2014; Xia & Walker, 2015). However, this dissertation extensively explores factors related to China's urbanization process rather than merely analyse the obvious regional disparity in corporate organization. Based on recent works (Gu & Zou, 2012; Liu, 2015; Cartier, 2015; He et al., 2016; Ning, 1998; Gu, 1999; Lu, 2000; Wei et al., 2002; Lin, 2004; Wu, 2006; Wei et al., 2009; Taylor, et al., 2012; Gao et al., 2014), the literature review mainly consists of exploring the relevance of the political system and globalization, both of which have direct impacts on the urban system in China. Finally, the external relations of cities in China are reviewed to find potential research questions in the study of urban networks.

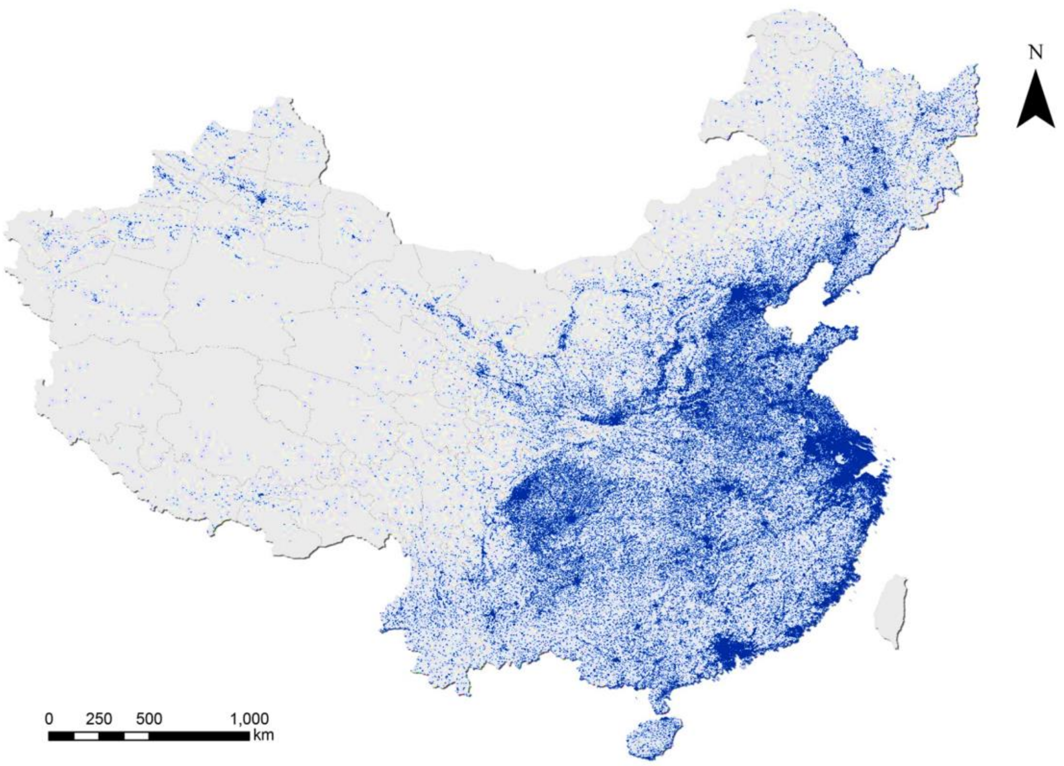

Figure 1.2 Distribution of mainland Chinese urban population based on e-commerce sales in 2013
Source: Wang's (2014) private data from Shenzhen. Drawing by Zhao and Xu.

1) Impacts of the political system on urban China

China has been a rural country for more than two thousand years. As late as 1949, the urbanization level was only 10.6% (Duan & Li, 1999). The centralized political system has been the dominant power in society for a long time. And the national urban system in historical China is characterized by government intervention. When King Zhou Cheng (*Zhou cheng wang,* 周成王) gained power over the whole country at the beginning of the Zhou dynasty (1046–256 BC), princes and chancellors were awarded cities whose size was determined by the leader's place in the political hierarchy. Hence, the size of the population of most cities was dependent on the administration hierarchy in China (Liu et al., 2015). For instance, Xi'an, having been the capital of the empire for a long time, attracted more people from all over the world than any other Chinese city during the Tang Dynasty (618–907), and was one of the originating places of the famous Silk Road (Figure 1.3). Other cities such as Quanzhou and Guangzhou underwent notable developments when overseas trade along the Maritime Silk Road was permitted by the central government in the Song and Yuan dynasties (960–1368). During the Ming dynasty (1368–1644) and early Qing dynasty (1644–1839), Guangzhou had been the only port city with commercial contacts with global markets because of tight regulations imposed by the Empire's government. Most cities in China, including Shanghai, were not open to international traders until 1840 when the army was defeated by the British navy during the Opium War. Since the 1950s, the household registration (*hukou,* 户口)

system, which is totally government controlled, has been an important tool to control population migration (Shen, 2006; Hou, 2011).

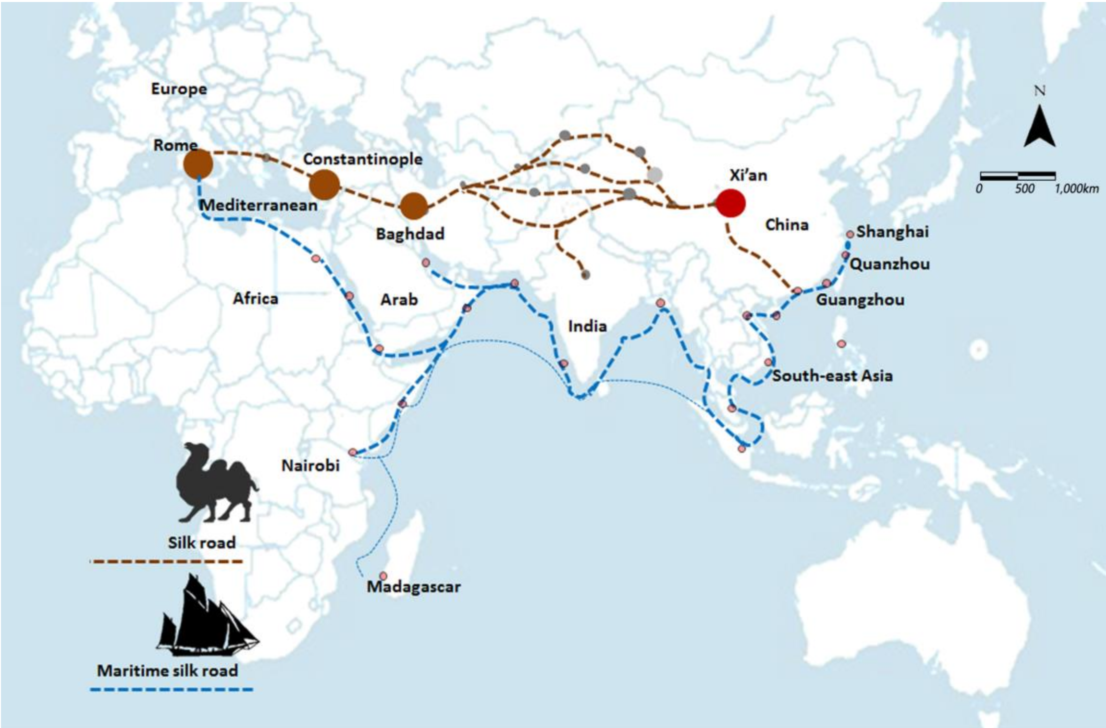

Figure 1.3 Silk Road and Maritime Silk Road in history

Even though the market drive has become more important in the urbanization process since 1978, the state has the power to establish new cities or enlarge existing ones (Cartier, 2015). Nowadays, state-owned enterprises still have a great influence on regional development (Gu & Zou, 2012; Cartier, 2015; He et al., 2016). Wang et al. (2014) found that the proportion of state-owned enterprises significantly reduces the urban concentration of the provincial–urban system in China. Pan and Xia (2014) indicated that a city's level in the political hierarchy remains a significant factor in the geography of headquarters' functions even after controlling for agglomeration-economic factors. Other research also found that firm performance is best explained by whether the ownership type is state-owned across regions (Jiang & Nie, 2014; Xia & Walker, 2015).

When it comes to the political system at the scale of city region in contemporary China, previous studies often ignored prefectures' 'internal geographies', as these prefectures' central cities are often assumed to dominate the development of the entire region, with non-central sub-regions having little chance to command or even attract economic activity from other prefectures. This results in a Christaller-like central place pattern[1] in each prefecture region, an effect that can be likened to a

1 Central place theory, which was initially put forward by Christaller (1930), is a geographical theory concerning the number, size and location of human settlements in an urban system (Goodall, 1987). Taylor and Derudder (2015) described it as a generic urban process, a type of radiative

system of water pumps with pipelines continually absorbing economic resources from a prefecture's non-central sub-regions to its central city (Zhou & Hu, 1992; You et al., 2005; Wang et al., 2015). In such a context, prefecture-level analyses focusing on central cities may seem warranted. However, a range of rescaling processes has implied that different levels of government have become involved in competing for investment by harnessing economic activity within its own administrative boundaries (Ma & Wu, 2005; Wu, 2015). The net result may be that regional and local development is increasingly driven by economic interaction outside of prefectures (Xue & Wu, 2015), a complicated process that would be reflected in an interaction pattern composed of functionally connected spatial units.

2) Impacts of globalization on urban China

Relations with the external world have also had great impacts on the development of certain Chinese cities throughout the country's history. For instance, thriving trade routes between China and the rest of the world brought about the rise of such port cities as Quanzhou and Guangzhou (Zhang, 2015; Li et al., 2016). And the boom in the textile industry, with products exported to other countries through maritime 'Silk Roads', in the Ming-Qing dynasties (1368–1911 AD) resulted in the rise of small towns in the Yangtze River Delta and the Pearl River Delta (Chan et al., 2015). Looking at another aspect, Hou (2011) revealed that the growth in China's urban population was determined by the food supply when the external linkages with the world economy were seriously insufficient during 1949–78.

Along with China's re-emergence on the world stage since 1978, Chinese cities have gradually been getting involved in the global economy (Wu, 2006; Wei et al., 2009). According to this process, a lot of research focused on the impacts of globalization on urban China (Ning, 1998; Gu, 1999; Lu, 2000; Wei et al., 2002; Lin, 2004; Wu, 2006; Wei et al., 2009; Taylor et al., 2012; Gao et al., 2014). The terms 'globalization' and 'marketization' are often used to reflect the change in Chinese cities (Lin, 2004; Wu, 2006)[2]. In scientific research on this topic, studies mainly tend to focus on the FDI and export-oriented growth, both of which are related to the new international labour division (Ning, 1998; Lu, 2000; Wu, 2006). In this context, large numbers of rural workers migrate to the coastal region and thus contribute to the growth of the urban population in China.

Since the global city has been represented as a key manifestation of globalization (Sassen 1991,

relation between an urban place and its hinterland.

2 Drawing on Ning (1998) and Wu (2006), I equate globalization with FDI or export growth, while marketization is more related with the development of private companies and the privatization process of SOEs, institutes, hospitals, etc.

2002), this has become a ‘new meta-narrative’ for studying contemporary urban change in China (Wu, 2006). It was in the late 1990s that the terms ‘world cities’ and ‘global cities’ became widely recognized in the field of urban studies in China (Ning, 1998; Gu, 1999; Lu, 2000). Meanwhile, Wang and Ning (1999), Gu (1999) and Jiang (2004) noted the impacts of communication technology on the development of urban China. As a result of China’s accession to the World Trade Organization (WTO) in 2001, the pace of the ‘open-door’ policy has quickened (Lin, 2003). This has also brought about the rise of mega-city regions in the coastal region. To explore the spatial structures of these city regions, many scholars have focused on the network system to reveal cities’ external relations (Tang & Zhao, 2010; Zhao & Duo, 2013; Zhao et al., 2015; Zhao et al.; 2016).

3）Cities’ external relations in China

In recent years, the external relations of major cities in mainland China have been thoroughly researched (Derudder et al., 2010; Lai, 2012; Taylor et al., 2014). As several Chinese cities have begun to participate as more central players in this global network (Timberlake et al., 2014), Lai (2012) found differentiated markets between Hong Kong and two other gateway cities in mainland China, namely Shanghai and Beijing, in financial firms’ network. The connectivity of major Chinese cities in the world city network has also been revealed through the lens of advanced producer services (APS) firms (Derudder et al., 2010; Taylor et al., 2014). Their results indicate the significant rise of cities in China and the relative decline of those in Europe and northern America in 2000–08 (Derudder et al., 2010). More specifically, Shanghai and Beijing have recorded the greatest growth in in city-dyad connectivity, whereas Hong Kong, although showing increasing city-dyad connectivity with other Chinese cities, has undergone a reduction in city-dyad connectivity with London and New York (Taylor et al., 2014). Zhao et al. (2012) also explored the aviation networks connecting 55 cities in the urban system of mainland China (Figure 1.4) and found that the spatial distribution of airline flows is similar to that of the APS network. Generally speaking, China has already evolved from a traditional rural country into a modern state with several gateway cities linking to other global cities.

But it should be noted that the experience of the star twins of Shanghai and Beijing does not represent that of the large number of other prefecture-level cities because of the existing regional differences in mainland China. Zhou (2016) argued that finer-grained analyses including prefectures’ sub-regions may enhance our understanding of new path for future urbanization in mega-city regions of China. Hence, exploring in more detail the external relations of a large number of other cities can help us to understand the situation of the urban network. Moreover, diversified features may be revealed at different spatial scales, which include the national, regional and sub-regional urban systems (Taylor et al., 2009).

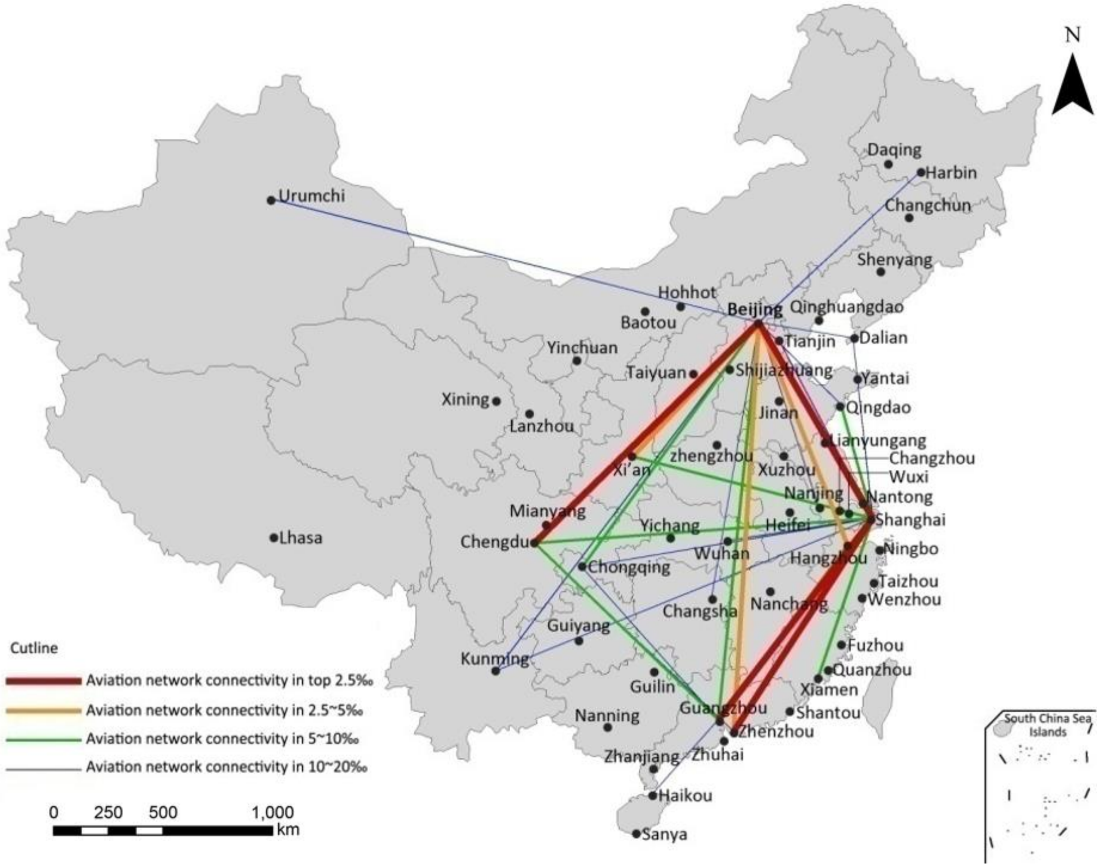

Figure 1.4 Aviation network in mainland Chinese in 2010
Source: Zhao et al. (2012)

At the same time, the multifaceted growth dynamics of global city regions in China present a number of challenges to researchers and policymakers alike. In the recent planning document of the 'New Path of Urbanization (2015-2020)', the central government anticipates that mega-city regions will accommodate more people from rural areas, whereas most local governments usually compete with each other to attract leading firms, especially headquarters, from all over the world to maintain the connections with the government at different scales (Fan et al., 2007; Li et al., 2008; Pan & Xia, 2014). The literature on mega-city regions in China has been referenced enormously ever since Hall (1999) recognized the megacities of the Yangtze River Delta (YRD) and the Pearl River Delta (PRD). City networks were studied from the perspective of corporate structures until recently, and the spatial structure from the perspective of city regions has become a hot topic in China. Although research on intercity networks in polycentric city regions has boomed in recent years (Tang & Zhao, 2010; Luo, 2010; Lu et al., 2012; Zhao, 2015 b), to date this research has mainly emphasized empirical results rather than conceptualising polycentricity. Hence, it is necessary to summarize the conceptual state of the art and then extend the related statistics tools to measure polycentricity in the context of contemporary China. All of this leads to potential research questions for future work.

1.3 Research proposal

1.3.1 Research questions

As revealed by Derudder et al. (2010), the last decade has seen a West-to-East geo-economic transition, which has, rather unsurprisingly, resulted in altered patterns in global urban networks. The most notable changes relate to the relative decline in the connectivity of cities in Europe and northern America, and the rising connectivity of east European and Asia-Pacific cities in general and of Chinese cities in particular (Derudder et al., 2010). However, these urban geographies are far from straightforward in that, despite a general rise of Chinese cities in the networks of globalized corporations, Beijing and Shanghai have become major nodes in these urban networks (see also Ma & Timberlake 2013; Taylor et al., 2014). Although this singling out of a limited number of metropolitan basing points in the reproduction of the capitalist world economy corroborates some of the key tenets of world-city formation as envisaged by Friedmann (1986) and Sassen (2001), there is more to the urban dynamics of corporate organization in the Chinese market. On the other hand, the geography of global producer service (APS) in China represents the limited underlying economics and selection of cities because of the national regulation of the Chinese state-processed economy and the location strategies of global APS firms. Therefore, the Chinese urban network created by APS firms cannot be simply studied as a subnetwork of GaWC's global network, but needs an empirical study based on a wide range of leading APS in the Chinese market. Hence, one of the purposes of this dissertation is to explore the finer-grained geographical changes in networks' patterns.

Subsequently, what are the features of the external relations of cities in the corporate network in China? And what are the geographical characteristics of urban networks when analysed by different methods? Given these focuses, this dissertation mainly deals with the geographies of urban networks in China rather than with how these changing geographies may or may not be harnessed by urban planning or regional governance, topics that have already been addressed extensively in the academic literature (e.g. Zhou & Hu, 1992; Wang, 2009; Ke & Feser, 2010; Wang et al., 2015; Wu, 2015; Xue & Wu, 2015). To answer these two questions, empirical studies for the urban network in mainland China were conducted for this dissertation.

The research hypotheses are drawn from a previous literature review: H1) Using different algorithms and data sources of firms will reflect diversified landscape of urbanization in mainland China; H2) there are complex geographical processes at different scales in the urban networks in China; H3) the specific political system has impacts on the urban networks in China; and H4) changes in urban networks in China have been strongly shaped by the process of globalization. The first two hypotheses on methods & data sources and geographical scales are dealt with before the specific empirical research on the basis of current theory, whereas the last two can only be tested against the results of empirical studies.

1.3.2 Study Area

This research focused on cities in mainland China, namely the geopolitical area under the direct jurisdiction of the People’s Republic of China (PRC). It generally excludes the Special Administrative Regions of Hong Kong and Macau, as well as Taiwan, whose institutions are different. There are 283 prefecture-level cities in the 31 provincial regions of mainland China. The number of cities looked at in each chapter depends on the respective research objectives and data sources. For instance, only 25 prefecture-level cities in the YRD and the PRD were selected for Chapter 4 since the goal of this chapter was to verify a novel method for measuring APS networks in typical city regions.

Considering the complexity of regional differences in China, small and medium-size prefectural-level cities were included in this research in order to draw comprehensive maps of urban networks in China. Further, this dissertation also presents an analysis of the city networks of the two mega-city regions of the YRD and the PRD, both of which were first identified by Sir Peter Hall (1999). It should be pointed out that the BTH is far from being a polycentric metropolis as defined by Hall and Pain (2006) because of the poverty belt around Beijing. Although China’s central government regards the BTH as one of the world’s three most advanced urban regions, some scholars argue that regional inequality prevents it from being a polycentric city region (Zhao et al., 2016). Thus, the dissertation mainly focuses on the networks in the city region of the YRD and the PRD.

1.3.3 Data sources

As multi-locational firms are the agents underlying intercity networks in the global era, this dissertation uses the data on corporate spatial organization to explore the urban networks. According to article 14 of The Company Law of the People's Republic of China (2005), a company wanting to set up a branch or subsidiary company must file a registration application with the company registration authority. This means that the different layers of government have an impact on the location of companies’ branches and subsidiaries in China[3].

3 A company in China can usually only establish branches in another county-level spatial unit when it has the permission of the local county-level government to do so. If an investment from a foreign country exceeds a certain threshold or is related to infrastructure construction, it has to be permitted by the National Development and Reform Commission (NDRC). Each layer of government has enterprises whose ability to set up branches *are made by officials of the respective political hierarchy.

In the empirical studies, two types of data on corporate spatial organization were collected to map urban networks in China. The first type required was that on the presence and the importance of the offices of major PS firms in Chinese cities. Data were collected from websites on the most important firms in the following sectors: banking, insurance, securities, law, accounting, consulting, architecture and advertising[4]. The research focused on firms with a presence in at least two cities. In line with GaWC research, data on the presence of every firm in a city was standardized into values ranging from 0 to 5. All such assessments were made firm by firm. The analysis was thereby restricted to cities in mainland China, that is, excluding cities in Taiwan, Hong Kong and Macau. The result was a city-firm matrix detailing the presence of PS firms across cities, which was used as the input for the analysis of connectivity amongst Chinese cities.

The second type of data was the ownership links in the corporate organization of firms from all sectors. To produce the data matrix of areal associations, we used data on the geography of firms located in the YRD and the PRD drawn from the publicly available company directories[5]. Whereas in the interlocking network model the mere co-presence of a firm in any pair of places is assumed to be sufficient to assume the presence of flows, we adopted a more restricted stance as taken in the research by Alderson & Beckfield (2004) and Tang & Zhao (2010). For each firm with more than a single presence in a certain place, we examined whether this involved a legal ownership link as suggested by the terms ‘subsidiary’, ‘agency’ or ‘branch’. From this perspective, a mega-city region’s constituent urban networks were explored by looking at the ownership linkages running from a corporation’s headquarters to ‘other’ branches of the firm. Hence two types of data sources, which are in line with existing research, are used in the empirical chapters of this dissertation.[6]

---

4 Online data sources for PS firm rankings: (1) top 100 firms in the commercial and residential architectural design market of China (2010), http://www.dilists.com; (2) top 100 managerial consultancy companies in China (2010), http://www.ysoso.cn/a/life/yi/2010/0305/1631.html; (3) top 100 accounting firms in China (2010), http://www.cicpa.org.cn; (4) top 300 law firms in China (2010), http://www.lawon.cn and http://www.moj.gov.cn; (5) top 100 Chinese 4A advertising companies (2010), http://a.com.cn; (6) top 10 Chinese-funded insurance companies by insurance premium (2008), http://wenku.baidu.com/view/aa6b0420192e45361066f54a.html; (7) all foreign insurance and banking companies that have Chinese branches (2008), and all Chinese-funded banks in the top 500 companies in China (2009), http://news.xinhuanet.com.

5 The publicly available company directories are provided by Ebuy Information Ltd (http://www.ebuywww.net.cn/) and Emage Company Ltd (http://www.emagecompany.com/).

6 The producer service firms’ data can be verified as the ranking of top enterprises is publicly available. Connections between headquarters and branches are drawn from an enterprise directory, which is also publicly available. I concede that the resulting data quality is not perfect, but the data are in line with existing research (Chen et al., 2009; Tang & Zhao, 2010), a point that has been recognized by reviewers of this paper.

1.3.4 Organization of this dissertation

Figure 1.5 shows the structure of this dissertation and how the research questions/chapters interrelate. There are seven chapters, i.e. the introduction, five empirical chapters and the conclusions. It should be noted that the findings related with the four research questions cannot be separated from each other, because the impacts of globalization and the political system will materialize in various geographical forms, furthermore, methods of mapping urban networks in China also depend on the data sources. As a consequence, each chapter relates to more than one research question. Chapters 2–6 correspond to papers that have been published or prepared for publication in international peer-reviewed journals.

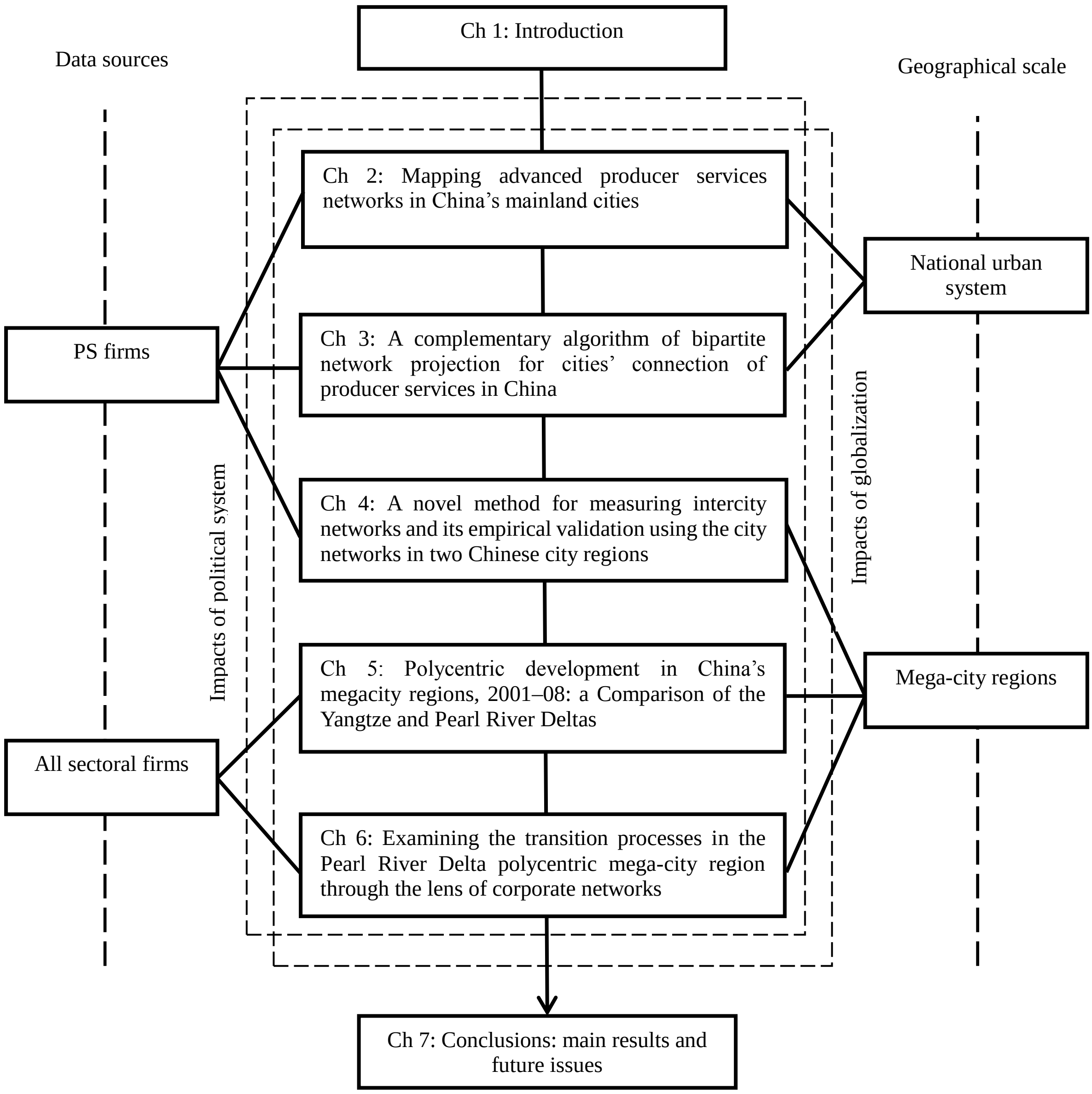

Figure 1.5 Dissertation outline

Chapter 2 analyses the geographies of urban networks created through the lens of leading PS firms in China. The typical algorithm of the interlocking network model is applied in this chapter. Because of the national regulation of the Chinese state-owned economy and the location strategies of global PS firms, the geography of global PS in China as examined by the Globalization and World Cities Research Network (GaWC) could not be studied as a subnetwork of GaWC's global network, but needed an empirical study based on a wide range of leading PS firms in the Chinese market. This study then explores the spatial differentiation in the connectivity of Chinese cities based on the location strategies of PS firms in China.

Chapter 3 explores a complementary method of measuring asymmetric connections of PS firms, namely that of bipartite network projection. Inspired by the network of resource-allocation dynamics (Zhou, Ren & Medo, 2007), a weighting method to extract the hidden information of two-mode networks was developed for this dissertation. That is to say, the location strategies of firms, which are important for local governments seeking investments, are regarded as a process of recommendation. In this process, PS offices are looked upon as the scarce resources to be allocated in the bipartite network.

Chapter 4 extends the recently proposed algorithm (Henanman & Derudder, 2013) by introducing a new method for approximating urban networks, combining the geographical classification with information on the hierarchization of PS networks. This method considers both regional and hierarchical network features and avoids the information loss associated with the conversion from two-mode firm–city networks to one-mode city–city networks. In addition, networks estimated by using the proposed method are suitable when employing social network analysis. The Yangtze River Delta (YRD) and the Pearl River Delta (PRD) are used as the empirical cases in this chapter.

Chapter 5 analyses the geographies of these polycentric networks in what are arguably China's two most important mega-city regions: the YRD and the PRD. To this end, this chapter deploys a methodology that allows the analysis of the shifting spatial organization of mega-city regions through the lens of the headquarters–branch linkages of corporations (Alderson & Beckfield, 2004; Rozenblat & Pumain, 2007; Zhao & Tang, 2010). From this perspective, a mega-city region's constituent urban networks are explored by looking at the ownership linkages running from a corporation's headquarters to other branches of the firm. In the process, this research extends and refines the statistical tools that are often used to measure polycentricity.

Chapter 6 presents an analysis of the shifting spatial organization of the PRD, a large-scale urbanized region bordering Hong Kong. It includes major cities such as Guangzhou and Shenzhen, as well as a range of other rapidly changing cities and towns. The methodology measures and compares the different networking components of the PRD's spatial organization, and uses data on the geography of firms' networks as revealed by the spatial links between locations of headquarters and subsidiaries in 2001, 2008 and 2013. To reflect the complex evolution of urban networks in the PRD, eight sectors are analysed in the empirical study.

Chapter 7, the final chapter of this dissertation, summarizes the main findings drawn from the combined conclusions of Chapters 2–6, and presents some avenues for further research for mapping urban networks in China.

1.3.5 Anticipation of possible contribution

Based on the possible algorithms and the data available at different geographical scales (see Table 1.1), the empirical studies in Chapters 2–6 represent my contribution to the field of urban studies on city networks in China. The first contribution is the exploration of the geographical character of corporate networks using different methods. Chapters 2, 3 and 4 concern PS firms' networks in China. More specifically, Taylor's (2001) classic method of interlocking network is used in Chapter 2, and two alternative methods are applied in Chapters 3 and 4. Chapters 5 and 6 then reveal the city network through the lens of the spatial links between headquarters and branches by Anderson and Beckfield (2001, 2010) and Zhao and Tang (2010). The second contribution (revealing network features at different spatial scales) is at two geographical levels, namely the general features at the scale of the national urban system and the specific features at the scale of both inter- and intra-city regions. For the former, Chapters 2 and 3 explore the city network of the national urban system in mainland China. For the latter, Chapters 4, 5 and 6 present detailed features of mega-city regions of the YRD and the PRD.

Table 1.1 Data, algorithms and geographical scales in Chapters 2–6

Chapter	Data	Algorithms	Scale
2	PS firms	Interlocking network model	Mainland China
3	PS firms	Locational recommendation model	Mainland China
4	PS firms	Combining geographical and hierarchical information	YRD and PRD
5	All sectoral firms	Headquarters-branches pairs	YRD and PRD
6	All sectoral firms	Headquarters-branches pairs	PRD

Chapters 2, 4, 5 and 6 are co-authored papers. I independently wrote Chapters 1, 3 and 7, and I conducted the data collection, analysis and interpretation for Chapters 1, 2, 3, 4 and 6. In collaboration with my co-authors, all the original manuscripts have been significantly improved in terms of research objectives, statements and language for inclusion in this dissertation.

References

Alderson, A. S., & Beckfield, J. (2004). Power and position in the world city system. *American Journal of Sociology, 109*(4), 811-851.

Alderson, A. S., Beckfield, J., & Sprague-Jones, J. (2010). Intercity relations and globalisation: the evolution of the global urban hierarchy, 1981-2007. *Urban Studies, 47*(9), 1899-1923.

Aranya, R. (2008). A global 'urban roller coaster'? Connectivity changes in the world city network, 2000-2004. *Regional Studies, 42*(1), 1-16.

Cartier, C. (2015). Territorial urbanization and the party-state in China. *Territory, Politics, Governance, 3*(3), 294-320.

Castells, M. (1996). *The rise of the network society*. Oxford: Blackwell.

Chan, T. C., Pai, P. L., Shaw, S. L., & Fan, I. C. (2015). Spatiotemporal evolution of market towns in the Jiangnan area during the Ming-Qing dynasties of China. *Historical Methods: A Journal of Quantitative and Interdisciplinary History, 48*(2), 90-102.

Chow, A. S., & Loo, B. P. (2015). Applying a world-city network approach to globalizing higher education: Conceptualization, data collection and the lists of world cities. *Higher Education Policy, 28*(1), 107-126.

Coffey, W. J., & Bailly, A.S. 1993. Producer services and systems of flexible production. *Urban Studies, 29*(6), 857-68.

Cohen, R. (1981). The new international division of labor. *Social Science Information*, *17*(1), 123-142.

Dawley, S., Marshall, N., Pike, A., Pollard, J., & Tomaney, J. (2014). Continuity and evolution in an old industrial region: the labour market dynamics of the rise and fall of Northern Rock. *Regional Studies, 48*(1), 154-172.

Derudder, B., & Parnreiter, C. (2014). Introduction: the interlocking network model for studying urban networks: Outline, potential, critiques, and ways forward. *Tijdschrift voor Economische en Sociale Geografie, 105*(4), 373–386.

Derudder, B., Taylor, P. J., Ni, P., Vos, A. D., Hoyler, M., Hanssens, H., Bassens, D., Huang, J., Witlox, F., Shen, W., & Yang, X. (2010). Pathways of change: shifting connectivities in the world city network, 2000—08. *Urban Studies, 47*(9), 1861-1877.

Duan, J., & Jiang, L. I. (1999). Characteristics, momentums and developing prospects on Chinese urbanization. *Economic Geography*, (6), 79-83. (in Chinese)

Fan, J. P., Wong, T. J., & Zhang, T. (2007). Politically connected CEOs, corporate governance, and Post-IPO performance of China's newly partially privatized firms. *Journal of financial economics*, *84*(2), 330-357.

Freeman, L. C. (2004). *The Development of Social Network Analysis: A Study in the Sociology of Science*. *The development of social network analysis: a study in the sociology of science*. Empirical Press.

Frideman, J. R. (1986). The world city hypothesis: development & change. *Urban Studies*, *23*(2), 59-137.

Friedmann, J., & Wolff, G. (1982). World city formation: an agenda for research and action. *International Journal of Urban and Regional Research*, *6* (3), 309-344

Gao, J., Wei, Y. D., Chen, W., & Chen, J. (2014). Economic transition and urban land expansion in provincial China. *Habitat International*, 44(4), 461-473.

Gu, S., & Zou, Y. (2012). The role of the local government in the financial development of the western region: A study based on Panel Data Model. *Modern Economic Science*. *34*(6), 63-69. (in Chinese)

Hall, P. (1966). *The world cities*. London: Weidenfeld and Nicolson.

Hall, P. (1999). Planning for the mega-city: a new eastern Asian urban form. Perspectives on 21st Century Urban Development: *Sustainable Eastern and Western Cities in the New Millennium*, Aldershot.

Hall, P., & Pain, K. (2006). *The Polycentric Metropolis: Learning from Mega-city Regions in Europe*. London: Earthscan.

He, S., Kong, L., & Lin, G. C. (2016). Interpreting China’s new urban spaces: state, market, and society in action. *Urban Geography*, 1-8.

Henanman, S., & Derudder, B. (2013). An alternative approach to the calculation and analysis of connectivity in the world city network. *Environment & Planning B Planning & Design*, *346*(3), 1218.

Hou, H., Liu, Y., Liu, Y., Wei, X., He, Q., & He, Q. (2015). Using inter-town network analysis in city system planning: a case study of Hubei province in China. *Habitat International*, *49*, 454-465.

Hou, L. (2011). Food supply, population growth and urbanization path: the role of small towns in China's urbanization history. *International Urban Planning*, *26*(1), 24-27. (in Chinese)

Hoyler, M., & Watson, A. (2013). Global media cities in transnational media networks. *Tijdschrift voor economische en sociale geografie*, *104*(1), 90-108.

Jian, B. (2004). Perspectives on urban and regional research in China: a view of globalization. *Acta Geographica Sinica*. *59*(z1), 93-100. (in Chinese)

Jiang, T., & Nie, H. (2014). The stained China miracle: Corruption, regulation, and firm performance. *Economics Letters*, *123*(3), 366-369.

Jin, Z. (2010). On structural properties of transnational urban network based on multinational enterprises network in China: as the case of link with South Korea. *Geographical Research*, *29*(9), 1670-1682. (in Chinese)

Lai, K. (2012). Differentiated markets: Shanghai, Beijing and Hong Kong in China's financial centre network, *Urban Studies*, *49*(6), 1275–1296.

Li, H., Meng, L., Wang, Q., & Zhou, L. A. (2008). Political connections, financing and firm performance: Evidence from Chinese private firms. *Journal of development economics*, *87*(2), 283-299.

Li, R., Wang, Q., & Cheong, K. C. (2016). Quanzhou: Reclaiming a glorious past. *Cities*, *50*, 168-179.

Lin, G. C. S. (2004). The Chinese globalizing cities: national centers of globalization and urban transformation. *Progress in Planning*, *61*(3), 143-157.

Liu, L., Dong, X., & Liu, X. (2008). Quantitative study of the network tendency of the urban system in china. *Philosophical Transactions of the Royal Society of London*, *140*(2), 3747-3753.

Liu, X., & Derudder, B. (2012). Two-mode networks and the interlocking world city network model: a reply to Neal. *Geographical Analysis*, *44*(2), 171–173.

Liu, X., Zhang, X., & Li, L. (2015). The size distribution of cities in China: stylized facts and experience demonstration. *Journal of Finance & Economics*. *41*(11), 108-123.

Lu, X., Ma, X., Li, G. (2012). Spatial Pattern of Regional City Network Based on International Advanced Producer Services' Layout in Pearl River Delta. *Economic Geography*, *32*(4), 50-54. (in Chinese)

Luo, Z. (2010). Study on the Functional Polycentricity of Yangtze River Delta. *Urban Planning International*, *25*(1), 60-65. (in Chinese)

Mahutga, M. C., Ma, X., Smith, D. A., & Timberlake, M. (2010). Economic globalisation and the structure of the world city system: the case of airline passenger data. *International Journal of Methods in Psychiatric Research*, *47*(9), 1925-1947.

Moulaert, F., & Tödtling, F. (1995). The geography of advanced producer services in Europe. *Progress in Planning*, *43*(1), 101-105.

Neal, Z. (2012). Structural determinism in the interlocking world city network. *Geographical Analysis*, *44*(2), 162-170.

Neal, Z. (2014). Validity in world city network measurements. *Tijdschrift voor Economische en Sociale Geografie*, *105*(4), 427-443.

Newman, P., & Thornley, A. (2011). *Planning world cities: globalization and urban politics*. Palgrave MacMillan.

Ning, Y. (1998). New process of urbanization: dynamics and features of urbanization in China since 1990. *Acta Geograohica Sinica, 53*(5), 88-95. (in Chinese)

Pan, F., & Xia, Y. (2014). Location and agglomeration of headquarters of publicly listed firms within China's urban system. *Urban Geography, 35*(5), 757-779.

Pred, A. R. (1977). *City Systems in Advanced Economies: Past Growth, Present Processes and Future Development Options*. New York: Wiley.

Robinson, J. (2002). Global and World Cities: A view from off the map. *International Journal of Urban and Regional Research, 26* (3), 531-534.

Sassen, S. (1991). *The global city: New York, London, Tokyo*. Princeton University Press.

Sassen, S. (2001). *Global city: New York, London, Tokyo*. Political Science Quarterly.

Shin, K. H., & Timberlake, M. (2000). World cities in Asia: cliques, centrality and connectedness. *Urban Studies*, *37*(12), 2257-2285.

Zhao, X. B., & L. Zhang. (2007). Foreign direct investment and the formation of global city-regions in china. *Regional Studies, 41*(7), 979-994.

Smith, D. A., & Timberlake, M. F. (2001). World city networks and hierarchies, 1977-1997: an empirical analysis of global air travel links. *American Behavioral Scientist, 44*(10), 1656-1678.

Smith, M. P., & Guarnizo, L. E. (1998). *Transnationalism From Below*. Transaction Publishers.

Soja, E.W., Morales, R., & Wolf, G. (1983). Urban Restructuring: An Analysis of Social and

Spatial Change in Los Angeles. *Economic Geography, Restructuring in the Age of Global Capital*, *59*(2), 195-230.

Tang, Z., & Zhao, M. (2010). Economic globalization and transformation of urban system in the Yangtze River Delta region. *Urban Planning Forum*, *23*(1), 29-34. (in Chinese)

Taylor, P. J., & Walker, D. R. F. (2002). Measurement of the world city network. *Urban Studies*, *39*(13), 2367-2376.

Taylor, P. J. (2001). Specification of the world city network. *Geographical Analysis*, *33*(2), 181-194.

Taylor, P. J., Derudder, B., Faulconbridge, J., Hoyler, M., & Ni, P. (2014). Advanced producer service firms as strategic networks, global cities as strategic places. *Economic Geography*, 90(3), 267-291.

Taylor, P. J., Evans, D. M., Hoyler, M., Derudder, B., & Pain, K. (2009). The UK space economy as practised by advanced producer service firms: identifying two distinctive polycentric city-regional processes in contemporary Britain. *International Journal of Urban & Regional Research*, *33*(3), 700–718.

Taylor, P. J., Derudder, B., Hoyler, M., Ni, P., & Witlox, F. (2012). City-dyad analyses of china's integration into the world city network. *Urban Studies, 51*(5), 868-882.

Tichy, N. M., Tushman, M. L., & Fombrun, C. (1979). Social network analysis for organizations. *Academy of management review*, *4*(4), 507-519.

Timberlake, M., Wei, Y. D., Ma, X., & Hao, J. (2014). Global cities with Chinese characteristics. *Cities*, *41*, 162-170.

Townsend, A. M. (2001). Network cities and the global structure of the internet. *American Behavioral Scientist*, *44*(10), 1697-1716.

Ulusoy, Ö., Tansel, A. U., & Arkun, E. (2015). *Recommendation and Search in Social Networks*. Cham: Springer International Publishing.

Wang, X., Xie, X., & Yang, B. (2014). State-owned economy and the evolution of city size distribution in China. *Economic Review*, (2), 16-27.

Wu, F. (2006). *Globalization and the Chinese city*. Routledge.

Wu, K., Fang, C., Zhao, M., & Chen, C. (2013). The intercity space of flow influenced by high-speed rail: a case study for the rail transit passenger behavior between Beijing and Tianjin. *Acta Geographica Sinica*, *68*(2), 159-174.

Xia, F., & Walker, G. (2015). How much does owner type matter for firm performance? Manufacturing firms in China 1998–2007. *Strategic Management Journal*, *36*(4), 576-585.

Y. H. Dennis Wei, Li, J., & Ning, Y. (2009). Corporate networks, value chains, and spatial organization: a study of the computer industry in China. *Urban Geography*, *31*(8), 1118-1140.

Y. H. Dennis Wei & Li, W. (2002). Reforms, globalization, and urban growth in china: the case of Hangzhou. *Eurasian Geography & Economics*, *43*(6), 459-475.

Zhang, X. (2015). Globalization and the megaregion: investigating the evolution of the Pearl River Delta in a historical perspective. *Megaregions: Globalization's New Urban Form*.

Zhao, M., Chen, C., & Deng, Z. (2012). *The Comparison between Airline Network and Advanced Producer Services Network in China.* 2012 Annual Meeting of the Association of American Geographers, in Chicago.

Zhao, M., Liu, J., & Chen, C. (2012). Intercity rail transit: the features of regional integration between Changchun and Jilin. *Urban Insight*, (5), 86-95. (in Chinese)

Zhao, M., Li, Z., Zhong, Y., & Derudder, B. (2016). Polycentric network topology of urban agglomerations in China. *Progress in Geography*, *35*(3): 376-388. (in Chinese)

Zook, M. A. (1999). Old hierarchies or new networks of centrality? The global geography of the internet content market. *American Behavioral Scientist*, *44*(10), 1679-1696.

Chapter 2: Mapping advanced producer services networks in China's mainland cities

Abstract: We analyse the geographies of urban networks created by leading producer services (PS) firms in the Chinese market. We explore the spatial differentiation in the connectivity of Chinese cities based on the location strategies of 323 PS firms in 287 Chinese cities. Beijing, Shanghai, Guangzhou, and Shenzhen are primary network nodes. The distributions of banking, securities, and insurance services networks appear more even than non-financial PS firms. Regional disparity exits in terms of polycentric urban development in coastal China as well as centralization model in central and western areas. We suggest that owing to the continued tight regulation of China's state-processed economy and the nature of the location strategies of 'globalized' PS firms, the urban networks created by Chinese PS firms are not only an extension of urban networks at a global scale but also an embodiment of economic activities at other scales.

This chapter is based on, and adapted from: Zhao, M., Liu, X., Derudder, B., Zhong, Y., & Shen, W. (2015). Mapping producer services networks in mainland Chinese cities. *Urban Studies*, *52*(16), 3018-3034.

2.1 Introduction

The urban dimension of producer services (PS) provision has a long tradition in urban studies research (e.g. Coffey and Bailly, 1992; Moulaert and Tödtling, 1995). Over the last two decades, the literature on the PS-urbanization nexus has assumed a new dimension in that the on-going internationalization of the PS sector has created interest in its impact on the globalization of metropolitan economies in general (Sassen, 2001), and in the emergence of globalized urban networks – as epitomized by the research carried out in the context of the Globalization and World Cities research network – in particular (GaWC, see Taylor et al., 2001). The premise of studying the emergence of global urban networks from the perspective of the presence of PS firms is that contemporary globalization is characterized by worldwide, boundary-crossing linkages involving people, capital, information, services, and goods (Holton, 2008). As places where contemporary globalization and its constituent transnational flows are being (re)produced, cities serve as hubs in the networking and globalization of individuals, corporations, and nations. As a corollary, network perspectives have come to be employed to assess the positionality of cities in contemporary globalization (e.g. Castells, 2000; Sheppard, 2002), and urban scholars have identified the PS sector as a key example in this regard (Faulconbridge et al., 2008; Taylor et al., 2014).

As a consequence, empirical research on the global networking potential of cities is often – although most certainly not exclusively (see Shin and Timberlake, 2000; Smith and Timberlake, 2001; Alderson et al. 2010; Mahutga et al., 2010; Neal, 2014) – explored through the lens of cities' connectivity in the office networks of PS firms. The particular empirical focus on 'globalized' PS firms has been criticized as constituting a 'partial' approach to globalized urbanization (Robinson, 2002; Smith and Guarnizo, 1998), as this clearly only involves a small and very particular share of the multifaceted networking from, to, and through cities. However, although indeed 'partial', the role of PS in economic globalization is far from cursory. Sassen (2001), for instance, argues that PS activities are at the cutting edge of contemporary metropolitan economic growth in the wider context of economic globalization. Although with the exception of some banks and insurance companies firms involved in the production of PS are not among the largest capitalist enterprises in the world economy, they are interpreted as 'indicator enterprises' (Taylor and Aranya, 2008). That is, by analogy with 'indicator species' in ecology, these firms are not dominant in quantitative terms but do imply the presence of 'vibrant' metropolitan economies (Dawley et al., 2014).

The last decade has seen a West-to-East geo-economic transition, which has, rather unsurprisingly, resulted in altered patterns in the transnational urban networks created through globalized PS provision. The most notable changes relate to the relative decline in the connectivity of cities in Europe and Northern America, and the rising connectivity of East European and Asia-Pacific cities in general and of Chinese in particular (Derudder et al., 2010). However, these urban geographies are far from straightforward in that, in spite of a 'general' rise of Chinese cities in the networks of globalized PS, Beijing and Shanghai in particular have become major nodes in these urban networks (Ma and Timberlake, 2013). Although this singling out of a limited number of metropolitan basing points in the reproduction of the capitalist world economy corroborates some of the key tenets of world-city formation as envisaged by Friedmann (1986) and Sassen (2001), there is more to the urban dynamics of PS provision in the Chinese market. Indeed, in spite of the continued integration of the Chinese economy and its cities with the global economy, the imprint of the Chinese state on the national economy is unmistakeable. For instance, the Chinese government continues to strive to integrate different parts of the space economy, a strategy that *inter alia* involves steering the geographical remit of major Chinese PS firms (Liu and Dicken, 2006). As a consequence, Chinese PS firms have equally had a major impact on the connectivity of Chinese cities as they have sought to expand their presence across the country.

Against this backdrop, this chapter attempts to analyse the urban geographies created by leading PS firms in the Chinese market and to compare these results with the treatise of Chinese cities in the research of the Globalization and World Cities (GaWC) research network. To this end, the remainder of this chapter is organized as follows. The next section provides a more detailed assessment of the relevance of a multi-scalar approach to urban PS provision in general and to the Chinese context in particular. This is followed by a discussion of data and methods, after which we explore the main tenets of the urban geographies created through PS location strategies in China. This chapter concludes with a discussion on the relevance of our results in the context of research on urban PS provision.

2.2 A multi-scalar approach to urban PS provision: the case of China

2.2.1 Chinese cities in the networks of 'globalized' PS firms

It can be said that the overarching rationale for studying the geographies of urban networks through the office networks of PS firms rests on two straightforward observations. First, to keep ahead in their business, PS firms require access to a skilled labour pool, information-rich and prestigious environs, and superior office, transport, and telecommunications infrastructure, all of which are predominantly found in major cities. The second observation is that PS firms have increasingly started to expand their business beyond their initial hinterland to service existing clients and find new ones. As a result, we have seen the emergence of PS firms with branches in multiple cities, thus generating a seamless service provision through a web of service centres. PS firms are obviously not bent on devising urban networks per se, but they do partake in location decision-making through which geographical patterns of intercity relations emerge. The methodological crux of studies of urban networks through PS firms' office networks, therefore, is that PS firms both react and contribute to evolving processes and scales of economic integration through their location decisions on placing offices to service clients in cities.

These elementary processes have in recent decades come to assume a quasi-global dimension, with some PS firms globalizing so that they have a presence in most leading cities across the world, servicing their multinational clients in foreign markets as well as seeking new ones. The GaWC research programme has thus taken the locational strategies of globalizing PS firms as a starting point for studying transnational urban network formation (e.g. Taylor & Walker, 2001; Derudder et al., 2010). Given GaWC's analytical focus on global economic integration, this implies an analysis of the location decisions of the largest, most globalized PS firms. For instance, the financial services firms in the most recent GaWC data gatherings are drawn from the global Forbes composite index ranking, a measure that combines rankings for sales, profits, assets, and market value lists (see Derudder et al., 2010).

Table 2.1 illustrates the implications of such an approach for our understanding of Chinese cities (Derudder et al., 2013)[7]. The table lists the connectivity of the 15 most connected Chinese cities based on GaWC's 2010 data gathering. Values are, the relative level of connectivity vis-à-vis London, which is the most connected city in the global economy according to GaWC measures. The table suggests clear-cut hierarchical tendencies amongst Chinese cities, centred on three main levels of connectivity: first, Shanghai and Beijing as dominant nodes complementing Hong Kong to form a leading triad of cities in the office networks of major PS firms (albeit with a qualitative difference to their role; see Lai, 2012); second, Guangzhou and Shenzhen as the key nodes of the Pearl River Delta (one of the most densely urbanized regions in the world and one of the main sites of China's economic growth); and third, the remainder of China's major cities with modest connectivity at best. Combined with the observations that (1) Shanghai and Beijing have witnessed the most substantial connectivity gains in the period 2000–2008 (Derudder et al., 2010) and (2) China is now being opened up not only through the well-established gateway of Hong Kong, but also through major transnational intercity connections centred on Beijing and Shanghai (Taylor et al., 2014), the emerging dominance of a select triad of Chinese cities in the office networks of PS firms seems obvious.

The GaWC approach has recently come under close scrutiny. Here, we focus on the more sympathetic critiques, which deem this strand of empirical research a useful tool to work with, albeit in need of further specification and elaboration to be able to fulfil its full potential. Put differently,

7 These banks were included in the latest GaWC data gathering. They have a more or less blanket presence in Chinese cities, and the major differences observed in Table 2.1 can therefore be attributed to the uneven presence of non-Chinese APS firms.

we deal with research that largely concurs with GaWC's treatise of PS firms as key economic agents in the creation of urban networks, but extend this general principle beyond its initial remit for studying global urban networks. Lai (2012), for instance, has revealed the merit of a proper qualification of GaWC connectivity rankings through an in-depth assessment of the different functional roles of foreign banks in different Chinese cities. Other researchers have suggested, drawing on Robinson's (2002) critique of GaWC-like approaches, that work on 'major' or 'global' PS firms should be extended through altered empirical frameworks. The line of reasoning behind this suggestion is that the selection of firms for measuring urban connectivity implicitly entails a de facto focus on 'mainstream' circuits of capital accumulation visible in the office networks of mostly 'Western' financial services firms (e.g. Bassens et al., 2010). The net result of such emphasis on urban connectivity in Western circuits of capital accumulation, Bassens et al. (2010) argue, is that it may result in geographically 'biased' mappings of urban networks that fail to chart service provisioning and circuits that fall outside the traditional sphere of the initial selection of firms. As a consequence, this may imply 'a problematic polarisation in urban studies between research on 'global' cities and work on presumably 'non-global' cities' (McCann, 2004, p. 2315). The crucial point here is not so much that the scale, relevance, and impact of the financial and business circuits articulated through the GaWC selection of PS firms be denied as that attention should also be paid to the accompanying urban networks created through alternative circuits of extra-local servicing at various scales, which may or may not be a simple extension of the patterns found in GaWC research.

Table 2.1 Connectivity of major Chinese cities in the network of 'global' APS firms (Ni et al., 2010).

Rank	City	Proportionate connectivity (1.00 = London)
1	Shanghai	0.69
2	Beijing	0.68
3	Guangzhou	0.32
4	Shenzhen	0.25
5	Chengdu	0.13
6	Tianjin	0.12
7	Nanjing	0.11
8	Dalian	0.11
9	Suzhou	0.09
10	Qingdao	0.08
11	Xiamen	0.07
12	Hangzhou	0.07
13	Shenyang	0.06
14	Fuzhou	0.06

In this chapter, we focus on the position of Chinese cities in the office networks of 'national' PS firms. Our starting point is based on Therborn's (2011) observation that, in spite of undeniable global economic integration other scales of economic integration (and disintegration) continue to matter, with a continuing pertinent role for the state. In the next section, we discuss China's PS market, and clarify how national regulation and the decision-making of global PS firms as regards location strategies steer the geographical involvement of PS firms in China at various scales.

2.2.2 The relevance of China's state-processed economy for PS-driven urban networks

Despite China's entry into the World Trade Organization (WTO) in 2001, state-owned enterprises occupy a significant portion of the national economy and business in China continues to be tightly regulated. The most evident example would be that most of China's own financial institutions continue to be state owned and governed (Chui and Lewis, 2006).

Governments in China play a decisive role in the development of the state-processed regional economy. Since capital is a major factor in the economic growth of Chinese cities, governments use financial tools to regulate the economy (Gu and Zou, 2012). First, governments can support specific SOEs by controlling banks (Jiang and Li, 2006). Most SOEs can obtain loans from local banks or the central government, and such loans are often guaranteed by the government. This means some enterprises have a stronger dependence on the local financial network (Lin and Li, 2001), especially those located in central or western China where state-processed banks have much power in the local financial markets (Gu and Zou, 2012). On the other hand, governments are also directly involved in economic development, which in turn affects the regional spatial structure through financial tools. Most top PS agglomeration districts such as Lujiazui in Shanghai, Chaoyang CBD in Beijing, and Futian CBD in Shenzhen have been largely set up by governments (Han, 2008). Faced with the international financial crisis in 2008, the Chinese government launched a construction programme with a large investment of 4 trillion RMB, a considerable part of which was used in the central and western regions for regional infrastructure such as high-speed railway and aviation hubs. On the basis of fixed assets investments (FAI) as a proportion of GDP (FAI/GDP), the coastal region ranks lower than the central and western regions, while the foreign directed investment as a proportion of GDP (FDI/GDP) indicates the opposite pattern. Obviously, the central and western regions of China relied more on capital investment from governments, which have to make up for the lack of both private capital (Wang and Zhang, 2009) and FDI, while the coastal region depends more on the world economy, which also promoted China's mega-city regions.

At the micro level, companies can obtain funds through the external market, in addition to local banks or the government. To meet the approval requirements of the CSRC, they would require the special services of accounting and legal firms, among others, which would therefore be inclined to locate branches in larger cities. Similarly, when companies need a marketing strategy to expand their market share, they would also buy effective advertising and management consulting services from higher-hierarchy cities. These non-financial firms will then experience a faster internationalization process (Fanny and Cheung, 2007). This means that non-financial service corporations have more freedom to pursue opportunities in the market. Of course, location strategies of China's non-financial firms correspond with world-city and global-city theories (Friedmann 1986; Sassen 2001). For example, more advertising companies have set up offices in Beijing during the period 1996 to 2001 (George et al., 2012). Incidentally, China's household savings rate has remained at a high level (Chi et al. 2011; Charles and Akiko 2012; Leslie et al. 2012), and banks, insurance companies, and securities companies need to effectively absorb part of these funds. Although the development of the Internet enables individuals to transfer funds without going to the transaction place, not all residents have access to personal computers, especially the elderly who invest a part of their pension.

These factors led to the dispersion of China's financial industry, in contrast to the non-financial sector. The central and western regions show more centralization tendencies, which means the hinterland economy is still dominant there, while provincial capital cities are becoming important gateway cities. Cities in the coastal regions have been integrated into the global division of industrial labour and show more multi-centric features.

Therefore, although producer services are rapidly developing in most Chinese cities, the involvement of global PS firms as featured in GaWC's empirical framework is location-dependent in that it reflects the interplay between tight state control and decision-making of global firms. The example of banking is of course the most straightforward and extreme one, but this clearly feeds into other PS sectors (e.g. the prime expertise of most globalized law firms with a presence in China, included in in GaWC's data, relates to financial regulation).

The net consequence for the analysis of the position of Chinese cities in the urban networks created by PS firms seems to be that these cannot be straightforwardly inferred from GaWC's analysis. While Shanghai's connectivity has been skyrocketing over the past few years, some other major Chinese cities remain almost 'cut off' from the influence of globalized PS firms, which explains their very low levels of connectivity in Table 2.1. Once again, we emphasize that there is nothing inherently 'wrong' with these conclusions, which seem to corroborate the predictions of Friedmann (1986) regarding the emergence of a limited set of 'basing points for global capital'. However, from the point of view of urban studies on PS provision through cities, this does call for a complementary analysis of the position of Chinese cities drawing on an empirical framework that focuses on the action space of pertinent PS firms in the day-to-day (re)production of Chinese urban networks. The following section introduces data and methods to engage in such an analysis.

2.3 Data and methods

2.3.1 The interlocking city network model

Our analysis draws on GaWC's interlocking network model (Taylor 2001). Here, we restrict ourselves to basics of the approach to provide the rationale for the measurement of urban connectivity in networks and the data needed for this. The INM essentially specifies the processes of city network formation emerging out of the location strategies of PS firms. Its operationalization requires an $n \times m$ matrix V, summarizing the location strategies of m PS firms across n cities. The values in the matrix cells are 'service values' V reflecting the importance of individual offices to a firm's network. Echoing the basic tents of spatial interaction modelling, the intercity connection between cities a and i generated by intra-firm flows within firm j is given by

$$C_{aij} = V_{aj} \cdot V_{ij} \qquad (2-1)$$

Where V_{aj} and V_{bj} represent the service value of firm j in cities a and i, and C_{aij} denotes the level of connectivity between cities a and i generated by firm j.

The total level of connectivity between any pair of cities is then given by aggregating intra-firm connections C_{aij} across all firms:

$$C_{ai} = \sum_{j=1}^{m} C_{aij} \qquad (2-2)$$

where C_{ai} denotes the level of connectivity between cities a and b.

Finally, the total network connectivity of cities within the urban network can be derived by aggregating C_{ab} across all cities in the analysis:

$$TNC_a = \sum_{i=1}^{n} C_{ai} \qquad (2-3)$$

Where TNC_a denotes the level of connectivity of city a. For reasons of clarity, results will be reported in both absolute and relative terms (i.e., as percentages of the maximum value).

2.3.2 Data collection

This specification guided the data collection: data are required on the presence and the importance of offices of major PS firms across Chinese cities. In practice, this implies a data collection strategy in which we need to (1) select firms, (2) assign standardized service values reflecting the importance of a firm's presence, and (3) select cities.

Selection of PS firms. We collected data on the most important firms from the following sectors:

banking, insurance, securities, law, accounting, consulting, architecture, and advertising. Our initial pool of firms included the top 100 managerial consultancy companies (as of 2010), the top 100 accounting firms (as of 2010), the top 300 law firms (as of 2010), the top 100 advertising companies (as of 2010), the top 10 Chinese-funded insurance companies ranked by insurance premium (as of 2008), all foreign insurance and banking companies that have Chinese branches (as of 2008), and all Chinese-funded banks among the top 500 companies in China (as of 2009). This initial database thus contained more than 800 firms. However, several, indeed most, of these firms were still ‘local’ in that they did not have multiple subsidiaries, making them unsuitable for measuring intercity connectivity. We thus focused on firms with a presence in at least two cities, which reduced our database to 323 PS firms: 48 banks, 56 securities companies, 38 insurance companies, 53 law firms, 33 accounting firms, 56 consulting and architectural firms, and 39 advertising companies. This group of firms is a mixture of globalized PS firms with a presence in Chinese cities, as well as major domestic PS firms, which allows us to consider both international and domestic network agents. Furthermore, the proportional distribution across sectors is in line with the method used in GaWC analyses.

Assigning service values. In line with GaWC research, assigning standardized service values focused on two features of a firm's office(s) in a city as shown on their corporate websites: first, the size of office (e.g. number of practitioners in the branches of law firms), and second, their extra-locational functions (e.g. regional headquarters). Information for every firm was standardized into values ranging from 0 to 5 as follows. The city housing a firm's headquarters was scored 5, a city with no office of that firm was scored 0. An 'ordinary ' or 'typical' office of the firm resulted in a city scoring 2. With something missing (e.g. no partners in a law office), the score reduced to 1. Particularly large offices were scored 3 and those with important extra-territorial functions (e.g. regional headquarters) scored 4. All such assessments were made firm by firm. The initial data were collected in May 2010, and checked and updated in October 2010.

Selection of cities. Considering the importance of the four major state-owned banks in the Chinese economy (the ‘Big Four’: the Bank of China [BOC], CCB, ABC, and ICBC), we limited our analysis to cities with primary branches of the ‘Big Four’. Specifically, primary branches of banks are those branches that can grant loans to enterprises while savings banks can only offer standardized personal services. As a consequence, rather than the savings offices of banks, it is the primary branches of the ‘Big Four’ banks who can be said to function as producer services in China. This resulted in a total of 287 cities. Our analysis was thereby restricted to cities in Mainland China, excluding cities from Taiwan as well as Hong Kong and Macau. Despite their close economic connections with Mainland China, setting up a branch in these regions requires domestic firms to enter a different jurisdiction, essentially pursuing an organizational expansion across borders. Apart from these juridical issues, this chapter focuses on a national urban network arising out of a state-processed economic development and urbanization processes, which excludes Hong Kong, Macau, and Taiwanese cities.

The end product of this data collection is a city-firm matrix detailing the presence of 323 PS firms across 287 cities, which was used as the input for our analysis of connectivity amongst Chinese cities. The next section discusses our results.

2.4 Results

2.4.1 China's urban PS provision: regional and sectoral patterns

In line with previous observations (Yang and Yeh, 2013), we observe a geographic concentration of network connectivity in the PS network along the eastern seaboard (Figure 2.1 & 2.2; Yang & Yeh, 2013), where the most connected cities and strongest dyads lie. Such concentration corroborates with the persistent east–west divide in socioeconomic development in China (Gustafsson & Shi, 2002; Zhang & Kanbur, 2005). Not only do cities in Eastern China contain more PS services, they also exemplify the most even intra-regional distribution of PS services. More specifically, the Gini coefficient of network connectivity among cities in eastern China is 0.59, in comparison to 0.81 for central China and 0.88 for western China[8]. This can be ascribed to the fact that many urban regions along China's eastern coast – the Yangtze River Delta, the Pearl River Delta, and the eastern Fujian urban region – are typical example of polycentric urban regions, which are characterized by multi-centred and relatively even intra-regional development.

Table 2.2 lists the 20 most connected Chinese cities in the overall PS servicing network as well as sub-networks inferred by focusing on firms in specific sectors. Beijing is by far the most connected city in most categories – with the exception of the advertising sector, possibly reflecting the fact that the YRD represents China's largest consumer market – with Shanghai being a close second. This implies that at the national level, Beijing clearly assumes a leading position in PS provision. This importance of the capital city corroborates the importance of China's state-driven economy; proximity to the central government and its economic and political power elites appears to be a key factor. Large SOEs and private corporations (as well as foreign companies that need to be close to regulatory forces; see Lai, 2012) thus cluster in Beijing. Shenzhen and Guangzhou are the other two cities that consistently rank among the top 10 in each of the PS sectors. Shenzhen, the major financial centre next to Shanghai consistently attains the third spot in the rankings, except in advertising, where it is ranked only sixth.

8 Gini coefficient ranges from 0 to 1, with 0 pointing to a complete even distribution of network connectivity among cities, and 1 indicating the complete inequality among network connectivity.

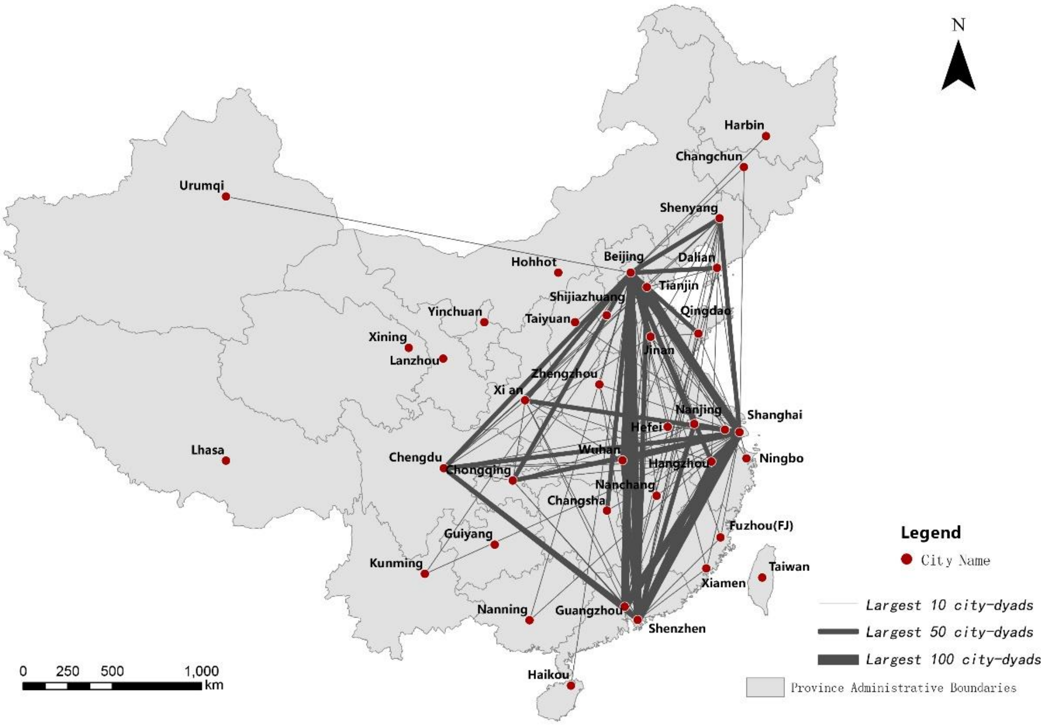

Figure 2.1 Advanced producer servicing network of Chinese cities: (a) largest 10; (b) largest 50; (c) largest 100 city-dyads

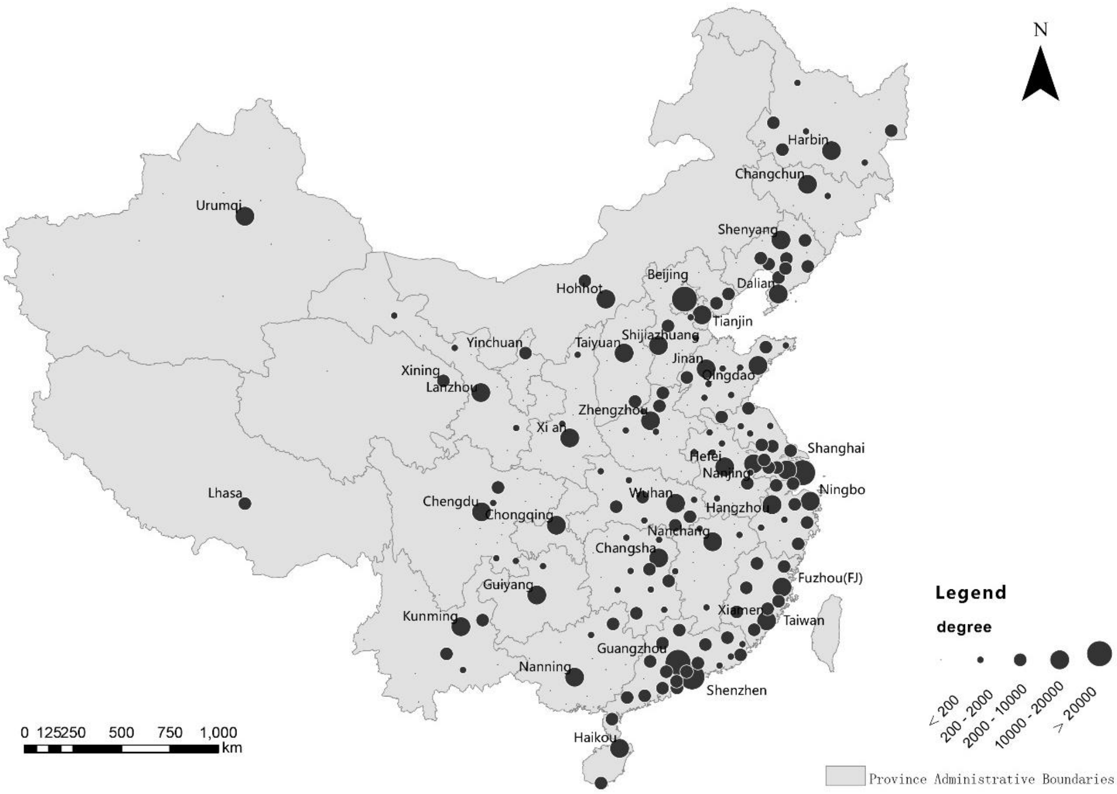

Figure 2.2 Geographic distribution of network connectivity (The radius of circles is proportional to the total connectivity of individual cities)

Table 2.2 Gini coefficients of coastal China, central China and western China

Coastal China		Central China		Western China	
Provincial Region	Gini	Provincial Region	Gini	Provincial Region	Gini
Yangtze River Delta	0.464	Anhui	0.819	Sichuan-Chongqing	0.860
Zhejiang	0.485	Henan	0.824	Sichuan	0.879
Jiangsu	0.373	Heilongjiang	0.726	Gansu	0.850
Fujian	0.247	Hubei	0.701	Shaanxi	0.859
Guangdong	0.411	Hunan	0.734	Xinjiang	0.898
Beijing-Tianjin-Hebei	0.703	Jilin	0.846	Yunnan	0.836
Hebei	0.680	Jiangxi	0.801	Ningxia	0.784
Shandong	0.779	Shanxi	0.842	Guizhou	0.882
Guangxi	0.861	Inner Mongolia	0.858	Qinghai	0.872
Liaoning	0.519			Tibet	0.857
Hainan	0.181				
Overall	0.586	Overall	0.810	Overall	0.882

Note: 1. Yangtze River Delta (YRD) include Shanghai, Zhejiang and Jiangsu while Guangdong contains Pearl River Delta (PRD). 2. Hainan has only two prefecture-level administrative cities which are Haikou and Sanya.

Table 2.3 ranks the 10 strongest city-dyads ranks the top 10 Chinese city-dyads. Unsurprisingly, all these 10 dyads involve at least one of the four leading mainland China cities, and 6 out of these 10 dyads are even between the four leading cities. Most notably, the strongest city-dyad in the China PS network, linking Beijing and Shanghai, is 40% stronger than the second most connected city-pair. The combination of large network connectivity in the four leading cities and strong dyads among them points to a triangular backbone of China's PS network, anchored by Beijing in the north, Shanghai in the east, and Guangzhou and Shenzhen in the south (the latter two cities are roughly 100 kilometres away from each other). As with the east-west divide, this urban triangle has been entrenched in the socioeconomic inequality of the Chinese economy.

Apart from the four leading cities, the sector picture becomes much fuzzier as these cities often occupy very different ranks in different sectors. For example, Wuhan, with an overall ranking of 8th, is ranked 4th in accounting and advertising, whereas it occupies only the 12th rank in banking, insurance, and legal service. Disparities among ranks in different sectoral networks are more evident for Tianjin, where the city is ranked 5th in banking and legal services but attains a 22nd position in advertising. Such disparities become more evident as we progress towards the bottom of rankings. A total of 29 cities have attained at least a top 20 rank in one of the sectors. Nevertheless, Chengdu, Hangzhou, Nanjing, Shenyang, Wuhan, and Xi'an appear in the top 20 for all seven sectors.

Table 2.3 Leading cities in the Chinese advanced producer servicing network

Rank	Overall		Bank		Secu		Insu	
1	Beijing	33081	Beijing	2580	Beijing	6095	Beijing	7612
2	Shanghai	28843	Shanghai	1674	Shanghai	5964	Shanghai	6551
3	Shenzhen	23760	Shenzhen	1519	Shenzhen	5008	Shenzhen	5422
4	Guangzhou	21341	Guangzhou	987	Nanjing	3557	Hangzhou	5349
5	Chengdu	18263	Ji'nan	969	Guangzhou	3480	Guangzhou	5271
6	Nanjing	18241	Tianjin	954	Wuhan	3124	Chengdu	5244
7	Wuhan	18175	Xi'an	903	Changsha	2839	Nanjing	5241
8	Hangzhou	18097	Chengdu	810	Hangzhou	2779	Tianjin	5199
9	Tianjin	17671	Hangzhou	768	Shenyang	2743	Ji'nan	5157
10	Shenyang	16732	Nanjing	753	Chengdu	2711	Shenyang	5127
11	Chongqing	16552	Shenyang	636	Chongqing	2706	Fuzhou	5091
12	Ji'nan	16542	Wuhan	564	Fuzhou	2588	Wuhan	4950
13	Xi'an	15840	Xiamen	555	Hefei	2544	Hefei	4920
14	Changsha	15277	Qingdao	551	Nanning	2506	Changsha	4920
15	Fuzhou	15260	Chongqing	528	Ji'nan	2488	Zhengzhou	4920
16	Qingdao	14964	Zhengzhou	522	Nanchang	2425	Shijiazhuang	4920
17	Dalian	14741	Fuzhou	495	Tianjin	2405	Dalian	4809
18	Zhengzhou	14520	Taiyuan	446	Taiyuan	2280	Nanchang	4725
19	Taiyuan	14028	Nanning	435	Xi'an	2271	Xi'an	4725
20	Kunming	13835	Changchun	432	Harbin	2097	Changchun	4596
Rank	Acct		Adve		Cons		Law	
1	Beijing	3029	Shanghai	1655	Beijing	2421	Beijing	2580
2	Shanghai	2346	Beijing	1547	Shanghai	2280	Shanghai	1674
3	Shenzhen	1907	Guangzhou	1401	Shenzhen	1660	Shenzhen	1519
4	Wuhan	1577	Wuhan	702	Guangzhou	1262	Guangzhou	987
5	Guangzhou	1477	Chengdu	687	Chengdu	1164	Ji'nan	969
6	Ji'nan	1328	Shenzhen	666	Chongqing	1162	Tianjin	954
7	Chengdu	1311	Hangzhou	582	Xiamen	1050	Xi'an	903
8	Tianjin	1194	Nanjing	571	Wuhan	1023	Chengdu	810
9	Hangzhou	1143	Qingdao	510	Xi'an	987	Hangzhou	768
10	Taiyuan	1059	Shenyang	492	Shenyang	888	Nanjing	753
11	Changsha	999	Chongqing	492	Nanjing	826	Shenyang	636
12	Chongqing	996	Kunming	492	Hangzhou	783	Wuhan	564
13	Shenyang	939	Hefei	474	Qingdao	628	Xiamen	555
14	Changchun	894	Xi'an	414	Ji'nan	609	Qingdao	551
15	Qingdao	882	Fuzhou	393	Tianjin	561	Chongqing	528
16	Nanjing	876	Guiyang	360	Changchun	489	Zhengzhou	522
17	Xi'an	810	Changchun	351	Zhengzhou	489	Fuzhou	495
18	Harbin	738	Zhengzhou	345	Urumqi	489	Taiyuan	446
19	Zhengzhou	702	Changsha	312	Dalian	438	Nanning	435
20	Dalian	681	Dalian	291	Fuzhou	420	Changchun	432
			Xiamen	291				

Note: Industry code: Acct, Account; Adve, Advertisement; Cons, Consultancy and architecture; Law, Law firms; Secu, Securities firms; Bank, Banking; Insu, Insurance.

Table 2.4 Top 10 Chinese city-dyads

Rank	City-Dyads	Connectivity	Relative Conn	Rank	City-Dyads	Connectivity	Relative Conn
1	Beijing - Shanghai	2700	1.000	6	Beijing - Chengdu	979	0.363
2	Beijing - Guangzhou	1581	0.586	7	Beijing - Tianjin	947	0.351
3	Beijing - Shenzhen	1557	0.577	8	Guangzhou - Shenzhen	934	0.346
4	Shanghai - Guangzhou	1443	0.534	9	Shanghai - Chengdu	859	0.318
5	Shanghai - Shenzhen	1329	0.492	10	Beijing - Wuhan	852	0.316

To explore the differences among PS sectors, we compare Gini coefficients for the distribution of cities' connectivity within serving networks created by financial (banking, security and insurance firms) and non-financial firms. Banking, securities, and insurance servicing networks are associated with smaller Gini coefficients (0.75 and 0.92 for the urban network formed by financial and non-financial firms, respectively), pointing to a relatively even distribution of urban connectivity within the financial servicing network.

Table 2.5 Gini coefficients of financial firms and non-financial firms

Financial firms		Non-financial firms	
Types	Gini	Types	Gini
Bank	0.767	Acct	0.926
Secu	0.717	Cons	0.922
Insu	0.749	Law	0.928
		Adve	0.931
Overall	0.748	Overall	0.918

Note: Industry code: Acct, Account; Adve, Advertisement; Cons, Consutlancy and architecture; Law, Law firms; Secu, Securities firms; Bank, Banking; Insu, Insurance.

2.4.2 Interpretation and discussions

Rather than discuss the trajectories and dynamics of individual cities/regions, we opt instead to draw three lines of reasoning underlying the China's uneven urban PS provision. First, China's urban PS provision is predicated on the vastly unequal economic development across China. The ensuing and constantly enlarging gaps between different parts of the country in terms of industrial development is often linked with the country's natural endowment, historical paths, and more recently, various state-led economic and reform policies (Peck & Zhang, 2013).

While we do not attempt to explain the entrenched geographical inequality of socioeconomic development in China (Zhang & Kanbur, 2005), we argue these geographic disparities have been shaping China's PS provision in multiple ways. On the one hand, though the country's tertiary economy is expanding rapidly, manufacturing remains a crucial sector in China's export-orient economy and serves as the major ‘feeder’ for producer services. While a good part of the global ‘advanced’ producer services provision is associated with financial and business transactions that have nothing to do with manufacturing production, China’s producer services are less ‘advanced’ in the sense that many of these services are strongly integrated with industrial bases. Accordingly, producer services cluster in the more industrialized eastern part of China. Moreover, in contrast to previous observations that advanced producer services usually cluster in large global cities, China’s manufacturing-led producer services provision relatively caters to the country’s smaller industrial cities. This is reflected in the more even distribution of urban connectivity in Eastern China, featuring urban regions that are abundant with small industrial cities.

While manufactures have served as major clients, thus providing the sufficient condition of producer services development, social and economic capitals, such as educated workforce and infrastructure investment, form the necessary foundation for the development of producer services. Thanks to historically cumulative development disparities (Massey, 1993), cities in Eastern China are usually abundant with inter alia better research universities, transportation infrastructures, and cultural amenities (Zhao et al., 2004). For example, the part of China with highest level of PS connectivity, such as Shanghai, Beijing, and Jiangsu, also host most top universities in China. Similarly, Chengdu’s relatively high position in our ranking, against the backdrop of locating in a relatively less developed province in Western China, could be linked to the city’s strategic airport development. In 2013, Chengdu Shuangliu airport has the fourth most international connections in Mainland China, trailing behind Beijing, Shanghai, and Guangzhou and providing a solid infrastructure foundation for the city’s producer services (Bel & Fageda, 2008).

Second, policies regarding producer services usually have an explicit spatial component and are made through complex and dynamic central–local interplays (Li and Wu, 2012). One centrally initiated PS policy would be the national banking system. Banking, along with insurance and security services, are amongst the most regulated by the Chinese government. Accordingly, integrating the space economy is an implicit part of their objectives, so that major SOEs in this sector have branches in all major cities across the country (see Figure 2.3a) for the geographic distribution of ICBC offices; Chiu & Lewis 2006). Such expansive locational strategies in turn contribute to the relatively even PS network in the financial sector. With the same rationale but at smaller geographic scales, regional governments set up development banks to facilitate regional economic growth, which in turn become an integral part of regional governance and display strong regional focus in terms of locational strategies. For example, the Guangdong Development Bank (Figure 2.3 b) was started to facilitate production in the Pearl River Delta in 1988. Although the bank has progressed significantly and internationalized (with Citigroup as its largest shareholder), its branches still predominantly locate within the Guangdong province.

Figure 2.3 a Branches' Location of ICBC in 2010

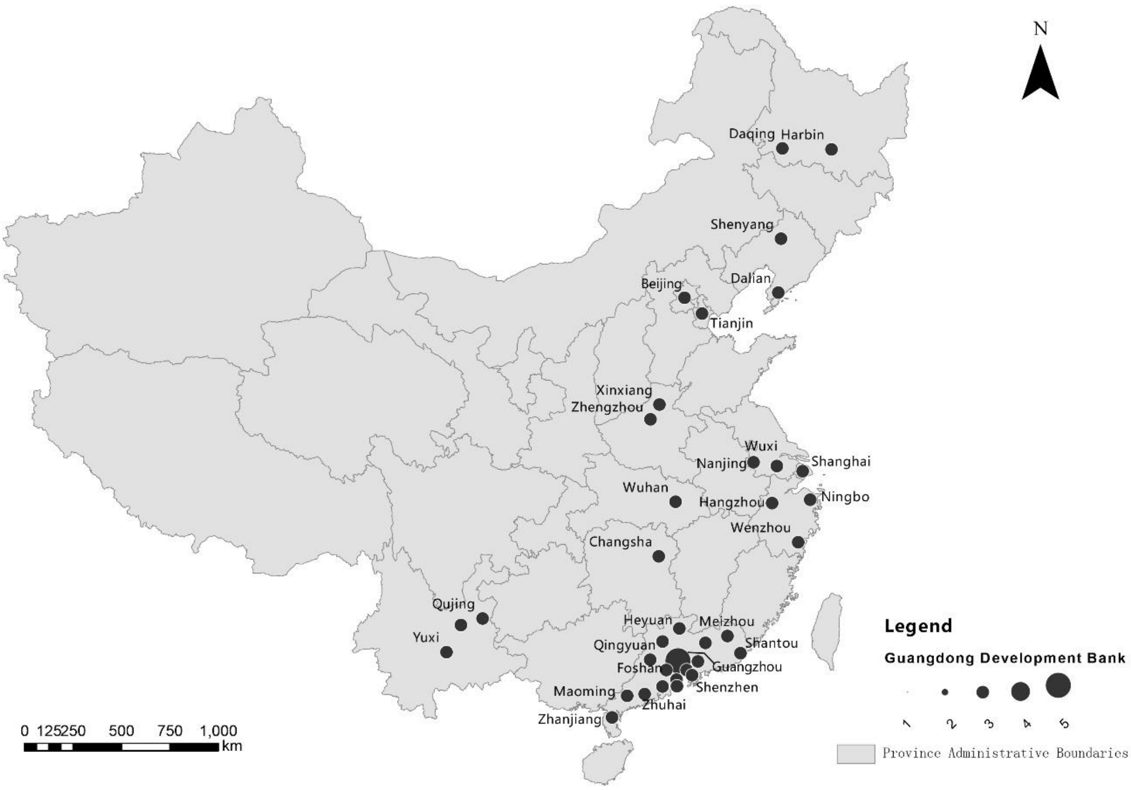

Figure 2.3 b Branches' Location of CGB in 2010

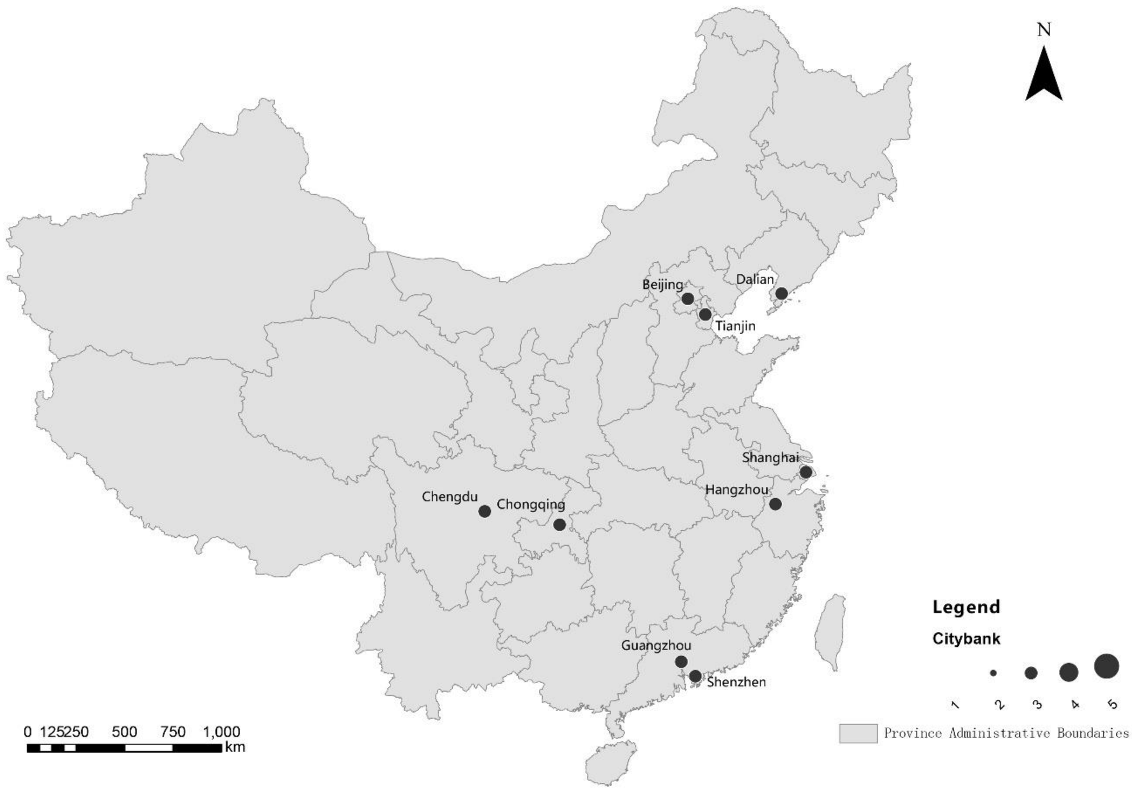

Figure 2.3 c Branches' Location of Citybank in 2010

At the local end, policy enclaves are often created in different cities through central-local interactions. These policy enclaves are often in the form of economic zones, and vary greatly in terms of geographic extent, development focus, and institutional frameworks (Zeng, 2010). More specifically, these economic zones range from the first municipal-wide Special Economic Zones (SEZs), which targets export-processing and stimulate producer services indirectly, to the more recent Shanghai Pilot Free Trade Zone (FTZ), whose mission statements explicitly features the promotion of financial industries. Furthermore, with increasingly larger policy autonomies and in light of the central role of services in post-industrial societies, local governments enthusiastically embrace developmental initiatives that have a strong service component. One case in point would be the 'Wuhan 2049 plan', which aims to develop modern producer services and transform the provincial capital in Central China into one of the economically and technologically most competitive city in the world by 2049 (Wuhan Municipal People's Government, 2013). In addition, literally tens of Chinese cities have published plans that aim at becoming financial centres or centres for back-office operations. The overlay of these spatially explicit policies has further added the unevenness in China's urban PS provision.

Third, local and global circuits of servicing intertwine in the sense that the degree to which individual localities are involved in global production networks would affect the locational strategies of PS firms in the Chinese market (Liu & Dicken, 2006; Derudder et al., 2013). This is exemplified by the distribution of the foreign banks (Figure 2.3c) in China. Granted that foreign banks' services and locations are affected by aforementioned spatially explicit policies, foreign firms cluster in China's most open and globally connected cities along the Eastern seaboard. Local PS firms' development is also affected by localities' involvement in the global capital circulation. For example, the economic take-off of the Pearl River Delta and Yangtze River Delta is propelled by the regions' connections with overseas Chinese capital from Hong Kong and Taiwan, as well as the opportunities to be locked in the global manufacturing system (Peck & Zhang, 2013).

Finally, the impact of the state sector on urbanization (e.g. industrial cities in central China) should not be ignored. In the period of the First 5-Year Plan (1953–1958), the Soviet Union provided China with a considerable number of industrial projects. And eight inner cities – including Wuhan, Chengdu, Taiyuan, Lanzhou and Zhuzhou – were planned to develop manufacturing in the 1950s. When the relationship between China and the Soviet Union hit bottom following the Cultural Revolution (1966–76), more factories were relocated to central and southwest China according to *san xian jian she*, the policy of setting up factories far away from coastal regions, where the economy was assumed to be vulnerable to invasion by both the Soviet Union and the United States. These economic geographies in history, usually implemented by SOEs, have also influenced the location of PS in China (Zeng, 2011).

2.5 Conclusions

Because of the national regulation of the Chinese state-processed economy and the location strategies of global APS firms, the geography of global APS in China represents the limited underlying economics and selection of cities. Therefore, the Chinese urban network created by APS firms cannot be studied as a subnetwork of GaWC's global network, but needs an empirical study based on a wide range of leading APS in the Chinese market.

This analysis reveals the spatial inequality in the Chinese urban network of APS firms: First, our overall and sector-wise connectivity analysis confirms a hierarchical structure. Not surprisingly, Beijing and Shanghai occupy the top positions in this hierarchy, but their dominance are less apparent than those revealed in the global analysis. Moreover, unlike other studies that assert Shanghai has surpassed Beijing in the world city system, our analysis suggests that Beijing leads in the national urban network. Second, the hierarchies of banking and insurance servicing network are flatter than those of law, advertising, and consultancy, which are more influenced by market factors. On the contrary, banking and insurance sectors are more dominated by SOEs, which have branches all over the country and generate a large amount of intercity connectivity in the INM. Third, there is a geographic concentration of network connectivity in Eastern China, and a 'triangle' in Coastal China is formed by three highly inter-connected urban clusters: the Beijing-Tianjin-Hebei (BTH), the Yangtze River Delta (YRD) and the Pearl River Delta (PRD).

The empirical approach to understanding urban and regional structures, as exemplified in the current chapter, should be complemented with qualitative investigations, which would provide insights into non-systematic local context as well as phenomena that are not readily quantifiable. As a case in point, a lot of producer servicing functions in China has been performed not through formal corporate activities, but instead through informal interpersonal networks, or *guanxi*. For example, as mentioned, the development of the Pearl River Delta capitalizes on the region's close kinship ties with diasporadic Chinese capital, and such kinship relationships have been instrumental in various aspects of socioeconomic development, ranging from seeking financial support to promoting specific projects. Nevertheless, these interpersonal networks are very hard to capture and measure, calling for complementary qualitative readings.

References

Alderson, A. S., & Beckfield, J. (2004) Power and Position in the World City System, *American Journal of Sociology, 109*(4), 811-851.

Alderson, A. S., Beckfield J., & Sprague-Jones J. (2010) Inter-City Relations and Globalization: The Evolution of the Global Urban Hierarchy, 1981-2007. *Urban Studies, 47*(9), 1899-1923.

Bassens, D., Derudder, B. and Witlox, F. (2010) Searching for the Mecca of Finance: Islamic Financial Services and the World City Network, *Area*, *42*(1), 35–46.

Castells, M. (2000). *The Rise of Network* Society. Cambridge, MA: Blackwell.

Charles, Y., & Akiko, T. (2012). The Determinants and Long-Term Projections of Saving Rates in Developing Asia. *Japan and the World Economy*, *24*(2), 128-137.

Chi, C., Jean, P., & Eden,Y. (2011). The Chinese saving puzzle and the life-cycle hypothesis: A revaluation, *China Economic Review*, *22*(1), 108-120.

Chiu, B., & Lewis, M. (2006). *Reforming China's State-Owned Enterprises and Banks.* Cheltenham: Edward Elgar.

Dawley, S., Marshall, N., Pike, A., Pollard, J., & Tomaney, J. (2014). Continuity and evolution in an old industrial region: the labour market dynamics of the rise and fall of Northern Rock. *Regional Studies*, *48*(1), 154-172.

Derudder, B., Taylor, P. J., Ni, P., Vos, A. D., Hoyler, M., Hanssens, H., Bassens, D., Huang, J., Witlox, F., Shen, W., & Yang, X. (2010). Pathways of change: shifting connectivities in the world city network, 2000—08. *Urban Studies, 47*(9), 1861-1877.

Faulconbridge, J. R., Hall, S. J. E., & Beaverstock, J. V. (2008). New insights into the internationalization of producer services: organizational strategies and spatial economies for global headhunting firms. *Environment & Planning A, 40*(1), 210-234.

Fanny, S., & Cheung, W. (2007). International expansion of transnational advertising agencies in China: An assessment of the stages theory approach, *International Business Review, 16*(2), 251-268.

Feng, J., He, L., & Hiroshi, S. (2012). Public Pension and Household Saving: Evidence from Urban China, *Journal of Comparative Economics, 39*(4), 470-485.

Friedmann, J. (1986). The World City Hypothesis, *Development and Change*, *7*(17), 69-83.

George, C., Fiona, F., & Fox, Z. (2012). The New Geography of Information and Consulting Services in China: Comparing Beijing and Guangzhou, *Habitat International*, *36*(4), 481-492.

Gu, S., & Zou, Y. (2012). The Role of the Local Government in the Financial Development of the Western Region: a Study Based on Panel Data Model, *Modern Economic Science, 34*(6), 63-69. (in Chinese)

Guan, C., & Gao, Y. (2011). A Probe into Agglomeration of Urban Services Industry and Its Regional Disparity, *Urban Studies, 18* (2), 108-113. (in Chinese)

Gustafsson, B., & Shi, L. (2002). Income Inequality within and across Counties in Rural China 1988 and 1995, *Journal of Development Economics, 69*(1), 179-204.

Han, K. (2008). Study on Economic Structures and Administrative Models of CBD, *Thesis for Doctoral Degree of East China Normal University*, 78-116. (in Chinese)

Holton, R.J. (2008). *Global Networks*. New York: Palgrave Macmillan.

Jiang, W., & Li, B. (2006). Institutional Environment, State-Owned Property Right and Bank Lending Discrimination, *Journal of Financial Research, 317*(11), 116-126. (in Chinese)

Lai, H. (2002). China's Western Development Program: Its Rationale, Implementation, and Prospects, *Modern China, 28*(4), 432-466.

Lai, K. (2012). Differentiated Markets: Shanghai, Beijing and Hong Kong in China's Financial Centre Network, *Urban Studies, 49*(6), 1275-1296.

Leslie, L., Celine, R., & Genevieve, V. (2012). A Real Model of Transitional Growth and Competitiveness in China, *Journal of Asian Economics, 22*(8/99), 267-283.

Li, W., & Cai, X. (2004). Statistical Analysis of Airport Network of China, *Physical Review E, 69*(4), 046106-046111.

Liu, W., & Dicken, P. (2006). Transnational Corporations and 'Obligated Embeddedness': Foreign Direct Investment in China's Automobile Industry, *Environment and Planning A, 38*(7), 1229-1247.

Ma, X., & Timberlake, M. (2008). Identifying the Leading World City in China: A Network Approach, *GeoJournal*, *71*(1), 19-35.

Ma, X., & Timberlake, M. (2013). World City Typologies and National City System Deterritorialisation: USA, China and Japan, *Urban Studies, 50*(2), 255-275.

Mahutga, M., Ma, X., Smith, D., & Timberlake, M. (2010). Economic Globalisation and the Structure of the World City System: The Case of Airline Passenger Data, *Urban Studies*, *47*(9), 1925-1947.

Matthiessen, C.W., Schwarz, A.W., & Find, S. (2010). World Cities of Scientific Knowledge: Systems, Networks and Potential Dynamics. An Analysis Based on Bibliometric Indicators, *Urban Studies*, *47*(9), 1879-1897.

McCann, E. (2004). Urban Political Economy Beyond the 'Global City', *Urban Studies, 41*(12), 2315-2333.

Robinson, J. (2002). Global and World Cities: A View from off the Map, *International Journal of Urban and Regional Research, 26*(3), 531–554.

Sassen, S. (2001). *The global city: New York, London, Tokyo*. New Jersey: Princeton University Press.

Sheppard, E. (2002). The Spaces and Times of Globalization: Place, Scale, Networks, and Positionality. *Economic Geography, 78*(3), 307–330.

Taylor, P. J.J. (2001). Specification of the World City Network, *Geographical Analysis*, *33*(2), 181-194.

Taylor, P. J.J., & Walker, D. (2001). World Cities: A First Multivariate Analysis of Their Service Complexes, *Urban Studies, 38*(1), 23-47.

Taylor, P. J.J., Derudder, B., Hoyler, M., Ni, P., & Witlox, F. (2014). City-dyad Analyses of China's Integration into the World City Network. *Urban Studies*, *51*(5), 868-882.

Therborn, G. (2011). End of a Paradigm: the Current Crisis and the Idea of Stateless Cities, *Environment and Planning A*, *43*(2), 272-285.

Wang, J., & Zhang, H. (2009). Private Investment: History, Recent Developments and Trends, *Research on Economics and Management*, (10), 85-89. (in Chinese)

Yang, F.F., & Yeh, A.G.O. (2013). Spatial development of producer services in the Chinese urban system, *Environment and Planning A, 45*(1), 159-179.

Zeng, S. (2011). *The China's service industrial structure change in the perspective of industrial linkages: the hypothesis of self-enforsing and related test.* Doctoral thesis, Nanjing University.

Zhang, X., & Kanbur, R. (2005). Spatial Inequality in Education and Health Care in China, *China Economic Review, 16*, 189-204.

Zhao, S.X.B., Zhang, L., & Wang, D.T. (2004). Determining Factors of the Development of A National Financial Center: The Case of China, *Geoforum, 35*(5), 577-592.

Zhong, Y., & Yan, X. (2008). Relationship between Producer Services Developing Level and Urban Hierarchy—A Case Study of Zhujiang River Delta, *Chinese Geographical Science, 18*(1), 1-8. (in Chinese)

Chapter 3: A complementary algorithm of bipartite network projection for cities' connection of producer services in China

Abstract: To reflect the imbalanced geography of producer services (PS) firms in the global economy, we applied a complementary method of measuring city networks, based on an alternative algorithm for calculating the asymmetric city-dyads in bipartite networks. Inspired by the network of resource-allocation dynamics, we developed a weighting method to extract the hidden information of two mode networks. That is to say, the location strategies of firms, which are always important for local governments seeking investments, are regarded as a process of recommendation. In this process, PS offices are looked upon as the scarce resources to be allocated in the bipartite network. On this basis, 106 Chinese cities were chosen as a sample for arithmetic analysis. By statistical analysis of the asymmetry between each pair of city-dyads, core cities and periphery cities were distinguished within China's urban system of PS firms under the model of the recommendation system of location choices. The results also suggest that typical provincial capitals tend to link with cities that accommodate firms with widely dispersed offices in China.

This chapter is adapted from: Zhao, M., Derudder, B., Zhang, P., & Peiqian, Z. (2016). A complementary algorithm of bipartite network projection for cities' connection of producer services in China. *Annals of Regional Science*, under review.

3.1 Introduction

The imbalanced geography of the leading producer services (PS) has become one of the most important trend in the process of economic globalization. The key functions of world cities (Hall, 1966; Friedman, 1982) or global cities (Sassen, 2001) in the world economy are indicated by the presence of leading PS firms. In the research on the world city network (WCN) proposed by the Globalization and World Cities (GaWC) Research Network, Taylor (2001), Derudder (2010), Neal (2012), Liu and Derudder (2012) and Henanman and Derudder (2013) have carried out numerous empirical studies and confirmed global cities' status in the world city network by using different quantitative methods to define the city-dyads of PS networks.

Exploring city networks based on the locational data of enterprises in the PS sector is at the cutting edge of urban studies (Taylor, 2001). Based on the assumption that firms are key actors in the formation of cities' networks, Taylor (2001) proposed to use social network analysis to quantitatively explore the locational data of advanced PS firms forming the 'world city network' (WCN). This kind of social network, which is composed of linkages between a set of nodes representing cities and a set of nodes representing firms, is commonly called a bipartite network or two-mode network (Liu & Derudder, 2013; Neal, 2014). In general, a bipartite network is 'a set of network nodes divided into two disjoint sets so that no links are present between two nodes within the same set' (Ulusoy et al., 2015). Taylor's method (2001) – the interlocking network model (INM) – is a one-mode projection of the two-mode network: the data is transformed so that it features connections within the same set of nodes (i.e. between cities). This represents a breakthrough for studies on the WCN as it allows analysing the structure of city network through the lens of co-locations of multi-locational PS firms. The approach has also been utilized in many empirical studies with other agents producing the city-dyads, namely NGOs (Taylor, 2004), media conglomerates (Hoyler & Waston, 2013) and higher education institutes (Chow & Loo, 2015).

In recent years, how to analyse this type of bipartite network for WCN studies has become a matter of heated discussion (Derudder & Parnreiter, 2014). Neal (2012, 2014) and Henanman and Derudder (2013) have questioned the method of the INM and explored alternative/amended methods based on the probability of linkages among cities.

There are several arithmetic ways to explore the bipartite network projection for cities' connections. The first method is Alderson & Beckfield's (2001, 2010) algorithm on headquarters and offices, which is based on connections between any two cities that accommodate the headquarters and an office of an enterprise, respectively. The second method is Taylor's (2001) algorithm, which conveys the matrix of a two-mode network to a one-mode network by means of the interlocking network model. The third method, which was introduced by Neal (2013), is to set up a complementary 'sorting process' perspective in which connections are viewed as arising from the complex process through which firms are 'sorted' into cities. The fourth one, put forward by Henanman and Derudder (2013), considers the hierarchy of offices at different geographical scales and forms an algorithm focusing on gateway cities in sub-regions.

The first and second analytical methods have been widely adopted in the WCN research field in recent years (Derudder, 2010; Taylor & Derudder, 2015). The third and fourth methods are rarely used to quantify the relationships between cities. The principle of the two-mode network is the relationship between different individuals and clubs in which individuals interact with each other and thus result in a social network. This principle was initially put forward by Simmel (Tichy, Tushman & Fombrun, 1979; Freeman, 2004). However, there is a need to exploit the interchangeability of different approaches and model the same set of city-by-firm data with multiple models (Liu & Derudder, 2013). This will allow us to solve the issues of structurally determined results that may arise from the technicality of individual models (Neal, 2012).

To this end, this chapter is organized as follows. The following section provides the background to algorithms on PS firms' network. This include a discussion of the interlocking network model (INM), after which we propose a complementary algorithm (that the of locational recommendation model; LRM) indicating the imbalanced geography of PS firms. This is followed by a description of the data and research methods, after which we use the complementary method to explore the urban network through PS location strategies in China. This chapter reports the results concerning the asymmetric flows and comparison of degree centrality indicated by the INM and the LRM.

3.2 Background to algorithms on PS firms' network

3.2.1 Algorithm of the interlocking network model

The connectivity calculated by the interlocking network model (INM) is based on the data of multi-locational corporate organizations of PS firms. The model first projects the original two-mode dataset of city-by-firm network into a one-mode city network (Liu, Taylor & Derudder, 2014), and then establishes the structure of the world city network (see Table 3.1 and Figure 3.1). In this table, each row of the table represents a firms' urban networks in each city (Taylor et al., 2002). The modelling of contemporary intercity relations through the INM appears to produce a reasonable representation of how cities are connected to each other (Taylor et al., 2014). To make the calculating process more clear, a binary variable (0/1) is used to reflect the condition of having/not having locational service value, in which '1' represents the existence of offices and '0' represents no offices. Then, the INM uses multiplication to find out whether each pair of cities has offices in one specific corporation. In Table 3.1, for example, firm x_1 has offices in cities y_1 and y_2, both of which have the service value of 1, so the connection of city y_1 and city y_2 within the network of company x_1 is calculated as $1 \cdot 1 = 1$. The further example was that for all of the four companies' networks, the connection between city y_1 and city y_2 can be calculated based on the presence of offices in these four firms: $1 \cdot 1 + 0 \cdot 1 + 0 \cdot 0 + 0 \cdot 0 = 1$. More of the connections between cities were calculated in this way, producing a symmetrical one-mode relation matrix among cities (Table 3.2).

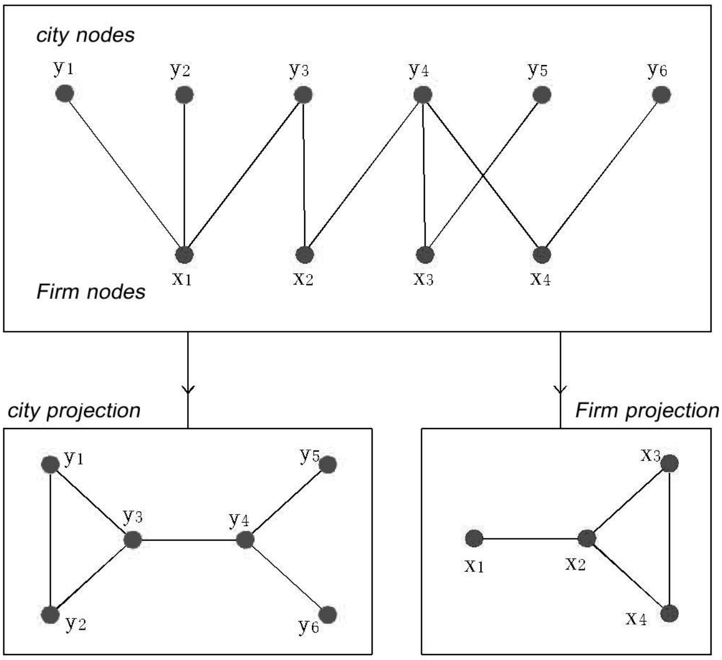

Figure 3.1 A bipartite network, and its city projection and firm projection.

Table 3.1 Relation matrix of cities and firms in the producer services sector

	City y_1	City y_2	City y_3	City y_4	City y_5	City y_6
Firm x_1	1	1	1	0	0	0
Firm x_2	0	0	1	1	0	0
Firm x_3	0	0	0	1	1	0
Firm x_4	0	0	0	1	0	1

Table 3.2 Relation matrix between cities by the INM

	City y_1	City y_2	City y_3	City y_4	City y_5	City y_6
City y_1	—	1	1	0	0	0
City y_2	1	—	1	0	0	0
City y_3	1	1	—	1	0	0
City y_4	0	0	1	—	1	1
City y_5	0	0	0	1	—	0
City y_6	0	0	0	1	0	—

In the general calculation, according to the interlocking network model (INN), the most basic relationship between cities can be represented as:

$$C_{aij} = V_{aj} \cdot V_{ij} \qquad (3-1)$$

In the equation, V_{aj} represents firm *j*'s service value in city *a*, and V_{ij} represents firm j's service value in city *i*. C_{aij} is the number of basic connections between city *a* and city *i*. Formula (3-1) represents the basic relationship between city *a* and city *i* according to company *j*'s service value in both cities. In the calculation process of the INM, the 'service value' for every firm is standardized into values ranging from 0 to 5, reflecting the importance of individual offices instead of binary variables (0/1) above. Here, INM is treated as one type of bipartite network (Neal, 2012), just as listeners are connected with a music-sharing library (Zhou, Ren, & Medo, 2007). Moreover, the linkage is related to the service value reflecting the importance of the office.

We define *m* as the number of all producer service enterprises. Then the overall connection between city *a* and city *i* defined by X_{ai} can be written as follows:

$$X_{ai} = \sum_{j=1}^{m} C_{aij} \qquad (3-2)$$

And the degree of city *a* can be represented as follows:

$$X_a = \sum_{i=1}^{n} X_{ai} \qquad (3-3)$$

In the equation, X_a is a city's degree in the network of n cities. If a city has a higher degree, it fits better into the whole network of PS firms. In the last decade, the INM has been widely used in empirical studies of cities' networks of APS.

3.2.2 Limitations of the interlocking network model

In recent years, discussion on the limitations of the algorithm of the INM has become a focal point in studies on the WCN (Neal, 2012; Liu & Derudder, 2012; Liu & Derudder, 2013; Henanman & Derudder, 2014) and many scholars have begun to look for an alternative method. As Derudder & Liu (2013) have argued, calibration approaches are needed to improve the falsifiability of modelling results. Here, this research would focus on the imbalanced geography of PS firms that was not totally reflected in the method of the INM.

Theoretically, global cities' (Sassen, 2001) or world cities' (Friedman, 1986) 'control and demand' function means that leading firms, which are a kind of strategic resource that local governments always want to attract, are scarce in the process of globalization and informatization. Sassen (2001) held the view that PS offices, which require professionals to meet face to face, are highly concentrated in several global cities. Therefore, these locations are the most important for PS offices in the global era of 'space of flows' (Sassen, 2001; Castells, 1996). In other words, the need for face-to-face meetings enhances the locational advantages of global cities, which means that the demand for specific places shows the scarcity of locational spatial resources.

Based on Castells' (1996) theory of space of flows, the INM method works well in city connection analysis, but it cannot directly reflect the competing results for the leading PS offices, whose locational choices lead to the distribution of strategic resources by local governments. As Pain et al. (2016) have argued, the connectivity of cities in global networks is a means of addressing economic development problems and improving the competitiveness of cities in a global context. Following this point, we assume that a gateway city, namely a city that connects the region to the global economy (Pain et al., 2016), should attract more firms as strategic resources linking to other places. However, problems occur when number of offices is regarded as the locational resources of each city in the INM. We chose six cities and four companies to show this shortcoming of reflecting the preferences of firms' locating in the INM. In Figure 3.2, city y_3 is connected with three other cities through companies x_1 and x_2, and city y_4 is connected with three other cities through companies x_2, x_3 and x_4. Both of the cities' connectivity in the network is 3 when calculated by the INM method. On the other hand, it can also be found that two companies establish offices in city y_3, while three companies establish offices in city y_4, but the INM method ignores the number of company offices, which is essential in analysing the importance of a city. Back to Figure 3.2: city y_4 serves as a network hub for three companies (x_2, x_3, x_4), while city y_3 serves as a network hub for two companies (x_1, x_2). More companies rely on city y_4 than on city y_3, showing that city y_4 is more important than city y_3. However, the INM method fails to explain the phenomenon.

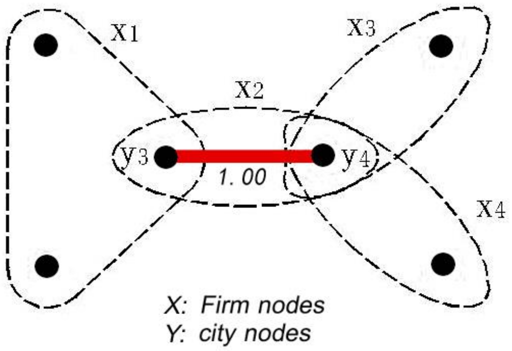

Figure 3.2 Illustration of cities' symmetric connection in the INM

In the context of firms' actual location-selection processes, a city's appeal to firms is important since it determines the development of a city. In particular, a city's status in a city network is also determined by the probability of its firms having offices in other cities. For example, in mainland China, KPMG has only five offices (i.e. in the gateway cities of Beijing, Shanghai, Hangzhou, Guangzhou and Shenzhen), whereas the Bank of Communications has offices in 35 prefectural cities.

If we assume that the offices represent the locational resource to be allocated to cities, we see that the Bank of Communications brings about 1/35 of the locational share to each of its host cities, whereas KPMG brings about 1/5. It is the same as people writing a research paper: a single author puts all of her/his effort into the paper, whereas multiple authors put less effort into their paper. Therefore, the former is more highly recognized as contributing to the paper than the latter. Thus, when re-examining the location choice of PS firms, we find that a few companies similar to KPMG fit more in Sassen's (2001) global cities, whereas the Bank of Communications disperses its offices widely and indicates lower scarcity for its host cities.

However, in the INM, KPMG does not help major cities by having fewer offices than the Bank of Communications. This creates a paradox: connectivity should also reflect the market competition indicated by the scarcity of strategic firms, while the result of the INM cannot fully convey the scarcity of leading enterprises, which is obviously more important for those mayors who want to attract investment. Thus, we need a complementary method to indicate the preference of key firms' for certain gateway cities.

3.2.3 Location recommendation model

To reflect the appeal of PS in the cities' network, we referred to a model introduced by Zhou, Ren & Medo (2007), who present another analytical method for the analysis of two-mode networks. Just like an advisory service on book-selling websites that personally recommends new books to their customers (Maslov & Zhang, 2001), offices' location choice indicates the city preferences of firms' in the bipartite network (Taylor, 2001, 2002). Hence, in the example of city connection, two cities are connected through the same company when an 'opinion network' is built for the recommendation of the company (Maslov & Zhang, 2001; Blattner, Zhang & Maslov, 2007). This is comparable to the method of the INM.

We then regarded PS firms' setting up offices in different cities as a kind of resource allocation, which is local governments' motivation for appealing to leading companies. And we named it the method of location recommendation model (LRM). In this method, these location choices made by firms are regarded as a process of recommendation to allocate resources. It also emphasizes the concerns of potential market benefit for the affiliated offices, as they indicate specific locations. In addition, a connection between two cities in a city network may indicate more detailed information than the INM.

To be specific, we initially defined city-by-firm datasets of cities' locational service value according to Taylor's definition of different hierarchy levels of firms' offices, to demarcate the locational service value of multi-locational companies in their cities. We then performed the location recommendation model (LRM) for the bipartite network in two steps: one from cities to firms, the other from firms to cities (see Figure 3.3). First, companies' overall locational service value in every city was divided by the number of offices the city has, to distribute locational resource value equally to every firm. Next, we summarized the total locational resource value that each firm got from each city it had an office in. The calculation was then used in all companies to work out locational values in all investigated cities.

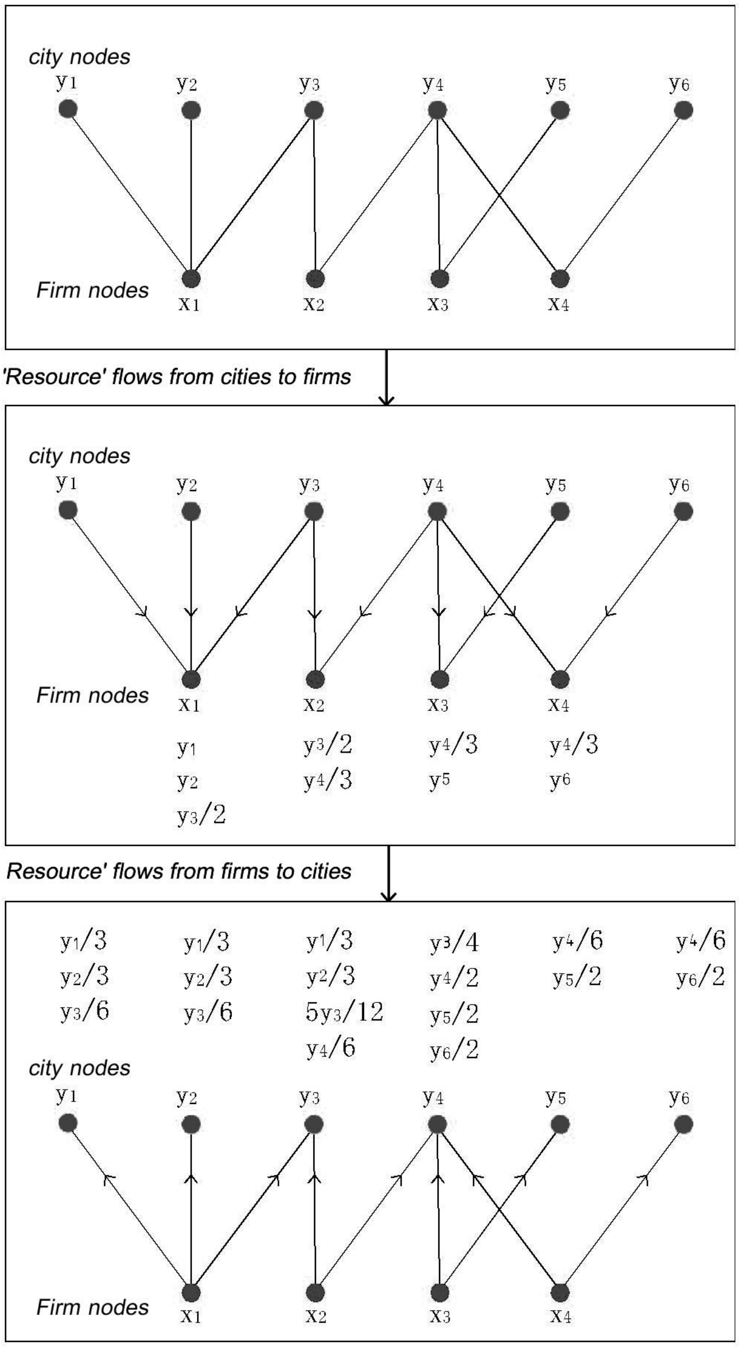

Figure 3.3 Illustration of the resource-allocation process in bipartite network

Hall (1966) and Friedmann (1982) have argued that the key function of world cities is the power of control in the world economy, while Alderson & Beckfield (2004, 2010) regarded it as the basic character of the world city network (WCN). Since the measurement of the WCN should indicate the impact of world/global cities, any kind of model should reflect the scarcity of the quality and availability of resources for every firm. As Dunning & Norman (1987) argued, when it comes to the office location choice of international companies, the quality and availability of resources are more important than the direct costs. This means that cities can also be regarded as one kind of resource related to the firms' revenue. Furthermore, Bagchi & Sen (1997) found that accounting and advertising companies seek new markets through geographical reorganization. It is then natural to adopt the process of distributing locational resources mentioned above as the location recommendation model for the bipartite network of firms–cities introduced by Taylor (2001).

A more specific way to measure the location recommendation model is as follows. First, we worked out the number of cities that attract any office of company *j*. This number is k(y), and the number of firms' offices that a city has is $k(x)$. Then, we defined $f(x_i)$ as the total locational resource value of firms in city *i*. For firm *j*, we can work out its resource using the equation below, which is based on the work of Zhou, Ren & Medo (2007),

$$f(y_j) = \sum_{i=1}^{n} \frac{V_{ij} \cdot f(x_i)}{k(x_i)} \qquad (3-4)$$

In the above formula, $f(y_j)$ is the locational resources distributed to company j and also reflects the scarcity of locational service value for this firm. However, in geographical studies, we focus more on connections between cities. According to the study by Zhou, Ren & Medo (2007), the edge weight ω_{aj} represents the resource weight from city *i* to city *a* as given in the formula below:

$$\omega_{ai} = \frac{1}{k(x_i)} \sum_{j=1}^{m} \frac{V_{aj} \cdot V_{ij}}{k(y_j)} = \sum_{j=1}^{m} \frac{V_{aj} \cdot V_{ij}}{k(x_i) \cdot k(y_j)} \qquad (3-5)$$

In this algorithm, asymmetrical matrix W=$\{\omega_{ai}\}_{n\times n}$ formed by an edge weight represents the projection weight in every city with the split of bipartite network, and ω_{aj} represents the importance of city *a* to city *i* in each network in all of the PS firms. In the projection matrix of city–city (W), W appears to be a company's possibility of establishing offices in city a when one PS company has any office in city *i*. It should be noted that ω_{aj} in formula (3-5) keeps the internal consistency compared with the cities' connection in formula (3-2) of the INM. The researchers also considered different levels in headquarters and offices, which helped to compare the scarcity of locational service value between cities in PS firms.

According to formulas (3-4) and (3-5), and to Zhou, Ren & Medo's definition (2007), if we consider the asymmetric connection between cities, we can calculate the resource conglomeration of city *a* in PS firms' network:

$$f'(x_a) = \sum_{j=1}^{m} \frac{V_{aj} \cdot f(y_j)}{k(y_j)} = \sum_{i=1}^{m} \omega_{ai} \cdot f(x_i) \qquad (3-6)$$

We used the algorithm of resource allocation to measure the scarcity of resources in the bipartite network. The measurement of scarcity meets the need of the strategy of multi-locational companies, especially for key firms that have offices in only a few cities. The algorithm reveals the specific cities' locational attraction for PS firms, based on the theory of Friedmann (1982) and Sassen (2001) that global cities have a great impact on the world economy through certain leading companies. It is also firmly connected to the core–periphery world system theory (Wallerstein, 1979), namely that a large number of areas are dependent on a few main cities.

Unlike the INM, formula (3-5) includes *k(x)* and *k(y)*; the former is related to the number of offices in cities, and the latter to the number of cities in which a company has opened offices. Obviously, the calculation difference between the INM and the one that considers edge weight is probably due to the distinction between the number of offices in cities and the number of cities in which a company has opened offices. To find out what the main difference is, we need to segregate the initial equation (3-5) with edge weight.

First, we only considered the locational value rate a company allocates to any two cities. When more cities have offices of company *j*, the number of connections in company *j* between cities increases, so a connection between city *a* and city *i* is less important. Adding up the connection weight of company j, we can summarize the number of type I city-dyads between city *a* and city *i*.

$$CI_{ai} = \sum_{j=1}^{m} \frac{V_{aj} \cdot V_{ij}}{k(y_j)} \qquad (3-7)$$

We still also consider the number of firms with offices in city *i* – $k(x_i)$ – to analyse city a. If $k(x_i)$ increases, indicating the connection between city a and *i* has less influence on city a, it means that city *i* is less important in the external relations of city *a*. This can be worked out using the edge weight equation. We call these type II city-dyads.

$$CII_{ai} = \sum_{j=1}^{m} \frac{V_{aj} \cdot V_{ij}}{k(x_i)} \qquad (3-8)$$

Contrary to type I city-dyads, the connections of type II city-dyads result in an asymmetrical matrix, since connections between cities *a* and *i* provide them with different weights. The asymmetry indicated by this model reflects whether a city's neighbouring cities have attracted enough offices. In other words, asymmetrical connections between cities in this algorithm do show the attraction difference in welcoming offices to cities. This approach, however, is also debatable since there are other ways to diffuse resources in line with the recursive conceptions of centrality or power (Neal, 2011). It should be noted that this method gives larger cities a larger share in the algorithm, since the connections of smaller cities will be divided more by the number of offices located in the larger cities.

Comparing Taylor's connection equation of the INM (3-2) with equations (3-7) and (3-8) of the LRM, shows that the strength of connection is included in the LRM. Moreover, regardless of an asymmetrical hierarchy between cities, we can work out the degree of type I connectivity using $\Sigma_i CI_{ai}$, considering the number of cities in which the company j locates offices, from equation (3-7). We can also work out the degree of type II connectivity using $\Sigma_i CII_{ai}$, considering the number of firms that are attracted to the neighbouring city *i*, from equation (3-8). Two kinds of degrees show the number of offices and cities that have a negative influence on locational value, which suggests key firms' scarcity for mayors, who are seeking investments from all over the world. That is to say, if the degree of type I connectivity for a city is higher, this city will tend to rely more on enterprises setting up offices in fewer cities with the most locational value; but if degree of type II connectivity is higher, the city tends to rely more on cities that attract fewer offices and always acts as the central place in its hinterland. As figure 3.4 shows, an imbalanced connection between city y_3 and city y_4 will be given in the LRM, namely ω_{34} is 0.17 while ω_{43} is 0.25. This is because by attracting more offices, city y_4, plays a more important role in its hinterland than city y_3.

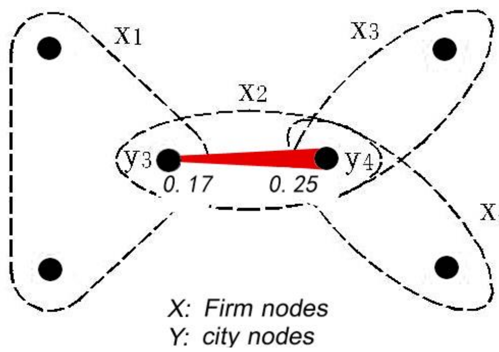

Figure 3.4 Illustration of cities' asymmetric connections in the LRM

From the above analysis, we can see that the INM has a unique connection and degree, but that the LRM calculates city-dyads and degree of type I by the number of host cities for each firm, city-dyads and degree of type II connectivity by the number of offices for each connecting city, and edge weight and absolute degree by combining the two factors. The comparison between the INM and the LRM is as follows (see Table 3.3).

The calculation process of the INM does not reflect the scarcity of locational choices among cities, while in the LRM, the scarcity of two locational resources can be seen. It would further solve the problem that some enterprises (e.g. KPMG) that prefer dominant cities with a few offices, get a lower degree in the INM.

Table 3.3 Comparison of connection and degree between INM and LRM

	INM		LRM					
	City-dyads	Degree	City-dyads			Degree		
			CI	CII	Edge	CI	CII	Nodal
Number of host cities for a company setting up offices	○	○	√	○	√	√	○	√
Number of firms' offices for a city attracting in	○	○	○	√	√	○	√	√

3.3 Data and methods

3.3.1 Data collection

We collected data on the top PS firms in banking, insurance, law, accounting, consulting, architecture and advertising, and then visited the website of each company that had offices in two or more cities. The data were collected in May 2010 and checked in Aug 2012. After that, 205 companies were selected for data analysis, namely 48 banks, 38 insurance companies, 30 law firms, 33 accounting firms, 31 management consulting and architectural design companies, and 25 advertising companies. They were classified into six rankings from 0 to 5 according to the service value offered by a firm in a city. We therefore had an initial matrix of 205 companies and 106 cities. Compared with the previous chapter, this part uses fewer cities and firms because we wanted to know more information about imbalanced geographical features among larger cities rather than obvious differences resulting from urban size. These provincial capitals and non-capital megacities are the main places competing for leading PS firms in China.

3.3.2 Research methods

The research focused on the comparison of the INM and the LRM in PS firms of urban networks in mainland China. Specifically, we paid attention to the hierarchy of cities from a geographical perspective. Therefore, the comparison was aimed at the distinction between city degrees in different algorithms. To show the difference in city networks between the two algorithms, we took 106 cities as samples to compare the absolute degree of the INM and the LRM, so that we could further work out locational features of these sample cities for companies in the PS sector.

We used a t-test to obtain further detail about the imbalanced flows in the LRM. This method makes it possible to classify the core or peripheral cities according to each asymmetric city-dyad. It is difficult to tell whether the number of offices in cities or the number of cities in which a company has offices has a bigger impact on the absolute degree of LRM or the absolute degree of INM. Hence, we also analysed residual value in regression equations to see the difference in degrees, namely the absolute degree of the INM, the degree of type I connectivity and the degree of type II connectivity. To explore these differences, we built up regression equations and calculated the residual between the expected value and the actual value. This allowed us to analyse the impacts of 1) the number of host cities for a company setting up offices, and 2) the number of offices attracted by a city in the national network through comparing the expected value and the actual value.

3.4 Results

3.4.1 Imbalanced flows indicated by the LRM

1）Type I city-dyads

Of the type I city-dyads, Beijing, Shanghai, Shenzhen and Guangzhou are connected to each other the most firmly. According to equation 3-7, if two cities have firms with offices in more cities, a city-dyad in the firms' networks will have a lower value because it contributes less locational value to this pair of city-dyads. The reason why the type I city-dyad of Guangzhou–Shenzhen has a lower value than that of Beijing–Guangzhou, Beijing–Shenzhen, Shanghai–Guangzhou and Shanghai–Shenzhen is that companies with offices in both Guangzhou and Shenzhen usually have offices in the two major cities of Beijing and Shanghai. In this context, there are fewer linkages between firms in Guangzhou and Shenzhen than there are between those in Beijing and Shanghai. On the other hand, there is also competition between Guangzhou and Shenzhen to attract leading PS offices. If an office is located in Guangzhou, for example, its market places could include Shenzhen and it is not necessary to open another office there. Obviously, the connections of type I show both the scarcity and the excludability of market locations.

Next, we further compared the value of the INM city-dyads (equation 3-2) and the connections of type I of the LRM (equation 3-7). City connections in the INM rely on the calculation of two-mode networks, regardless of the scarcity of companies' locational choice as a kind of resource relocating process for any given city. However, in the LRM, when a company has more offices, the importance of each office is comparatively less at each location. Using such a model to analyse the flows of type I city-dyads, we found that the LRM shows firmer connections between cities than the INM.

2）Type II city-dyads

We also analysed the flows of type II city-dyads. In fact, the connections of type II city-dyads are fundamentally different from the connections of type I city-dyads, because the former are based on the ability of neighbouring cities to attract offices. Therefore, the connection matrix is asymmetrical. A comparison of each pair of city-dyads showed that Beijing reflects the obvious strength of connecting with other cities by attracting more offices. The connection rate of Shanghai–Beijing is the highest in all city-dyads; therefore Shanghai appears to be connected the most firmly with Beijing. According to the algorithm, the number of offices, *k(x)*, in Beijing is 180, and that of Shanghai is 176; there is thus little difference. Nevertheless, since offices' service value in Beijing is higher, indicating more headquarters or regional headquarters, Beijing is more dominant than Shanghai in type II connections with each other.

3）Asymmetry of edge weight

The asymmetrical matrix $W=\{\omega_{ai}\}_{n\times n}$ formed by edge weight can be used to distinguish the difference between cities regarding the attraction of PS firms. We used edge weight ω in LRM to analyse the comparative advantage between two cities in PS firms. Since the edge weight is also an asymmetrical matrix (106*106), except for defaults in diagonal line, bidirectional connections between 106 cities form different ranges. When comparing the symmetric connections indicated by the INM and the asymmetric connections indicated by LRM on maps of city networks in China, it is difficult to tell the difference between the networks in their entirety (see figures 3.5 & 3.6), which can only be revealed by statistical analysis, whereas the differences between symmetric and asymmetric flows are relatively easy to capture at the city region scale. Specifically, links between Guangzhou and other cities in the PRD reflect the strength of the LRM, namely it produces flows with wide gradients between pairs of city-dyads, compared to those indicated by the INM (see figures 3.7 & 3.8). Thus, Guangzhou has a comparative advantage compared to the other seven cities in the PRD (i.e. excluding Shenzhen), since these links are wider when they are near Guangzhou.

Furthermore, we defined the value of edge weight, $(\omega_{ai}-\omega_{ia})$, between city a and city i as s_{ai}. Therefore, we could use an independent-sample t-test to 105 s_{ai} values according to core–periphery theory (Wallerstein, 1979). Using 0 as test values, we classified 105 cities into three groups in locational advantages of PS firms, using the level of significance in the t-test: cities with outstanding locational advantages, cities with moderate locational advantages and cities with few locational advantages (see Table 3.4).

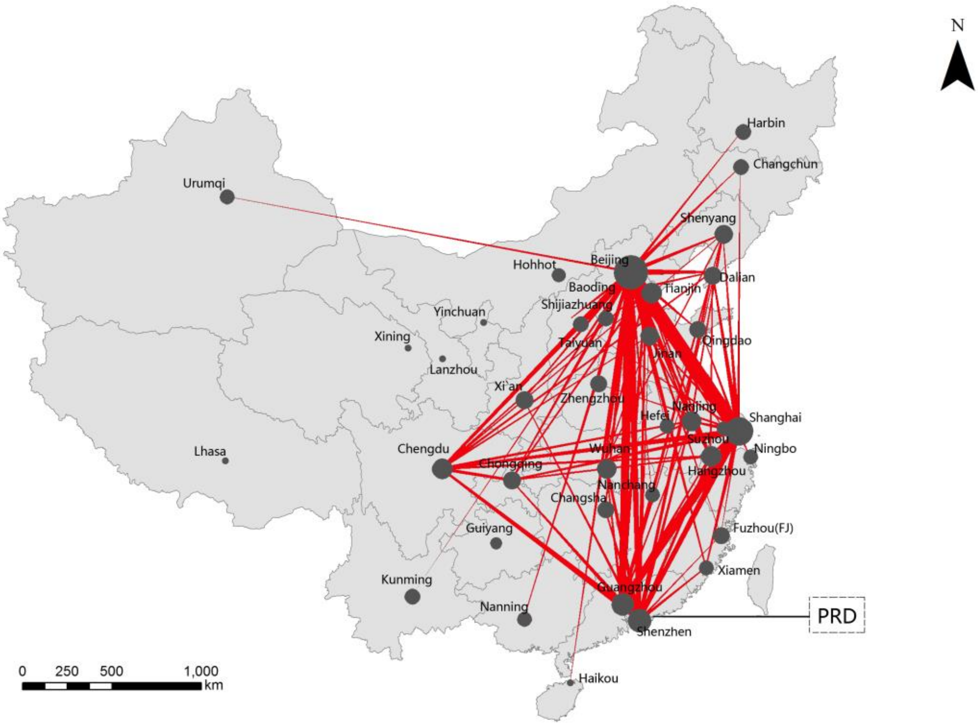

Figure 3.5 Asymmetric network of Chinese cities indicated by the LRM

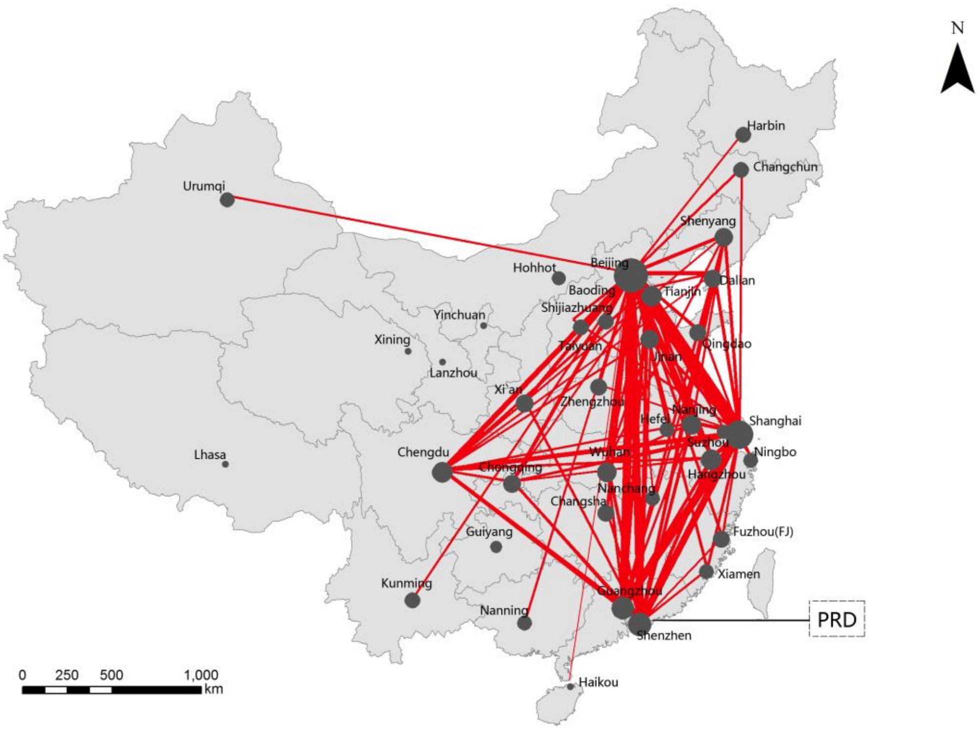

Figure 3.6 Symmetric network of Chinese cities indicated by the INM

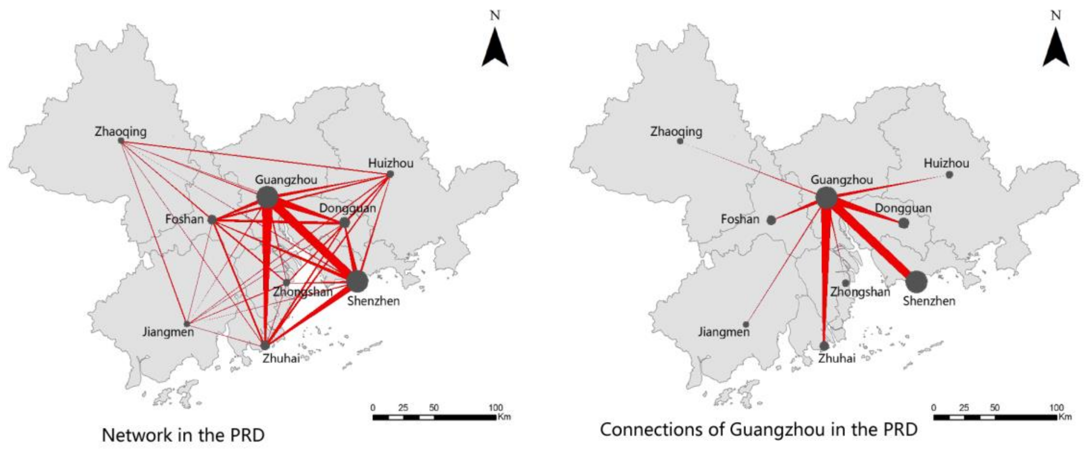

Figure 3.7 Asymmetric connections of Guangzhou in the PRD indicated by the LRM

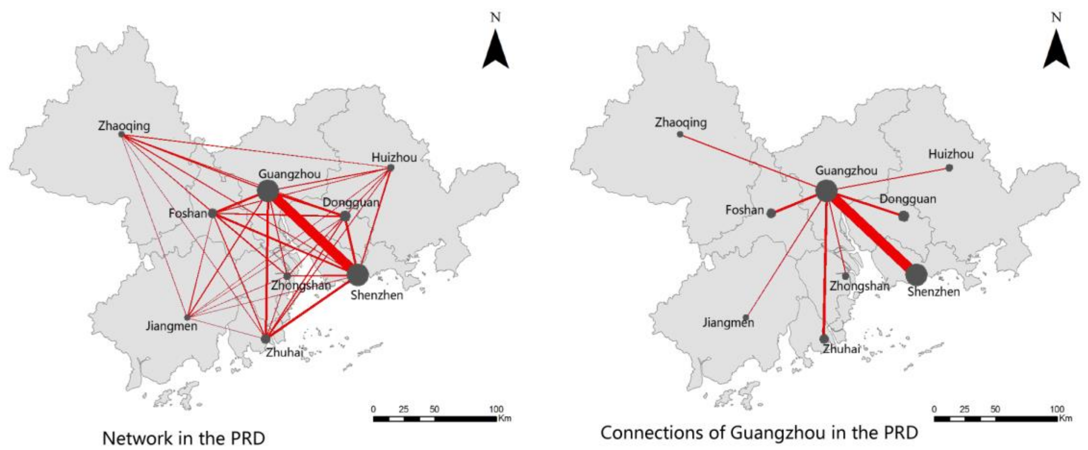

Figure 3.8 Symmetric connections of Guangzhou in the PRD indicated by the INM

Twenty cities have outstanding locational advantages for PS firms. These cities include Beijing and Tianjing in the region of Beijing–Tianjin–Hebei; Shanghai, Nanjing and Hangzhou in the Yangtze River Delta; and Shenzhen and Guangzhou in the Pearl River Delta. Four of the 15 cities with moderate locational advantages (i.e. Suzhou, Wuxi, Ningbo, Dongguan, etc.) are secondary cities in the Yangtze River and Pearl River deltas. The group of secondary cities also includes many provincial capitals like Changchun, Kunming, Haikou, Harbin, Nanning, Shijiazhuang, Hefei, Hohhot and Urumqi, which shows that these cities have locational advantages compared to the other cities in their hinterlands, but they are not outstanding in attracting locational resources (PS firms) compared to core cities in developed regions.

Moreover, we can see from the 71 cities with relatively few locational advantages that, in the locational distribution of companies in the PS sector, most cities are regarded as peripheral cities according to the independent-sample t-test. Whereas Taylor (2003) used multidimensional scaling to define cities as either core or peripheral, the LRM focuses directly on the asymmetry of edge weight between two cities, which precludes the problem that tends to occur in the multidimensional measurement of limits in parametric tests. It uses statistical methods to judge the directionality of one city to other cities, which shows the actual influence on every city of the polarization of locational distribution in leading PS firms.

Table 3.4 Locational advantage in city connection

Type	N	City
Outstanding advantages	20	Beijing(0.240)**, Shanghai(0.195)**, Shenzhen(0.115)**, Guangzhou(0.118)**, Chengdu(0.069)**, Tianjin(0.059)**, Wuhan(0.051)**, Nanjing(0.057)**, Hangzhou(0.056)**, Dalian(0.034)**, Chongqing(0.039)**, Shenyang(0.039)**, Jinan(0.038)**, Qingdao(0.032)**, Xiamen(0.020)*, Xi'an(0.026)**, Changsha(0.030)**, Fuzhou(0.022)**, Taiyuan(0.017)*, Zhengzhou(0.015)*
Moderate advantages	15	Suzhou(0.010), Changchun(0.009), Kunming(0.011), Hiakou(-0.010), Harbin(0.000), Nanning(0.005), Ningbo(0.009), Shijiazhuang(0.006), Hefei(0.002), Nanchang(0.002), Hohhot(-0.010), Urumqi(-0.002), Wenzhou(-0.006), Dongguan(-0.013), Wuxi(-0.004)
Few advantages	71	Baoding(-0.022)**, Guiyang(-0.013)*, Xining(-0.029)**, Lanzhou(-0.019)**, Zhuhai(-0.018)*, Yinchuan(-0.023)**, Foshan(-0.012)*, Lhasa(-0.038)**, Changzhou(-0.013)**, Yantai(-0.017)**, Nantong(-0.013)**, Quanzhou(-0.013)**, Dandong(-0.018)**, Huzhou(-0.017)**, Shantou(-0.018)**, Shaoxing(-0.014)**, Wuhu(-0.017)**, Yangzhou(-0.013)**, Zhenjiang(-0.014)**, Baotou(-0.017)**, Daqing(-0.017)**, Wushun(-0.017)**, Huangshi(-0.017)**, Huizhou(-0.017)**, Jiaxing(-0.014)**, Lianyungang(-0.017)**, Mianyang(-0.020)**, Qinhuangdao(-0.019)**, Taizhou(-0.013)**, Xiangtan(-0.018)**, Xuzhou(-0.017)**, Yuxi(-0.016)**, Zhongshan(-0.018)**, Zhuzhou(-0.019)**, Anyang(-0.019)**, Anshan(-0.017)**, Xianning(-0.010)**, Guilin(-0.022)**, Heyuan(-0.019)**, Jixi(-0.021)**, Jiangmen(-0.019)**, Jinzhou(-0.017)**, Jincheng(-0.017)**, Jingmen(-0.021)**, Liaoyang(-0.017)**, Liaocheng(-0.020)**, Longyan(-0.020)**, Maoming(-0.019)**, Meizhou(-0.019)**, Nanping(-0.020)**, Ningde(-0.020)**, Panjin(-0.019)**, Futian(-0.020)**, Tsitsihar(-0.017)**, Qingyuan(-0.019)**, Qujing(-0.015)**, Sanming(-0.020)**, Shaoguan(-0.019)**, Taizhou(-0.014)**, Tangshan(-0.018)**, Xiangfan(-0.021)**, Xinxiang(-0.019)**, Yanbian(-0.017)**, Yangjiang(-0.019)**, Yichang(-0.017)**, Yingkou(-0.017)**, Yongzhou(-0.020)**, Zhanjiang(-0.019)**, Zhangzhou(-0.018)**, Zhaoqing(-0.019)**, Sanya(-0.021)**

Note：Number in the bracket is the average of the s value, * significance >95%, ** significance >99%.

3.4.2 Features of varied kinds of centrality degree

1）Absolute degree in the LRM

We then continued to analyse cities' absolute degree from the LRM (see Figure 3.9). First, Shanghai and Beijing are at the top of the urban hierarchy among 106 cities in the regional distribution. However, Beijing is more connected than Shanghai as some SOEs' PS firms in Beijing would set up more offices to ensure that there are more cities to be served in the national network instead of merely competing for market share, something that is somewhat overlooked in Taylor and Derudder's (2010) analysis. Guangzhou and Shenzhen act as gateway cities at the city hierarchy level a little lower than Beijing and Shanghai, and behind them are 10 cities (Chengdu, Tianjin, Hangzhou, Wuhan, Nanjing, Dalian, etc.). Eight of these 10 cities are eastern coastal cities; the other two – Chengdu and Wuhan – are in the west and the middle of China, respectively (see Table 3.5). This shows that leading companies in the PS sector tend to concentrate their offices in eastern China rather than distribute them throughout the country.

Table 3.5 Twenty top cities in degrees of LRM and degrees of INM

Rank	LRM						INM	
	Absolute degree		Degree of type I		Degree of type II			
1	Beijing	5650.2	Shanghai	2967.3	Beijing	1031.3	Beijing	24880
2	Shanghai	4565.7	Shenzhen	2258.4	Shanghai	830.5	Shanghai	21150
3	Guangzhou	2959.8	Guangzhou	1798.4	Shenzhen	744.2	Shenzhen	17726
4	Shenzhen	2738.9	Beijing	1568.0	Guangzhou	704.7	Guangzhou	16847
5	Chengdu	1845.7	Chengdu	1529.9	Hangzhou	666.2	Hangzhou	14949
6	Tianjin	1679.7	Tianjin	1145.2	Nanjing	660.3	Tianjin	14882
7	Hangzhou	1517.6	Wuhan	1037.7	Wuhan	659.9	Chengdu	14868
8	Wuhan	1483.5	Hangzhou	967.2	Tianjin	659.1	Wuhan	14583
9	Nanjing	1467.4	Nanjing	950.1	Chengdu	650.3	Nanjing	14330
10	Dalian	1255.0	Dalian	918.6	Shenyang	640.6	Shenyang	13689
11	Chongqing	1247.1	Chongqing	836.8	Jinan	634.9	Jinan	13490
12	Shenyang	1212.8	Shenyang	817.2	Chongqing	622.1	Chongqing	13435
13	Jinan	1142.3	Jinan	771.0	Fuzhou	612.9	Xi'an	13056
14	Xi'an	1097.4	Qingdao	729.8	Dalian	611.7	Dalian	13036
15	Qingdao	1056.5	Xi'an	693.9	Xi'an	610.3	Fuzhou	12639
16	Xiamen	993.1	Xiamen	691.1	Changsha	607.4	Qingdao	12594
17	Changsha	989.6	Changsha	684.5	Zhengzhou	601.4	Changsha	12399
18	Fuzhou	954.0	Fuzhou	631.3	Qingdao	600.0	Zhengzhou	12216
19	Zhengzhou	817.1	Taiyuan	581.8	Kunming	592.0	Taiyuan	11871
20	Taiyuan	808.3	Suzhou	555.2	Taiyuan	588.7	Kunming	11667

We can see obvious polarization according to absolute degree (see Table 3.5), too: the absolute degree of Shenzhen (2738.9; rank: 4^{th} out of 106 cities) is half of that of Beijing (5650.2; rank: 1st). In general, compared to the significant gap among the first five cities with high absolute degrees (Beijing, Shanghai, Guangzhou, Shenzhen and Chengdu), decreasing gradients among other cities are smaller in absolute degree. This again indicates that competition for the locational resources of PS firms mainly occurs in leading cities.

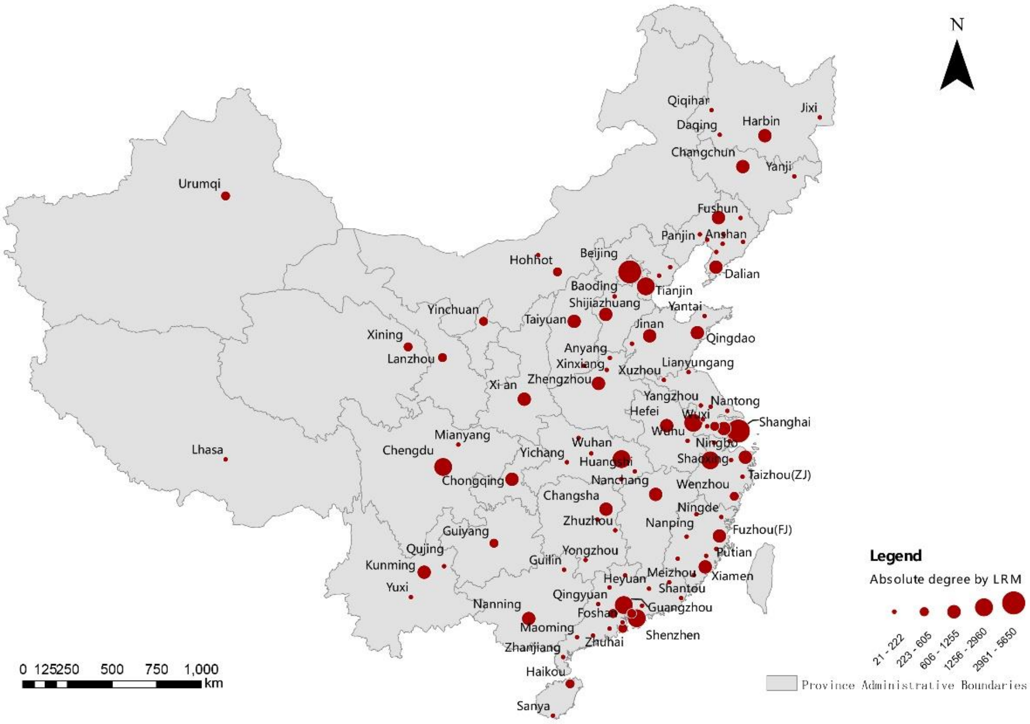

Figure 3.9 Geographic distribution of absolute degree indicated by the LRM

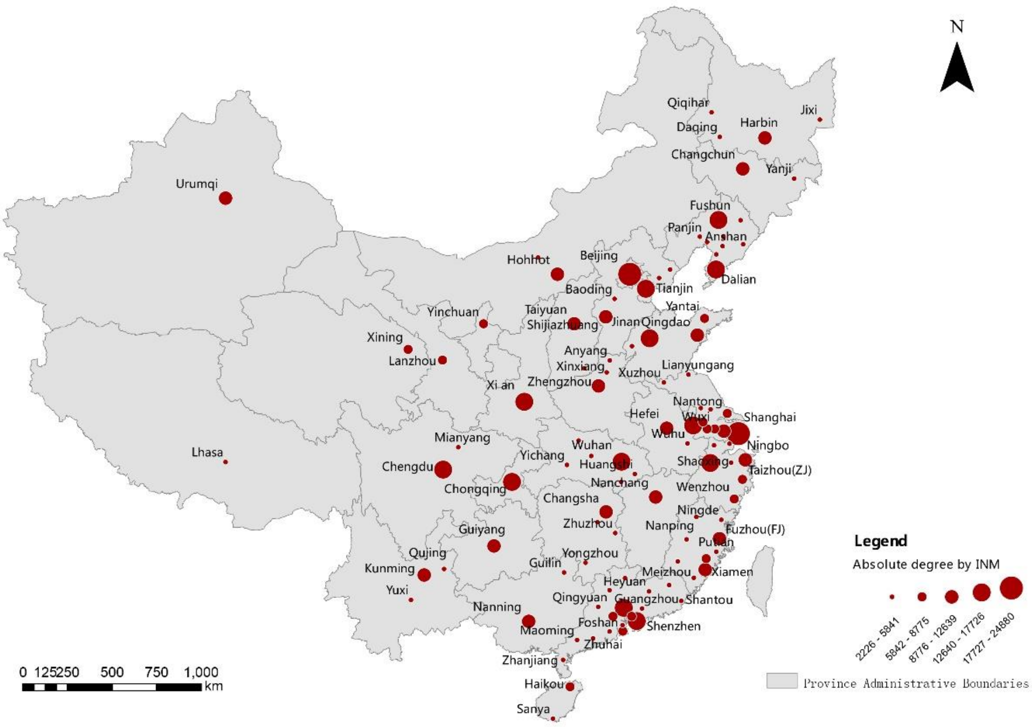

Figure 3.10 Geographic distribution of absolute degree indicated by the INM

2） Degree of type I connectivity

According to the original definition used in this research, the degree of type I connectivity is determined by the number of cities in which a company has offices. When a city mainly has companies that have offices located in a lot of places (e.g. Industrial and Commercial Bank of China, in mainland China), it will have less influence on the degree of type I connectivity.

We can see from the distribution of the degree of type I connectivity (see Table 3.5 and Figure 3.11) that Shanghai ranks number 1, followed by Shenzhen, Guangzhou and Beijing (4th). And we can see from the definition of degree of type I connectivity that Beijing is more likely to attract companies that have offices in many cities, while Shanghai and Shenzhen attract more companies with fewer offices. In fact, Beijing, as the capital of the nation, has more state companies with offices all over the country (Zhao, Liu & Derudder et al., 2015), whereas Shanghai and Shenzhen attract companies that only have offices in certain important places. The differences between the degree of type I connectivity and the absolute degree, indicated by the LRM, of the top four cities result from the locational strategy choices of diversified enterprises (see Table 3.5).

Figure 3.11 Geographic distribution of degree of type I connectivity indicated by the LRM

To explore the relationships of connectivity between the INM and the LRM, we adopted residual analysis, which was also used by Taylor, Derudder and Witlox (2007). In this way, the differences among diversified types of centrality can be captured by assessing the differences from the regression model. For any pair of variables whose relationship is assumed to obey a specific relation, the deviation from the value of the exception can be selected to reveal the difference between them.

In other words, the residual in a regression equation can not only measure the variable's degree of fit, but also find the significant figures that disobey the equation (Taylor, Derudder and Witlox, 2007). After transforming both variables by taking their logarithm, the following equation was used to describe the relationship:

$$ln(CI_a) = \alpha \pm \beta \cdot \ln(X_a) \pm \varepsilon_a \qquad (3-9)$$

CI_a is the degree of type I connectivity, Xa is connectivity of city a in IMN, α is the estimated intercept of the axis, β the estimated gradient, and ε_a is the residual, or error term, recording the difference between degree of type I connectivity of CI_a by the LRM, and city's connectivity X_a by the IMN for any given city.

We then used linear regression to analyse 105 cities (the degree of Xianning is too low to be compared with the other 105 cities) to see whether there are any differences between the distribution of two-dimensional scatters of degrees in INM and degree of type I connectivity in LRM. In the results, the residuals are reported as standardized measures (in units of their standard deviation from the mean) to aid interpretation. We could then observe the excursion of cities (by comparing the expecting value and actual value) from the residual results in standardized measures. In this way, we analysed the distinction between two types of degrees.

We found a strong correlation between the degree of CI indicated by the LRM and that indicated by the INM, with a coefficient of determination of 0.95 in the regression equation. Furthermore, the estimated gradient, β, is 1.97, which means that the urban hierarchy measured by the degree of type I connectivity is more obvious than that indicated by the INM. Hence the method of the LRM for degree of type I has succeeded in avoiding the problem in the INM by which the urban hierarchy is too flat. Here, we can see that many cities' actual degree of type I connectivity is higher than expected in the regression equation with a standard deviation of 0.5 (see Figure 3.12). Since the distribution modes of different companies in the PS sector vary, enterprises with a broad locational distribution (such as the Industrial and Commercial Bank of China, Bank of China, China Pacific Insurance Company, and other financial enterprises) contribute less to the scarcity of locational value for the host cities. On the other hand, companies that focus on gateway cities contribute a lot to the degree of type I connectivity. The result from the LRM shows the character of imbalanced geography of PS in China.

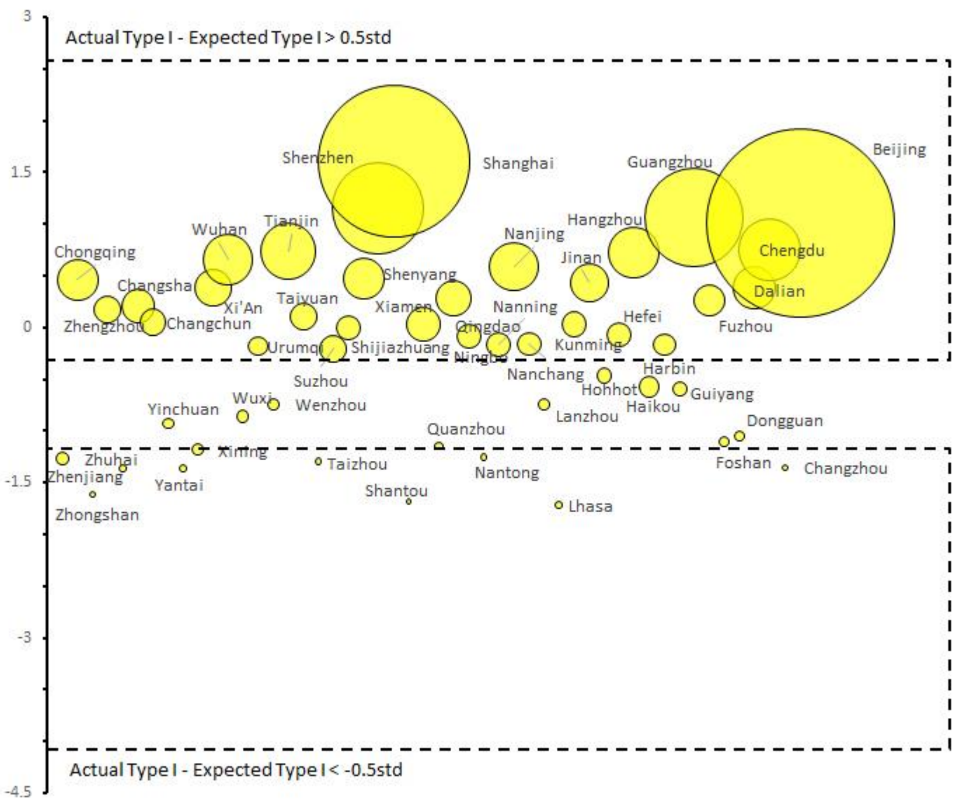

Figure 3.12 Residual results between the expected and the actual value of type I connectivity. The size of the circles indicates the degree produced by the INM.

3）Degree of type II connectivity

The degree of type II connectivity is based on the absolute degree in addition to the weight of the network size of neighbouring cities. When one city in a pair of city-dyad intends to link with neighbouring cities with more PS offices, that city is less important in the firms' locational choice strategy according to this city-dyad. In contrast, a city that intends to connect cities with fewer PS offices has a stronger locational attraction when offices are regarded as scarce resources.

In the sequence of cities, the degree of type II connectivity of the top 20 is usually larger than the absolute degree. Beijing, Shanghai and Shenzhen constitute the top 3 for type II connectivity (see Table 3.5 & Figure 3.13). Chengdu shows another significant difference between type II connectivity and absolute degree, indicating a relatively higher rank measured by the degree of type II connectivity, which means Chengdu connects more with such larger cities as Chongqing, Beijing and Shanghai, and less with cities in its own province. Similarly, Xiamen and Xi'an tend to link with top cities in city networks nationwide instead of in their hinterlands.

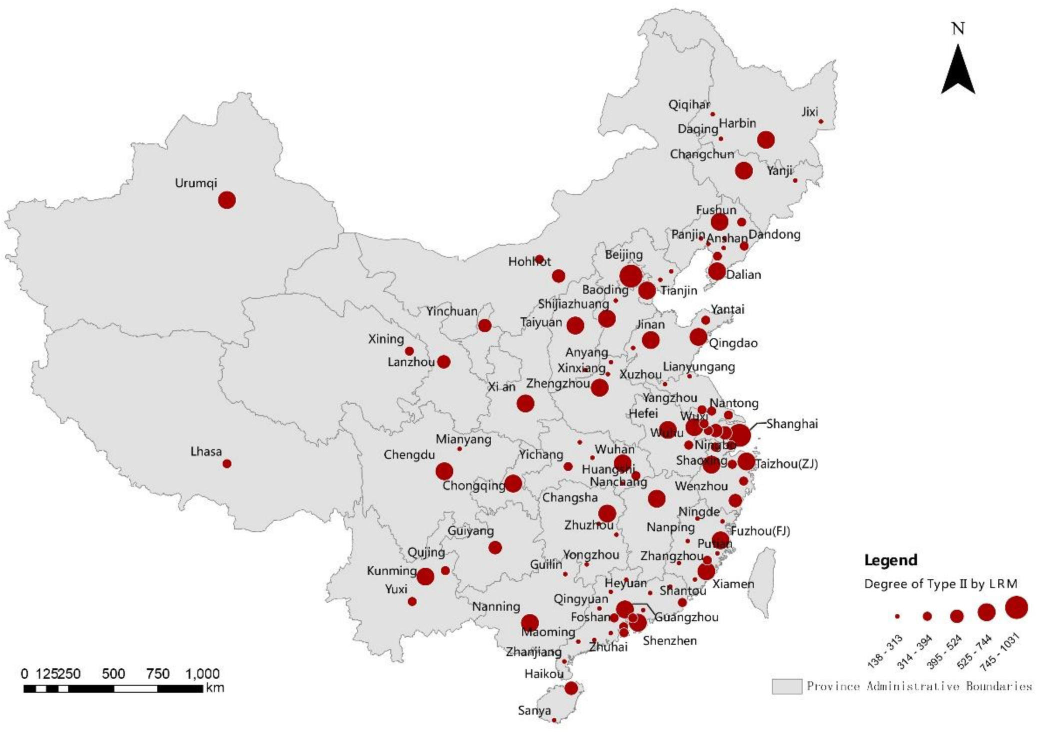

Figure 3.13 Geographic distribution of degree of type II connectivity indicated by the LRM

The distribution of type II connectivity is still strongly related to that of the INM. The regression between CII and IMN can be written as below:

$$ln(CII_a) = -0.6486 - 0.7469 \cdot \ln(X_a) \pm \varepsilon_a$$

We could then also compare the expected value of type II connectivity and its actual value from the residual results in standardized measures (see Figure 3.14). In this way, we analysed the difference between two types of degrees. The results show that some cities' actual degree of type II connectivity is higher than expected in the regression equation with a standard deviation of 0.5. These cities include Shanghai, Guangzhou, Shenzhen, Tianjin, Chengdu, Suzhou, Xining, Dalian, Foshan, Haikou and Xiamen. These cities also tend to link with other cities with fewer companies' offices. In contrast, the actual value of the degree of type II connectivity in cities, including Beijing, is lower than the expected value with a standard deviation of 0.5, and most of these are provincial capitals.

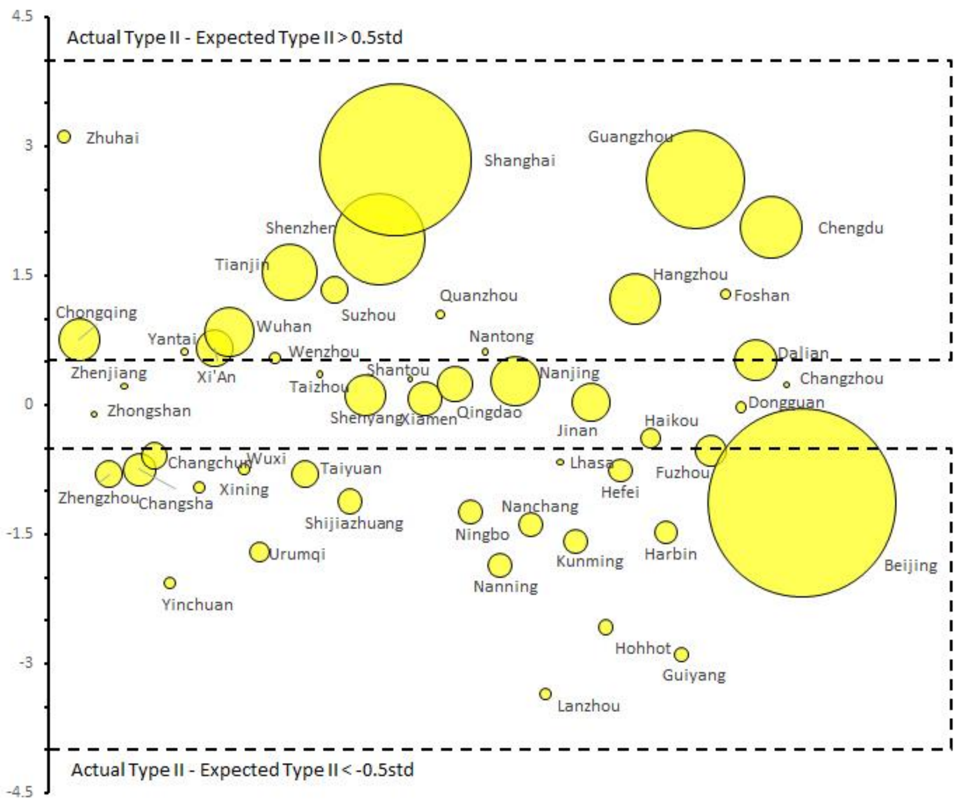

Figure 3.14 Residual results between expected and actual value of type II connectivity. The size of the circles shows the degree indicated by the INM.

Of the top 50 connected cities as measured by the INM, 31 are provincial capitals. We then compared the difference of the average for their residual results between expected value of type II connectivity and its actual value (see Table 3.6). We found significant differences between these two groups. Non-provincial capitals tend to link with stronger neighbouring cities that have a higher proportion of strategic offices, whereas provincial capitals link with less powerful neighbouring cities that have a larger share of general offices. In addition, small and medium-sized cities always rely on provincial capitals because of administration factors in this locational pattern. That is to say, provincial capitals serve as central places for small and medium-sized cities, which seldom attract offices except for state-owned banks.

Table 3.6 Residual results of capital and non-capital cities for type II

Group	N	Mean	Std. deviation	t	Sig.(2-tailed)
Capital cities	31	-0.464	1.515	-2.603	0.012
Non-capital cities	19	0.545	0.947		

3.5 Conclusion

The city networks of producer services (PS) firms represent the spatial organization of the urban system. To reflect the imbalanced geography of PS firms in the global economy, we applied a complementary method of measuring city networks, namely that of bipartite network projection through resource allocation. Inspired by the network of resource allocation dynamics, we used a weighting method to extract the hidden information of two-mode networks. That is to say, the location strategies of firms, which are always influenced by local governments seeking investments, are regarded as a process of recommendation. In this process, PS offices are regarded as scarce resources to be allocated in the bipartite network.

On this basis, the researchers explored the urban networks of 106 Chinese cities by using the algorithm of LRM. Provided by LRM, connections between two cities in a city network indicate an asymmetric flow. Based on further statistical analysis of asymmetry between each pair of city-dyads, core cities and peripheral cities were distinguished within China's urban system of PS firms under the model of the recommendation system of location choices. The results also suggest that typical provincial capitals tend to link with cities that accommodate firms with widely dispersed offices.

By comparing the degree of centrality between the LRM and the INM, further urban geographies of intercity networks can be revealed. In China, provincial capitals have had great power in the economy of the regional hinterland ever since the Yuan dynasty. Today, the development of most provinces still relies on their capital cities having an abundance of state-owned enterprises (Zhao, Liu & Derudder, 2015). In most provinces, PS companies set up offices only in the gateway cities of provincial capitals, whereas other smaller cities in peripheral areas accommodate several offices of state-owned banks, even though these banks mean poor efficiency for the local economy (Boyreau-Debray, Cull, Dollar, Honohan & For, 2003). Moreover, since cities' connectivity can be shown with different degrees, this helps to reflect the locational patterns of leading PS firms in practice. It should be noted that richer information can only be revealed when compared with the results of Taylor's (2001) interlocking network model. Therefore, this algorithm should supplement the INM rather than be used as a totally new methodology. This does not mean that the INM, which is used to map urban networks, should now be replaced by the network of resource allocation dynamics.

References

Alderson, A. S., & Beckfield, J. (2004). Power and position in the world city system. *American Journal of Sociology, 109*(4), 811-851.

Alderson, A. S., Beckfield, J., & Sprague-Jones, J. (2010). Intercity relations and globalisation: the evolution of the global urban hierarchy, 1981—2007. *Urban Studies, 47*(9), 1899-1923.

Bagchi-Sen, S., & Sen, J. (1997). The current state of knowledge in international business in producer services. *Environment & Planning A, 29*(7), 1153-1174.

Blattner, M., Zhang, Y. C., & Maslov, S. (2007). Exploring an opinion network for taste prediction: an empirical study. *Physica A: Statistical Mechanics & Its Applications, 373*(36), 753–758.

Boyreau-Debray, G., Cull, T. T. R., Dollar, D., Honohan, P., & For, S. J. W. (2003). Financial intermediation and growth: Chinese style. *Social Science Electronic Publishing*, 1-46.

Castells, M. (1996). *Rise of the Network Society*. Cambridge, MA: Blackwell.

Limtanakool, N., Dijst, M., & Schwanen, T. (2007). A theoretical framework and methodology for characterising national urban systems on the basis of flows of people: empirical evidence for France and Germany. *Urban Studies, 44*(11), 2123-2145.

Liu, X., & Derudder, B. (2013). Analyzing urban networks through the lens of corporate networks: a critical review. *Cities, 31*(2), 430-437.

Derudder, B., & Witlox, F. (2005). An appraisal of the use of airline data in assessing the world city network: a research note on data. *Urban Studies, 42*(13), 2371-2388.

Derudder, B., Taylor, P. J., Hoyler, M., Ni, P., Liu, X., Zhao, M., Shen, W., & Witlox, F. (2010). Measurement and interpretation of the connectivity of Chinese cities in the world city network. *Chinese Geographical Sciences, 23,* 261-273.

Derudder, B., Taylor, P. J., Ni, P., Vos, A. D., Hoyler, M., Hanssens, H., Bassens, D., Huang, J., Witlox, F., Shen, W., & Yang, X. (2010). Pathways of change: shifting connectivities in the world city network, 2000—08. *Urban Studies, 47*(9), 1861-1877.

Derudder, B., & Parnreiter, C. (2014). Introduction: the interlocking network model for studying urban networks: outline, potential, critiques, and ways forward. *Tijdschrift Voor Economische En Sociale Geografie, 105*(4), 373-386.

Dunning, J. H., & Norman, G. (1987). The location choice of offices of international companies.

Environment & Planning A, 19(5), 613-63.

Freeman, L. C. (2004). *The Development of Social Network Analysis: A Study in the Sociology of Science. The development of social network analysis: a study in the sociology of science*. Empirical Press.

Friedmann, J. (2008). The world city hypothesis. *Development & change, 17*(1), 69-83.

Hall, P. G., & Pain, K. (2006). *The polycentric metropolis: learning from mega-city regions in Europe*. Earthscan.

Hall, P. G. (1966). *The world cities*. McGraw-Hill.

Henanman, S., & Derudder, B. (2013). An alternative approach to the calculation and analysis of connectivity in the world city network. *Environment & Planning B Planning & Design, 41*(3), 392-412.

Hoyler, M., & Watson, A. (2013). Global media cities in transnational media networks. *Tijdschrift voor economische en sociale geografie, 104*(1), 90-108.

Liu, X., & Derudder, B. (2012). Two-mode networks and the interlocking world city network model: a reply to Neal. *Geographical Analysis, 44* (2), 171- 173.

Maslov, S., & Zhang, Y. C. (2001). Extracting hidden information from knowledge networks.. *Physical Review Letters, 87*(24), 358-358.

Neal, Z. (2011). Differentiating centrality and power in the world city network. *Urban Studies, 48*(13), 2733-2748.

Neal, Z. (2012). Structural determinism in the interlocking world city network. *Geographical Analysis, 44*(2), 162-170.

Neal, Z. (2013). Brute force and sorting processes: two perspectives on world city network formation. *Urban Studies, 50*(6), 1277-1291.

Neal, Z. (2014). Validity in world city networks. *Tijdschrift Voor Economische En Sociale Geografie, 105*(4), 427-443.

Neal, Z. (2015). Comparing real and possible interlocking world city networks. *Association of American Geographers*, April 21, Chicago, IL.

Sassen, S. (2001). *The global city: New York, London, Tokyo*. New Jersey: Princeton University Press.

Pain, K., Van Hamme, G., Vinciguerra, S., & David, Q. (2016). Global networks, cities and economic performance: Observations from an analysis of cities in Europe and the USA. *Urban Studie*s, 53(6), 1137-1161.

Taylor, P. J. (2014). A research odyssey: From interlocking network model to extraordinary cities. *Tijdschrift voor Economische en Sociale Geografie, 105* (4), 387-397.

Taylor, P. J., & Peter, J. (2001). Specification of the world city network. *Geographical Analysis*, *33*(2), 181-194.

Taylor, P. J., Catalano, G., & Walker, D. R. F. (2002). Exploratory analysis of the world city network. *Urban Studies*, *39*(4), 2377-2394.

Taylor, P. J., Walker, D. R. F., Catalano, G., & Hoyler, M. (2002). Diversity and power in the world city network. *Cities, 19*(4), 231–241.

Taylor, P. J. (2003). Metageographical moments: A geohistorical interpretation of embedded statism and globalization. In M.A. Tétreault, R.A. Denemark, K. P. Thomas and K. Burch (eds). *Rethinking Global Political Economy: Emerging Issues, Unfolding Odysseys London*: Routledge, 46-64.

Taylor, P. J. (2005). New political geographies: global civil society and global governance through world city networks. *Political Geography, 24*(6), 703–730.

Taylor, P. J., Derudder, B., & Witlox, F. (2007). Comparing airline passenger destinations with global service connectivities: A worldwide empirical study of 214 cities. *Urban Geography, 28*(3), 232-248.

Taylor, P. J., Evans, D. M., & Pain, K. (2008). Application of the interlocking network model to mega-city-regions: measuring polycentricity within and beyond city-regions, *Regional Studies, 42* (8), 1079-1093.

Taylor, P. J. J, Derudder, B., Hoyler, M., Ni, P., & Witlox, F. (2014). City-dyad analyses of China's integration into the world city network. *Urban Studies, 51*(5), 868-882.

Tichy, N. M., & Fombrun, C. (1979). Social network analysis for organizations. *Academy of Management Review, 4*(4), 507-519.

Wallerstein, I. (1979). *The Capitalist World-Economy* Cambridge: Cambridge University Press.

Zhao, M., & Liu, Z. (2012). Research on China's city network based on production service industry. *City Planning Review*. (in Chinese)

Zhao, M., Wu, K., Liu, X., & Derudder, B. (2014). A novel method to approximate intercity networks and its empirical validation. *Journal of Geographical Sciences*, 69(2), 169-183.

Zhao, M., Liu, X., Derudder, B., Zhong, Y., & Shen, W. (2015). Mapping producer services networks in mainland Chinese cities. *Urban Studies*, *52*(16), 3018-3034.

Zhou, T., Ren, J., & Medo, M. (2007). Bipartite network projection and personal recommendation, *Physical Review E, 76*(4), 046115.

Chapter 4: A novel method for measuring intercity networks and its empirical validation using the city networks in two Chinese city regions

Abstract: A network perspective is increasingly used as an organizational paradigm for understanding regional spatial structures. Based on a critical review of existing empirical models for measuring intercity networks based on firms' linkages, this study extends the recently proposed regional core city model algorithm (Henanman & Derudder, 2013) by presenting a new method for measuring urban networks that is based on the locational strategies of firms. The new method considers both regional and hierarchical network features and avoids the information loss associated with the conversion from two-mode firm–city networks to one-mode city–city networks. In addition, networks measurement by using the proposed method are suitable when employing social network analysis. The method has been empirically validated by examining intercity firm networks formed by producer services (PS) firms in China's two largest city regions, namely the Yangtze River Delta and the Pearl River Delta. The presented empirical analysis suggests two main findings. First, in contrast to conventional methods (e.g. the interlocking city network model), the new method produces regional and hierarchical urban networks that more closely resemble reality. Second, the new method allows us to use social network analysis to assess betweenness and closeness centralities. However, regardless of the model applied, the validity of any method that measures urban networks depends on the soundness of its underlying assumptions about how network actors (firms, in our case) interact.

This paper been adapted from: Zhao, M., Wu, K., Liu, X., & Derudder, B. (2015). A novel method for approximating intercity networks: An empirical comparison for validating the city networks in two Chinese city-regions. *Journal of Geographical Sciences*, *25*(3), 337-354.

4.1 Introduction

In the past 30 years, urban systems throughout the world have been profoundly influenced and reshaped by globalization and informatization, leading to a complicated change in geographical scope combined with widening spatial differentiation and mushrooming connectivity (Sheppard, 2002; Dicken et al., 2001; Florida, 2005). Against this background, connections between cities and regions have been reconstructed, resulting in city networks; that is, in spatial organizational structures that comprise different sized cities interconnected at different spatial scales (Camagni et al., 2004). The term 'network' – an appropriate metaphor for the complicated relationship between social actors in this new era – has recently also become popular in the fields of social science and economics (Dicken et al., 2001). Whereas interactions between globalization and regionalization have led to networked global production, the coexistence of space of place and space of flow due to informatization has facilitated networked regional spaces (Henderson et al., 2002; Castells, 1996; Wu et al., 2013).

Further, there has recently been increasing interest in researching global production and world city networks (Henderson et al., 2002; Taylor, 2004; Gregory et al., 2009). City network research can typically be roughly classified as, depending on the spatial scale, studies of world city networks or studies of polycentric urban regions, which investigate intercity connections and interactions at the global spatial scale and the national and regional spatial scales, respectively (Taylor, 2002; Hall et al., 2006). The empirical research of intercity networks has inspired a large body of literature that can be divided into three main strands, namely firm corporate networks (Wall et al., 2011), infrastructure networks (Derudder et al., 2005; Choi et al., 2006) and socio-cultural mechanisms (Taylor, 2005). The first strand of the three was the primary approach used in the present study, whereas one of the dominant concerns in network studies in western urban geography is producer services (PS) network research (Taylor et al., 2009).

The regional restructuring of PS has become one of the most important manifestations of economic globalization. Sassen (2001) stated that even though the production activities of multinational corporations have increasingly been dispersed, the demand for spatial aggregation in management and decision-making processes has increased. According to Sassen (2001), global cities are the management centres of global economic networks, while the fact that PS represent the core industry in those global cities indicates their leading function in the world economy. The status of the global cities in the global production system is further reflected by the PS multinational corporations, a reflection that is closely related to the theory of world cities proposed by Hall (1966) and Friedmann (1986).

In the study of world city networks, Taylor (2001) proposed an algorithm based on the interlocking network model (INM), which provides a powerful tool to reveal the characteristics of world city networks quantitatively. In China, although the theory of world cities was introduced and interpreted very early, empirical studies of PS networks have only recently been carried out. For example, the intercity network research by Zhao et al. (2012), Tang et al. (2010), Tan et al. (2011) and Lu et al. (2012) investigated PS networks in such prototypical Chinese city regions as the Yangtze River Delta (YRD), the Chengdu–Chongqing region and the Pearl River Delta (PRD). Moreover, Taylor et al. (2014) and Derudder et al. (2013) researched the connectivity of Chinese cities among world city networks. Nevertheless, most of the above empirical studies were based on the INM, whereas investigations that employ the network model or its algorithm are relatively scarce.

The discussion and reflection on the INM have recently become key theoretical issues, with many scholars questioning the INM algorithm. For instance, Neal (2012) analysed the use of the INM algorithm to examine multi-location corporations, and pointed out that it is actually a one-mode network derived via the transpose computing of a two-mode network with social networks. Liu et al. (2012; 2013) systematically compared existing algorithms related to city networks, while Henanman (2013) explored geographical networks through visualization. Henanman & Derudder (2013) further pointed out that the INM algorithm ignores the geographical characteristics of linkages between firms and proposed a substitute algorithm that takes account of geographical spaces and the hierarchy of firms.

In this chapter, we present an improvement to the alternative algorithm proposed by Henanman & Derudder (2013), which is based on western studies of intercity advanced producer service networks. Following the presentation of the model's assumptions and an empirical comparison, we present the two typical urban regions in China (the YRD and the PRD) as case studies to explore and empirically research the algorithm for PS networks. In this regard, we strove to extend the use of social network analysis in the research of city networks, which is the major innovation of our study.

4.2 Major algorithms of city networks

4.2.1 Algorithm of interlocking network model (INM)

The INM algorithm was proposed by Taylor in 2001. It is a quantitative method that measures intercity networks based on PS data. To understand network linkages, Taylor (2001) assumed that there are *m* PS firms located in *n* cities. The service value of city *a* can be defined as the importance of the firm's local office in one city within its overall office network. This can be expressed by V_{aj}, which represents the service value of firm *j* in city *a*. The $n \times m$ matrix consists of the service values of all the PS firms in different cities. According to Neal (2012), Liu et al. (2012) and Henanman &

Derudder (2013), the compiled database of the PS matrix is a two-mode network that comprises cities and firms. This database should be transformed into a one-mode network in order to project it as intercity relationships. Hence, the essentiality of the INM algorithm is a transformation from a two-mode city-by-firm network matrix into a one-mode city-by-city network matrix. The fundamental transformation of service value matrix *V* can be expressed as follows:

$$C_{abj} = V_{aj} \cdot V_{bj} \qquad (4-1)$$

Where V_{aj} and V_{bj} are the service values of firm *j* in cities *a* and *b*, respectively, and $C_{ab,j}$ indicates the linkages between city *a* and *b* based on firm *j*. Then, the total connections in city *a* and *b* can be expressed as follows:

$$C_{ab} = \sum_{j=1}^{m} C_{abj} \qquad (4-2)$$

Each city has a maximum of (*n*-1) links. Furthermore, any city's node degree *Ca* can be expressed as follows:

$$C_a = \sum_{i=1}^{n} C_{ai} \quad (a \neq i) \qquad (4-3)$$

However, although the INM algorithm introduces an effective way to convert a two-mode network into a one-mode network, it results in numerous invalid linkages. Specifically, because this conversion ignores the spatial characteristics of cities and hierarchical nature of firms, it leads to inevitable information losses and flattens the nodality of city networks (Neal, 2012; Liu et al., 2012; Henanman & Derudder, 2013). Moreover, the INM algorithm does not sufficiently reflect the degrees of closeness, betweenness, in-degree and out-degree, or other network statistical indices because of the limitations of the model's assumptions, which leads to a technical deficiency when analysing intercity PS networks.

4.2.2 Method of combining geographic and hierarchical features (CGHM)

Based on the limitations of the INM described above, Henanman & Derudder (2013) proposed a new model algorithm -combining geographic and hierarchical features model (CGHM). These features have two obvious effects on the measurement. First, firms' worldwide hierarchical distribution information is incorporated into the calculation. By allowing for spatiality in the organization of PS firms' office networks, and based on the PS firm's distribution within the global office organization, a city with the maximum geographic service value is selected as the external linkage portal in each region. Moreover, the manufacturing services firms with lower geographic values connect to high-level cities through portal cities. This approach reflects the importance of geographical adjacency on network linkage and is closer to the network linkage of the PS sector in real life. More important, this approach overcomes the flat city nodes produced by the INM.

Second, a baseline model is established for the network linkage in order to preserve the basic parameter distribution properties of the network structure (e.g. degree distribution). For this purpose, the shuffling approach is applied to randomly shuffle the several iterative swapping steps necessary for node linkages (i.e. permutation or bootstrapping in the social network). After this random upper-level directed change, the linkage routes and directions among network nodes are retained for the intermediary calculation and analysis of nodes.

The basic process of the CGHM algorithm can be briefly described as follows: for any firm *j*, find its maximum service value in region k where the office is registered by considering the following two cases. First, if both the regional service values of offices of firm *j* in cities *a* and *b* in the same region *k* are greater than 0, but not equal, then mark the intercity linkage of firm *j*'s network between *a* and *b* as 1, and otherwise as 0. Similarly, if cities *a* and *b* are from different regions, but each has the largest regional service value city in its own region, then the intercity linkage is marked as 1, and otherwise as 0. On this basis, we calculate the unidirectional $C_{ab,j}'$ as follows:

$$C_{ab}' = \sum_{j=1}^{m} C_{ab,j}' \qquad (4-4)$$

This formula, which reflects the directional and multiple relations between cities, can be used to calculate the in-degrees and out-degrees of every city in the network. In-degree can be understood as all the relations a branch in a certain city has with its headquarters, while out-degree indicates all the relations that the headquarters has with its branches. Furthermore, the vector feature of C_{ab}' (C_{ab}'+C_{ba}') can be used to represent all relation linkages between cities *a* and *b*. In other words, out-degree reflects the power of the city in which the firm's headquarters is located, while in-degree reflects the city's prestige and ability to attract investments (Alderson et al., 2004).

4.3 Improvements to the CGHM algorithm

As described in Section 2, it is often difficult to use the INM algorithm to analyse network structures in depth because some key indices, such as closeness degree and betweenness degree in social network analysis, cannot be calculated by the INM. Betweenness, initially introduced by Freeman (1979), was used by Henanman & Derudder (2013) to evaluate the importance of a city as a node in a network. Betweenness in city networks can be calculated by identifying the shortest paths between cities and then analysing the number of times each city as a node is passed through when using these shortest paths. Henanman & Derudder (2013), for example, adopted a stochastic network algorithm, which is an indirect measurement that provides only an approximate search calculation of these paths. The CGHM algorithm uses the path analysis of intercity connectivity matrices that result from merged offices from different firms instead of calculating all the possible paths among individual firms. Hence, the formula is as follows:

$$B_i = \sum_{a=1}^{n}\sum_{b=1}^{n}\frac{G_{ab}(i)}{G_{ab}} \qquad (4-5)$$

The algorithm proposed above suffers the authenticity problem of social network linkages. According to the detailed study of city linkages conducted by Rozenblat (2010), the hierarchical linkages among firms and cities have to be considered when measuring intercity networks, since two offices, with different firms, located in the same place/city might not have a business relationship. The process of network linkages between three firms (*1*, *2* and *3*) and four cities (*a*, *b*, *c* and *d*) is illustrated in Figure 4.1. Here, it is assumed that firm *1* is involved in city linkage *a–b*, firm *2* in city linkage *b–c*, and firm *3* in city linkages *b–d* and *c–d*. If we add up all the linkages generated by these three firms, a topological structure that consists of a triangle and an extra edge is formed.

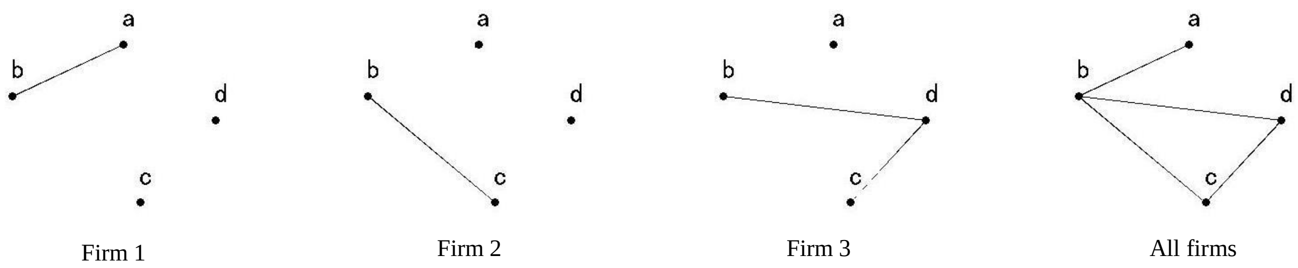

Figure 4.1 Overlaying process of firms' networks in cities

In Figure 4.1, city *b* acts as the intermediate node of cities *a* and *c* as well as of cities *a* and *d*. While the network statistical indices (e.g. average path length and closeness, as proposed by Freeman (1979)) are mathematically practical, this calculation confuses the linkages of firms *1*, *2* and *3* in cities *a*, *b*, *c* and *d*, which leads to the probability of false linkages. From the perspective of social networking, if there is no linkage between offices in firms *1* and *2* or between firms *1* and *3*, then city *b* cannot be regarded as an intermediate node between cities *a* and *c* or cities *a* and *d* (see the right-hand side of the overlay graph). In fact, the results of betweenness degree based on the merged offices of different firms are somewhat undermined by the same issue of false linkages.

To overcome the issue of false linkages, the present study focused on improving the calculation of betweenness. Following the linkage of each firm *j*, a separate calculation is conducted. This is denoted by $G_{ab,j}(i)$, which means evaluating the betweenness of each firm in the city–firm two-mode networks and then averaging the betweenness of all firms in the whole network. Thus, the whole calculation process of single firms can effectively avoid the authenticity issue faced when calculating the betweenness degree. The corresponding formula is as follows:

$$B_i = \sum_{j=1}^{m}\sum_{a=1}^{n}\sum_{b=1}^{n}\frac{G_{ab,j}(i)}{G_{ab,j}} \qquad (4-6)$$

Where B_i is the betweenness degree of city node i and $G_{ab,j}$ is the total number of possible shortest linkage paths between a and b in the network of firm j. $G_{ab,j}(i)$ represents the number of paths that pass through city i among all the shortest linkage paths between a and b in the network in which firm j is involved.

Similarly, we use Freeman's closeness degree, which is defined as the inverse of the sum of all the shortest step lengths between node i and all other nodes. For a firm network, it can be denoted as:

$$C_i = \sum_{j=1}^{m}\left[\sum_{a=1}^{n} d_{ai,j}\right]^{-1} \qquad (4-7)$$

Where C_i is the closeness degree of any city i and $d_{ai,j}$ is the shortest step length between a and i within the network of firm j. The closeness formula reflects the influence of network nodes on information flows as well as the degree of convenience when one city is linked to others in the city network. Additionally, the closeness of one node is defined as 0 when it has no link with other nodes in a firm network.

4.4 Data and study area

4.4.1 Data source

The city network linkage is a crucial way to investigate the regional organization of cities. Given the feasibility of data processing, empirical cases refer to polycentric urban region network studies in Europe. Similarly, Hall & Pain (2006) adopted the interlocking model to measure spatial linkages in Europe's mega-city regions, using the producer services data on multi-locational corporations compiled by the Globalization and World Cities Research Network (GaWC).

To collect data on producer services firms, we accessed the websites of PS firms that have branches in more than one city (data were collected in May 2010 and checked in August 2012), based on a related ranking of Chinese firms. In total, 290 firms were included in our sample (48 banks, 38 insurance companies, 30 law firms, 33 accounting firms, 31 consulting and architectural design firms, 25 advertising agencies and 85 securities companies). All firms were assigned to one of the following six quantitative levels (from 0 to 5) based on the reference PS values provided by the GaWC. When a firm is assigned 0, it means no office or a branch in that city, 5 refers to a city in which the headquarters is located, and 2 refers to a standard office or branch. Moreover, 1 and 3 refer to an office that is one grade below or above the standard level, respectively, and 4 refers to a city in which the regional headquarters is located. Of the 290 PS firms, 189 have branches in at least two cities.

4.4.2 Study area

Inspired by previous research by western scholars, we selected two typical high-level development city regions on the east coast of China, namely the YRD and the PRD, as our study cases. In the YRD region, there are 16 cities above prefecture level: Shanghai, Nanjing, Zhenjiang, Suzhou, Nantong, Yangzhou, Changzhou, Wuxi and Taizhou in Jiangsu Province, and Hangzhou, Huzhou, Jiaxing, Ningbo, Shaoxing, Taizhou and Zhoushan in Zhejiang Province. In the PRD region, there are nine cities, namely Guangzhou, Shenzhen, Foshan, Zhuhai, Dongguan, Jiangmen, Huizhou, Zhongshan and Zhaoqing, all of which are in Guangdong Province. Hence, 25 cities and 189 PS firms were available; we therefore took 189×25 of the matrixes as the database for the present research.

4.5 Results

4.5.1 The spatial distribution of intercity network connections

Given its authority in the analysis of PS networks, we used the INM algorithm to calculate the intercity network connections between these 25 cities (Figure 4.2). Further, we focused on the network characteristics of the top 10 cities ranked by node degree (Table 4.1). The INM algorithm provides a symmetrical matrix, with the linkages of Shanghai–Guangzhou and Shanghai–Shenzhen amounting to more than 1,000, much higher than Shanghai–Hangzhou (677) and Shanghai–Nanjing (576), even though Hangzhou and Nanjing are the two other provincial capital cities in the YRD. Moreover, the results of the INM algorithm show significant spatial connections between non-core cities in different regions, which ignores hierarchical features and thus could result in anomalies. For instance, Zhoushan in Zhejiang Province is the weakest city in the economy among all YRD and PRD cities. Yet, it has obvious intercity network linkages with Jiangsu and even some cities in Guangdong, the number of which exceeds the number of linkages it has with cities in its own province.

We then used the CGHM algorithm to analyse the intercity connections in the YRD and the PRD (Table 4.2). The table derived is an asymmetrical matrix, which is fundamentally different from that provided by the INM. The linkage assumption of the CGHM algorithm states that a subordinate firm must report to a higher one. First, we see that the top five intercity linkages are Shanghai → Hangzhou (25), Shanghai → Guangzhou (23), Shanghai → Shenzhen (23), Shenzhen → Shanghai

(22) and Shanghai → Nanjing (20), indicating that Shanghai, Shenzhen, Nanjing, Guangzhou and Hangzhou dominate regional producer services networks in the YRD and the PRD.

Table 4.1 Network matrix based on the INM

	SH	NJ	SZ	WX	HZ	NB	GZ	SN	DG	FS
SH		576	374	222	677	336	1153	1046	161	165
NJ	576		264	180	416	225	387	505	125	138
SZ	374	264		123	243	163	266	305	94	77
WX	222	180	123		163	132	177	207	97	90
HZ	677	416	243	163		260	482	563	133	134
NB	336	225	163	132	260		255	277	115	119
GZ	1153	387	266	177	482	255		720	168	159
SN	1046	505	305	207	563	277	720		186	178
DG	161	125	94	97	133	115	168	186		101
FS	165	138	77	90	134	119	159	178	101	

Note: SH = Shanghai; NJ = Nanjing; SZ = Suzhou; WX = Wuxi; HZ = Hangzhou; NB = Ningbo; GZ = Guangzhou; SN = Shenzhen; DG = Dongguan; FS = Foshan.

Table 4.2 Network matrix based on the CGHM

	SH	NJ	SZ	WX	HZ	NB	GZ	SN	DG	FS
SH		4	1	3	2	1	6	22	1	0
NJ	20		1	2	1	0	2	14	1	0
SZ	19	8		2	3	3	0	7	0	0
WX	16	10	5		9	6	3	11	1	0
HZ	25	3	1	2		1	3	14	1	0
NB	14	3	1	0	3		2	8	0	0
GZ	23	3	0	2	1	0		17	0	0
SN	23	4	1	2	2	0	6		1	0
DG	5	0	1	0	0	0	12	15		0
FS	5	0	0	0	0	0	13	17	2	

Note: SH = Shanghai; NJ = Nanjing; SZ = Suzhou; WX = Wuxi; HZ = Hangzhou; NB = Ningbo; GZ = Guangzhou; SN = Shenzhen; DG = Dongguan; FS = Foshan.

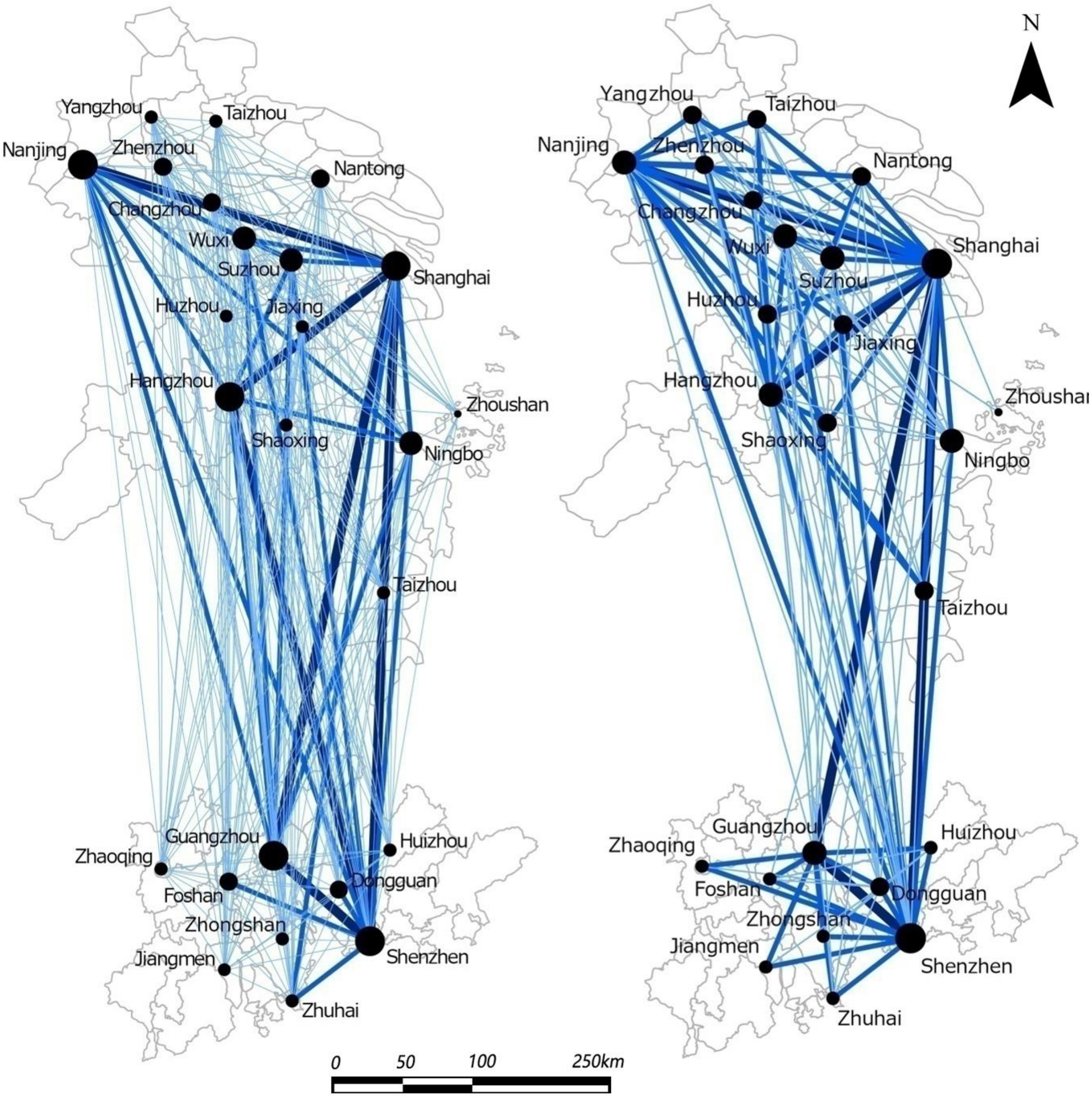

Figure 4.2 PS networks for the YRD and the PRD based on the INM and the CGHM

Second, the asymmetry of the CGHM table reflects the disequilibrium distribution of producer services. By observing each row in the Table 4.2, we can see that the number of headquarters or regional headquarters of producer services firms in Shanghai and Shenzhen is greater than 0, whereas the number of headquarters in Foshan is 0. This finding displays the characteristic of headquarters aggregation espoused in the world city hypothesis of Hall (1966) and Friedmann (1986), and confirms Sassen's (2001) opinion of global cities that the aggregation of management and control functions is strengthened even though production activities are dispersed regionally.

Third, the method of Taylor (2001) ignored the geographical restrictions on branch businesses, whereas the CGHM emphasized the importance of the regional headquarters of producer services. The difference is confirmed in the last two rows, which show that cities that rely on their manufacturing industries (e.g. Dongguan and Foshan) have less regional producer services headquarters compared to their export-oriented industries.

Figure 4.2 shows that the results of the CGHM algorithm somewhat ‘erased’ the connections between some cities established by the INM, clarifying the spatial pattern of intercity connections and mitigating the shortcoming that resulted from its calculation process (i.e. that it ignored geographical characteristics). In terms of the linking process within a firm’s internal network, a lower-level office will usually communicate with a local higher-level administrative office before contacting an office located outside the region. This process is dictated by the fact that the local higher-level office often has access to more company information and can tell the lower-level office which target local office(s) to contact, making it easier for the lower-level office to operate. In this way, the higher-level offices of a firm are more likely to act as network bridging nodes for the interregional connections between their lower-level offices.

Taylor et al. (2010) proposed two terms to explain the internal and external relationships of city connections: ‘town-ness’ and ‘city-ness’. The former is characterized by connections to the hinterland and is closely related to traditional central place theory, whereas the latter focuses on intercity connections. Economic globalization is an example of such interregional and external connections. Taylor also quoted Jacobs’s (1969) viewpoint to illustrate the importance of the external connections of cities rather than regional hinterlands. That is to say, a city cannot rely solely on its connections within regional hinterlands (Jacobs, 1969). Since the CGHM begins by dividing regions, a city’s connections to other cities within and outside the region need to be investigated. The node sets within each region were therefore divided according to a geographical scale. The linkage level k_{si} was then used to measure the sum of links between node i and the other city nodes within the region, while k_{ti} was used to express the summarized linkage level of node i in the whole network. Thus, the ratio of the regional connections of node i to the regional connections of all networks can be calculated as follows:

$$r_i = \frac{k_{si}/(n_{si}-1)}{k_{ti}/(n_{ti}-1)} \qquad (4-8)$$

Where n_{si} and n_{ti} refer to the number of neighbours of node i within the region and the entire network, respectively. If r_i is greater than 1, the connections of node i are considered to be intra-regional. If r_i is smaller than 1, this indicates that the external connections run outside the region.

By applying equation (4-8), we can thus calculate the intercity regional connections in the YRD and the PRD for the two network model algorithms (Table 4.3). It can be seen that, based on the INM, Shanghai, Nanjing, Hangzhou and Ningbo have lower internal connection ratios in the YRD, which demonstrates the trend towards the delocalization of the functional connections between the four cities in these two city regions. However, based on the CGHM, the internal connection ratios between all cities are greater than 1. Nanjing has a lower ratio of internal connections than Hangzhou, implying that the external connections of the former are more significant compared to the latter. In general, the contrasting results of these two algorithms are a natural outcome of the CGHM emphasizing the regional headquarters of producer services firms.

Similarly, based on the INM, Guangzhou, Shenzhen, Foshan and Zhongshan of the PRD have internal connection ratios that are smaller than 1. However, Shenzhen's external connections are more apparent than Guangzhou when the CGHM is used. This finding demonstrates the regional focus of this algorithm: the function of Guangzhou is closer to that of a provincial capital city; hence, its internal connections ratio under the CGHM is larger than that of Shenzhen. This result also reflects Shenzhen's stronger external linkages within the intercity producer service network.

Table 4.3 Ratios of intra-regional links based on the INM and the CGHM

YRD			PRD		
City	INM	CGHM	City	INM	CGHM
Shanghai	0.812	1.214	Guangzhou	0.793	1.988
Nanjing	0.988	1.475	Shenzhen	0.797	1.559
Zhenjiang	1.086	1.562	Dongguan	1.004	2.311
Suzhou	1.032	1.559	Zhuhai	1.068	2.24
Nantong	1.086	1.562	Foshan	0.995	2.453
Yangzhou	1.066	1.562	Zhaoqing	1.006	2.667
Changzhou	1.092	1.563	Shan	0.964	2.533
Wuxi	1.038	1.502	Jiangmen	1.006	2.667
Taizhou_JS	1.071	1.562	Huizhou	1.035	2.667
Hangzhou	0.956	1.485			
Huzhou	1.031	1.56			
Jiangxing	1.071	1.562			
Ningbo	0.998	1.514			
Shaoxing	1.071	1.561			
Taizhou_ZJ	1.055	1.562			
Average	1.030	0.963	Average	1.520	2.343

Another noteworthy finding is that cities in the YRD have lower internal connection ratios, which is not as obvious under the INM algorithm. We thus analysed the *t*-test results of the independent samples (see Table 4.4), with the significance level of the two-tailed test based on the Levene test value. The test showed that the significance level under the CGHM reaches $p<0.01$, whereas that under the INM does not pass the *t*-test. This result means that intercity producer services connections have more prominent interregional link characteristics in the YRD under the CGHM algorithm. Hence, the level of external connections is higher in comparison with the cities in the PRD.

Table 4.4 T test of the ratio of the intra-regional links for the YRD and PRD

Method	Variance	Levene test for equality		*t*-test for equality		
		F	Sig.	t	df	Sig. (2-tailed)
INM	Assume equal variances	13.856	0.001	-8.25	22	0.000
	Not assume equal variances			-6.494	8.567	0.000
CGHM	Assume equal variances	1.251	0.275	1.914	22	0.069
	Not assume equal variances			1.765	13.111	0.101

4.5.2 Comparing node degree by the two methods

Although node degree is an important issue in network research, there is no consensus on its numerical processing. We thus adopted a standardized method, in which the maximum value of each type was set at 1, followed by the ratio conversion of the range distribution from 0 to 1. Next, we compared the degree distribution under the two algorithms. For both algorithms, Shanghai's degree was the leading one, which was set at 1.

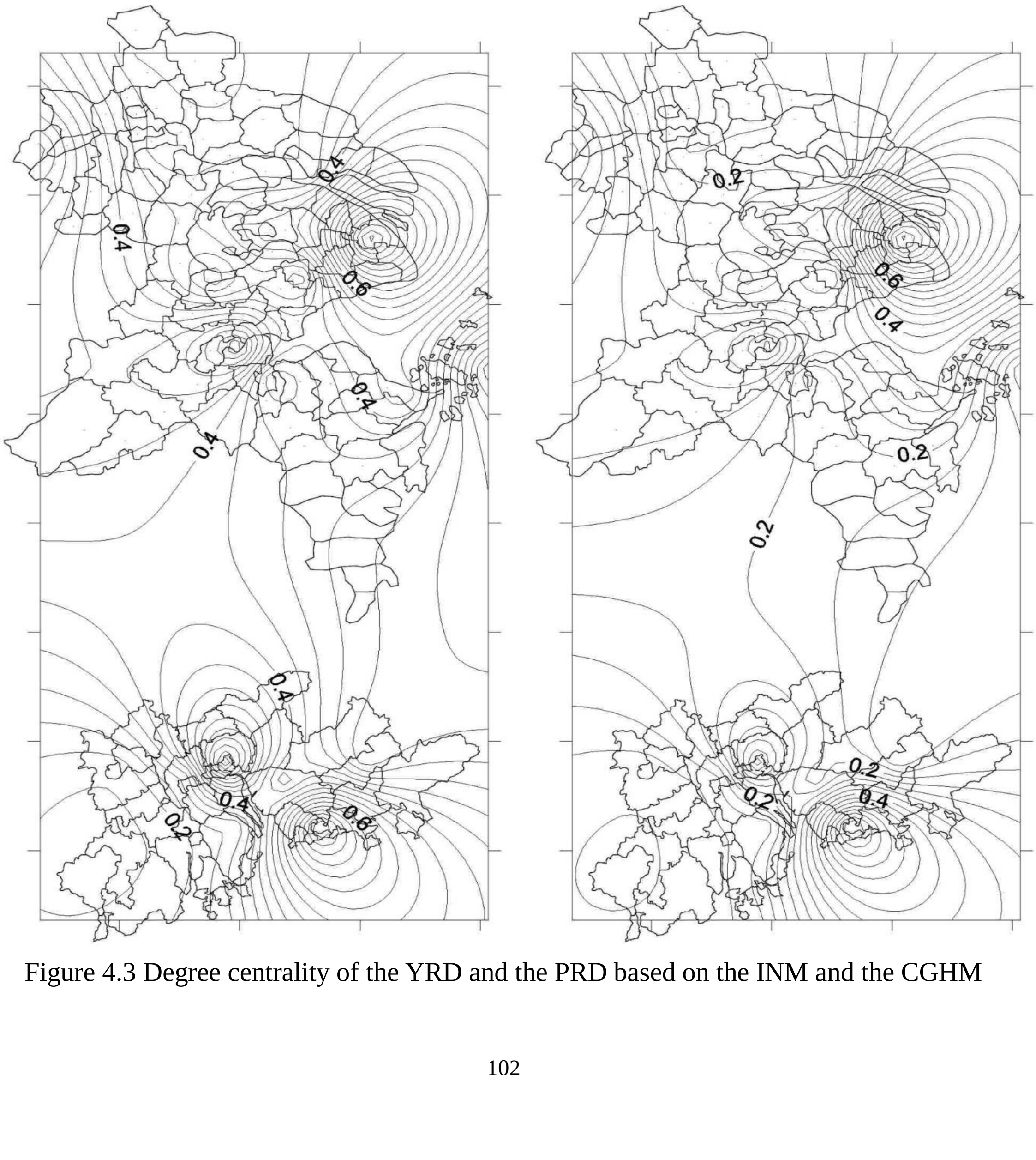

Figure 4.3 Degree centrality of the YRD and the PRD based on the INM and the CGHM

Figure 4.3 shows that the node degree under the INM gradually decreases. Only Zhaoqing and Jiangmen in the PRD and Zhoushan in the YRD have a degree smaller than 0.2. However, according to the CGHM's calculation results, a node degree below 0.2 is found for Yangzhou, Taizhou (Jiangsu), Changzhou, Nantong, Huzhou and Jiaxing in the YRD, as well as for Zhongshan, Zhaoqing, Jiangmen, Zhuhai, Dongguan, Huizhou and Foshan in the PRD.

We further adapted the degree in both algorithms to *P* in order to analyse the rank-size distribution. According to Newman (2003), Clauset et al. (2008) and Boccaletti et al. (2006), the degree distribution curve of the observable nodes in the geospatial network matches the scale-free characteristics, thereby presenting a power law distribution. The power law distribution of the nodes in the network can therefore be expressed as follows:

$$P_k = c \cdot k^{-\alpha} \qquad (4-9)$$

The rank-size distribution curve of node degree is shown in Figure 4.4 (Zhoushan is excluded because of its default data of degree). For both the CGHM and the INM, the distribution degree shows a clear power law distribution, with the coefficients of determination of the regression equations (R^2) being higher than 0.9 (Table 4.5). The CGHM calculation displays a steeper slope for the distribution curve of the regression equation than the INM (Figure 4.4). The α value in the rank-size regression equation is 0.859, which is higher than that under the INM algorithm (0.609). The prominent hierarchical characteristic of the CGHM can also be observed in Figure 4.4. Hence, given the geospatial polarization of world cities, we can conclude that the CGHM shows the dominance and controlling position of several cities in the YRD and the PRD.

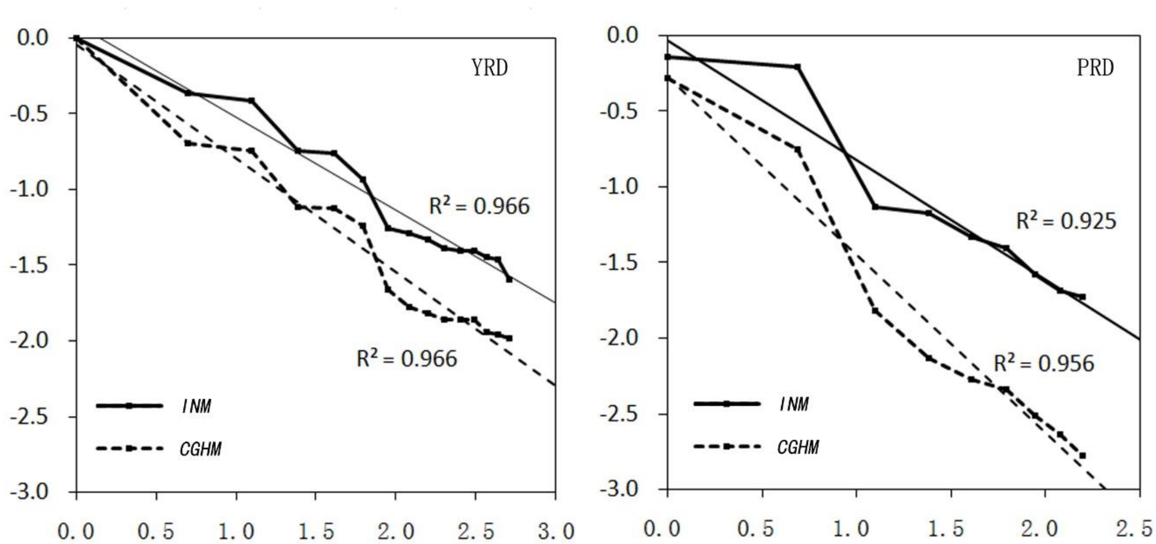

Figure 4.4 Distribution of degree based on the INM and the CGHM

Using the polycentric measurement of mega-city regions proposed by Hall et al. (2006) and Meijers and Burger et al. (2010), we adopted the rank-size analysis in order to measure the spatial organization in the YRD and the PRD. Both the degrees calculated by these two algorithms present a better fitting scale-free distribution and show clear differences in the spatial aggregation of producer services in the YRD and the PRD. Specifically, the intercity network in the YRD shows a flatter organizational characteristic, whereas spatial polarization still exists to some extent in the PRD. This difference is confirmed by the fitting degree of the CGHM algorithm, where the corresponding coefficient reaches 1.176 and conforms weakly to the typical primate city distribution.

Table 4.5 Regression equations of rank-size degree

	Algorithm	Regression equation	R^2
YRD	INM	$Ln(P_k)=-0.613ln(k)+0.088$	0.966
	CGHM	$Ln(P_k)=-0.751ln(k)+0.043$	0.966
PRD	INM	$Ln(P_k)=-0.792ln(k)+0.026$	0.925
	CGHM	$Ln(P_k)=-1.176ln(k)+0.271$	0.956

Further, we investigated the correlation of in-degree, out-degree, closeness and betweenness in each of the two algorithms (Figure 4.5). We found the correlation coefficients between the node degree of INM and out-degree / closeness / betweenness of CGHM are above 0.7, with a significant correlation of determination (R^2) of 0.881, 0.870 and 0.752, respectively, while there is poorer correlation between node degree of INM and in-degree of CGHM (R^2= 0.097). This result suggests that although the CGHM fits the INM well, the out-degree of the CGHM better reflects the actual hierarchical characteristics (Figure 4.5). Since the headquarters and other high-level offices of producer services firms are centralized in a few core cities (i.e. the out-degree of one city), an asymmetrical functional relation between cities is shown when using the CGHM. This relation is practically inevitable given the unequal regional distribution of headquarters and branches, and it results in the spatial aggregation of the control functions of world and global cities, as proposed by Friedman (1986) and Sassen (2001). Similarly, after studying the inequality of the production networks of multinational corporations, Dicken (2006) also found a difference between the definition of control and being controlled among the various sections of different companies' production systems. Moreover, Massey (1995) proposed that social relations are determined by ownership relations, namely the relation of spatial ownership portrayed as a geography of power relations – that of control versus being controlled, and influence versus being influenced. Hence, the in-degree and out-degree of the CGHM show the asymmetry of the economic connections in the YRD and the PRD and provide a geographical projection of the value chains in mega-city regions.

Table 4.6 shows the absolute dominance of Shanghai and Shenzhen in closeness and betweenness. However, Nanjing ranks third (higher than Guangzhou) for betweenness, which indicates that Nanjing plays the broker role more effectively, whereas Guangzhou may better connect the closeness of the other cities. Finally, 13 cities have a score of 0 for betweenness, reflecting the hierarchical phenomenon of the urban network in the two city regions examined in this study.

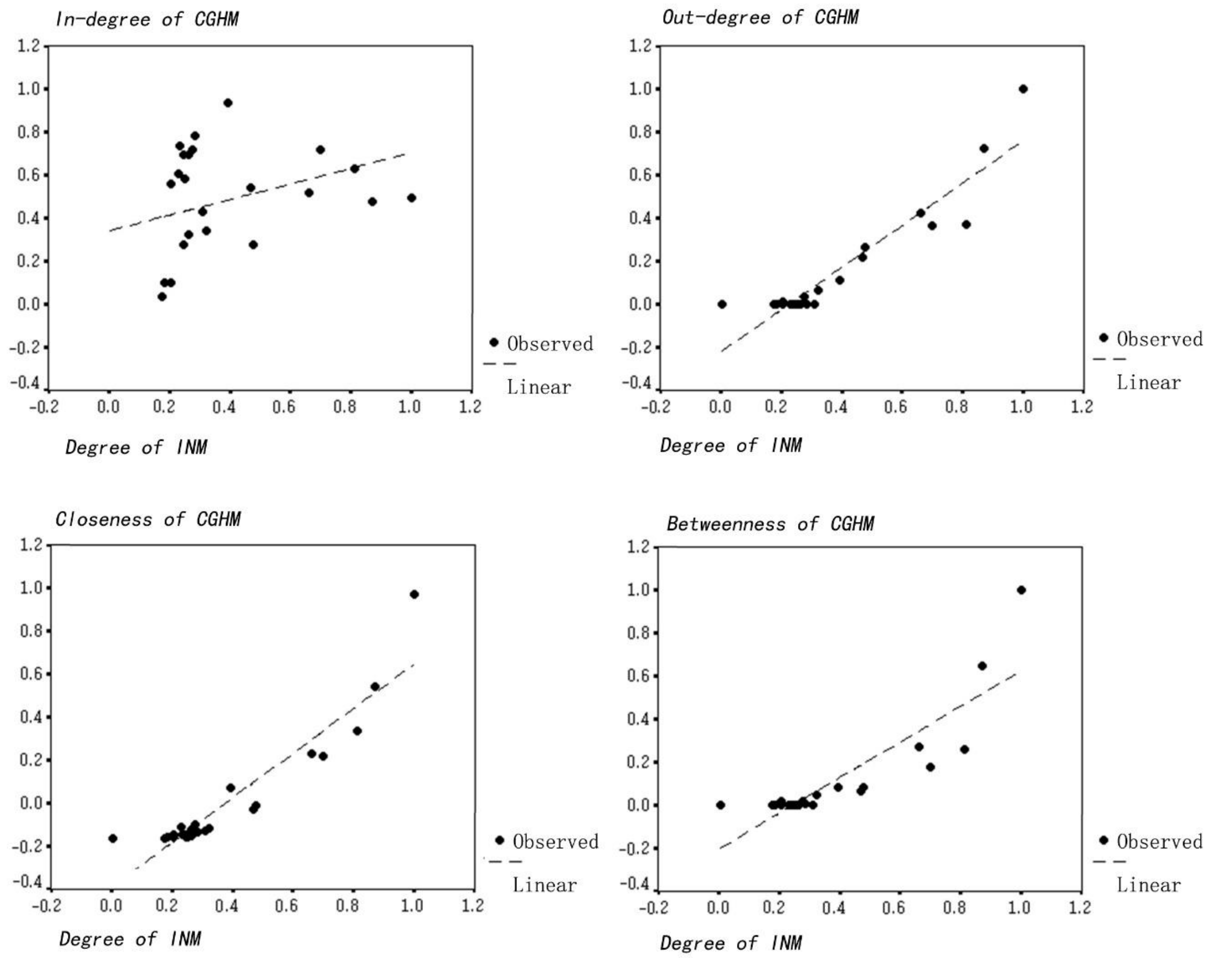

Figure 4.5 Comparison of degree centrality based on the INM and the CGHM

We further classified the sampled cities into five types based on node degree, betweenness and closeness and under the criterion of a standard deviation equal to 0.5 (Table 4.7). The type A cities are Shanghai, Shenzhen, Guangzhou, Nanjing and Hangzhou, which have outstanding results for all three indices, that is, good nodality, high connectivity and key positions compared with the other nodes. Shanghai is the leading type A city. The type B cities are Suzhou, Nantong, Wuxi, Changzhou, Ningbo, Shaoxing and Dongguan, which have moderate nodality performance in producer services networks. Zhuhai and Foshan are type C cities; they have a lower nodality degree and moderate values for the other indices. Zhenjiang, Yangzhou, Huzhou, Jiaxing and Taizhou in Jiangsu and Taizhou in Zhejiang have low closeness and are classified as type D. The type E cities are Zhaoqing, Zhongshan, Jiangmen, Huizhou and Zhoushan; they have lower than average nodality and closeness.

Table 4.6 Comparison of the degree nodality of the INM and the CGHM

City	Nodality		In-degree	Out-degree	Closeness	Betweenness
	INM	CGHM				
Shanghai	1.000	1.000	0.672	1.000	1.000	1.000
Nanjing	0.659	0.500	0.689	0.423	0.349	0.270
Zhenjiang	0.265	0.156	0.820	0.000	0.017	0.000
Suzhou	0.467	0.325	0.705	0.219	0.122	0.068
Nantong	0.284	0.169	0.885	0.000	0.032	0.005
Yangzhou	0.236	0.163	0.852	0.000	0.023	0.000
Changzhou	0.276	0.191	0.836	0.036	0.061	0.016
Wuxi	0.392	0.291	1.000	0.115	0.213	0.080
Taizhou_JS	0.246	0.156	0.820	0.000	0.012	0.000
Hangzhou	0.697	0.475	0.836	0.362	0.340	0.176
Huzhou	0.203	0.138	0.721	0.000	0.012	0.000
Jiangxing	0.246	0.156	0.820	0.000	0.019	0.000
Ningbo	0.476	0.328	0.508	0.265	0.140	0.080
Shaoxing	0.231	0.144	0.754	0.000	0.051	0.000
Taizhou_ZJ	0.250	0.141	0.738	0.000	0.011	0.000
Zhoushan	0.005	0.006	0.033	0.000	0.005	0.000
Guangzhou	0.813	0.472	0.770	0.373	0.443	0.257
Shenzhen	0.868	0.756	0.656	0.724	0.624	0.644
Dongguan	0.323	0.163	0.557	0.065	0.047	0.048
Zhuhai	0.264	0.103	0.541	0.000	0.042	0.000
Foshan	0.309	0.119	0.623	0.000	0.036	0.000
Zhaoqing	0.178	0.063	0.328	0.000	0.004	0.000
Zhongshan	0.245	0.097	0.508	0.000	0.021	0.000
Jiangmen	0.185	0.072	0.377	0.000	0.010	0.000
Huizhou	0.207	0.081	0.377	0.011	0.020	0.019

In general, the CGHM algorithm effectively improved the social network analysis results, showing that it more comprehensively characterizes the intercity PS networks than the INM. Moreover, since the INM algorithm assumes that all non-local branches are connected (i.e. an orthogonal network without the weights), it is inadequate for social network analysis, which is why western researchers of world city networks rarely perform this analysis using such an algorithm.

Table 4.7 Classification of the cities based on the CGHM

	Characteristics	Cities
A.	Significantly high nodality, closeness and betweenness	Shanghai, Shenzhen, Guangzhou, Nanjing and Hangzhou
B	Significantly high nodality and closeness	Suzhou, Nantong, Changzhou, Wuxi, Ningbo, Shaoxing and Dongguan
C	Significantly low nodality	Zhuhai and Foshan
D	Significantly low closeness	Zhenjiang, Yangzhou, Huzhou, Jiangxing, Taizhou-JS and Taizhou-ZJ
E	Significantly low nodality and closeness	Zhaoqing, Zhongshan, Jiangmen, Huizhou and Zhoushan

4.6 Discussion and conclusion

Understanding intercity network connectivity on the basis of PS firms is an important way to investigate the spatial organization of city regions. However, although it is an important methodology for measuring city linkages or connections, this study proposes a new method for measuring urban networks by using the locational strategies of PS firms. Specifically, we performed the traverse computation of individual firms throughout the entire process and applied a combination of geographical space and the firm's hierarchy. In this way, we avoided the information loss associated with the projection from a two-mode firm–city database to a one-mode city–city database, and thereby understood the actual social network linkage process.

In the presented empirical interpretation of two large metropolitan areas in China (i.e. the YRD and the PRD), the improved CGHM algorithm reveals clear hierarchical and geographical characteristics and better describes the spatial structure of intercity producer servicing networks. More importantly, we were able to use the network analysis indicators (node degree, closeness, betweenness, in-degree and out-degree) to broaden the research perspective on PS networks.

While the empirical analysis in this chapter was based on only two city regions, theoretically a minimum of three city regions are needed to ensure that the algorithm can calculate intercity PS networks adequately. Further, because we assumed that the only interregional linkage in a city network is through the primate city of each region to all the core cities, which have the highest service values in the network, the shortest path between any two cities can occur in at most three regions. To illustrate this point, for any network of firm *j*, if no linkages between core cities *a* and *b* in the two regions exist, and they therefore have to be linked through a third-party city *i* with the highest service value, the maximum number of path steps is four, which includes the five cities as nodes (Figure 4.6).

For example, let us take the three large city regions of the YRD, the PRD and Beijing–Tianjin–Hebei. When calculated using the CGHM, Shanghai has a higher total node degree (615) than Beijing (480). However, Beijing has a higher out-degree (486) than Shanghai (480), which reflects the power of control by PS headquarters. During the actual calculations, the practical use of the betweenness measure is limited by the amount of big data, and advanced calculation tools and software systems are also necessary. Therefore, given the limitation imposed by the length of this chapter, we focused only on the factors that need consideration, without going into the detailed computations.

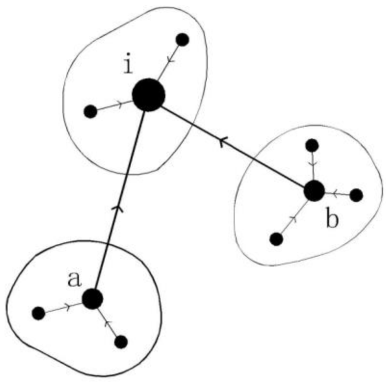

Figure 4.6 Possible topology based on the CGHM for three regions

Moreover, the CGHM algorithm is not perfect owing to the limitations of its assumptions, such as the issue of spatial scaling and firms' hierarchy. Further, the algorithm takes account of the 'region' in the model, which means that the choice of geographical units greatly influences the model results. Additionally, although some general network indices such as closeness and betweenness can be calculated through the CGHM in the path length analysis, the algorithm cannot calculate clustering coefficients, indicating that although it better reflects regional spaces and hierarchy, its specific method of analysis requires improvement.

As deductive analyses carried out using any theoretical model rest on the assumption(s) of the model's hypotheses, the structure of city networks is also constrained by the calibration model of the basic data. In this regard, our study has revealed only the tip of the iceberg. The empirical studies of the Randstad region carried out by Burger et al. (2010, 2013) showed that the functional polycentricity of mega-city regions has diversified patterns. Indeed, the external spatial characteristics of a city network depend on the actual sample type, which is indicative of a complicated macro-level system. Therefore, the internal and external spatial relations of urban regions cannot simply be determined by using one or two theoretical models.

Finally, although the algorithm of intercity networks continues to be debated by urban scholars, it is crucial that academic research continues to find deficiencies in and make improvements to existing theories. Innovations resulting from the continuing research into PS networks might include field investigations into producer services firms, whereas future studies should aim to clarify the mechanics of city connections and to make conclusive improvements to the various algorithms on the basis of those findings.

References

Alderson, A. S., & Beckfield, J. (2004). Power and position in the world city system, *American Journal of Sociology, 109*(4), 811-851.

Boccaletti, S., Latora, V., Moreno, Y., Chavez, M., & Hwang, D. U. (2006). Complex networks: structure and dynamics. *Physics reports*, *424*:175-308.

Burger, M. J., Knaap, B. V. D., & Wall, R. S. (2014). Polycentricity and the multiplexity of urban networks. *European Planning Studies, 22*(4), 816-840.

Camagni, R., & Capello, R. (2004). *The city network paradigm: theory and empirical evidence*. Netherlands: Elsevier BV.

Castells, M. (1996). *The rise of network society*. Oxford: Blackwell.

Choi, J. H., Barnett, G. A., & Chon, B-S. (2006). Comparing world city networks: A network analysis of Internet backbone and air transport intercity linkage. *Global Networks, 6*(1), 81-89.

Clauset, A., Moore, C., & Newman, M. (2008). Hierarchical structure and the prediction of missing links in networks. *Nature*, *453*(7191): 98-101.

Derudder, B., Taylor, P. J., Hoyler, M., Ni, P., Liu, X., Zhao, M., Shen, W., & Witlox, F. (2010). Measurement and interpretation of the connectivity of Chinese cities in the world city network. *Chinese Geographical Sciences, 23*, 261-273.

Derudder, B., & Witlox, F. (2005). An appraisal of the use of airline data in assessing the world city network: A research note on data. *Urban Studies, 42*(13), 2371-2388.

Dicken, P. (2006). *Global shift: mapping the changing contours of the world economy*. New York: Sage Publications.

Dicken, P., Kelly, P., Olds, K., & Yeung, H. (2001). Chains and networks, territories and scales: Towards a relational framework for analyzing the global economy. *Global Networks, 1*(2), 89-112.

Florida, R. (2005). *Cities and the creative class*. New York: Routledge.

Freeman, L. (1979). Centrality in social networks: Conceptual clarification. *Social Networks, 1*(1), 215-239.

Friedmann, J. (1986). The world city hypothesis. *Development and Change*, *17*(1), 69-83.

Gregory, D. (2009). *The Dictionary of Human Geography* (5th Edition). Oxford: Wiley-Blackwell.

Hall, P. G., & Pain, K. (2006). *The polycentric metropolis: learning from Mega-City Regions in Europe*. London: Earthscan.

Hall, P. (1966). *The world cities*. London: Heinemann.

Henderson, J., Dicken, P., Hess, M., Coe, N., & Yeung, H. W-C. (2002) Global production networks and the analysis of economic development. *Review of International Political Economy*, *9*(3), 436-464.

Henanman, S. (2013). Information-rich visualization of dense geographical networks. *Journal of Maps*, *9*(1), 68-75.

Henanman, S., & Derudder, B. (2013). An alternative approach to the calculation and analysis of connectivity in the world city network. *Environment and Planning B: Planning and Design*, *41*(3), 392-412.

Jacobs, J. (1969). *The economy of cities*. New York: Vintage.

Liu, X., & Derudder, B. (2012). Two-mode networks and the interlocking world city network model: A reply to Neal. *Geographical Analysis*, *44*(2), 171–173.

Liu, X., & Derudder, B. (2013). Analyzing urban networks through the lens of corporate networks: A critical review. *Cities*, *31*(2), 430-437.

Lu, X., Ma, X., & Li, G. (2012). Spatial pattern of regional city network based on international advanced producer services' layout in Pearl River Delta. *Economic Geography*, *32*(4), 50-54. (in Chinese)

Massey, D. B. (1995). *Spatial divisions of labor: social structures and the geography of production*. New York: Routledge.

Meijers, E., & Burger, M. (2010). Spatial structure and productivity in U.S. metropolitan areas. *Environment and Planning A*, *42* (6), 1383-1402.

Neal, Z. (2012). Structural determinism in the interlocking world city network. *Geographical Analysis, 44*(2), 162-170.

Newman, M. (2003). The structure and function of complex networks. *SIAM Rev.,45*,167-256.

Rozenblat, C. (2010). Opening the black box of agglomeration economies for measuring cities' competitiveness through international firms networks. *Urban Studies*, 47(13), 2841-2865.

Sassen, S. (2001). *Global city: New York, London, Tokyo*, New Jersey: Princeton University Press.

Sheppard, E. (2002). The spaces and times of globalization: place, scale, networks and positionality. *Economic Geography, 78*(3), 307–330.

Tan, Y., Yang, Y., & Leng, B. (2011). Urban network system in the Chengdu-Chongqing Region in the perspective of advanced producer services. *Progress in Geography, 30*(6), 724-732.(in Chinese)

Tang, Z., & Zhao, M. (2010). Economic globalization and transformation of urban System in the Yangtze River Delta Region: Interlocking network and value-added Hierarchy. *Urban Planning Forum, 187*(1), 29-34. (in Chinese)

Taylor, P. J. (2002). Measurement of the world city network. *Urban Studies, 39*(13), 2367-2376.

Taylor, P. J. (2004). *World city network: a global urban analysis*. London and New York: Routledge.

Taylor, P. J. (2005). New political geographies: Global civil society and global governance through world city networks. *Political Geography, 24*(6), 703-730.

Taylor, P. J., Evans, D. M., & Pain, K. (2009). The UK space economy as practiced by advanced producer service firms: Identifying two distinctive polycentric city-regional processes in contemporary Britain. *International Journal of Urban and Regional Research, 33*(3), 700-718.

Taylor, P. J. (2001). Specification of the world city network. *Geographical Analysis*, *33*(2), 181-194.

Taylor, P. J. (2007). Cities within spaces of flows: theses for a materialist understanding of the external relations of cities. In Taylor, P. J., Derudder, B., Saey, P., *Cities in Globalization: Practices, Policies and Theories.* London: Routledge, 287-297.

Taylor, P. J., Derudder, B., Hoyler M., Ni, P., & Witlox, F. (2013). City-dyad analyses of China's integration into the world city network. *Urban Studies, 50*(7), 1-15.

Taylor, P. J., Hoyler, M., & Verbruggen, R. (2010). External urban relational process: Introducing central flow theory to complement central place theory. *Urban Studies, 47*(13), 2803-2818.

Wall, R. S., & Knaap, G. A. (2011). Sectoral differentiation and network structure within contemporary worldwide corporate networks. *Economic Geography, 87*(3), 267-308.

Wu, K., Fang, C., Zhao, M., & Chen, C. (2013). The intercity space of flow influenced by high-speed rail: A case study for the rail transit passenger behavior between Beijing and Tianjin. *Acta Geographical Sinica, 68*(2), 159-174. (in Chinese)

Zhao, M., & Liu, Z. (2012). Research on China's city network based on production service industry. *City Planning Review*, (9), 23-28, 38. (in Chinese)

Chapter 5: Polycentric development in China's megacity regions, 2001–08: a Comparison of the Yangtze and Pearl River Deltas

Abstract: Large-scale urban regions are increasingly functioning as the territorial backbone of the global economy. Many of these mega-city regions are polycentric in that they consist of a range of densely interwoven cities and towns. The purpose of this chapter is to analyse the geographies of these polycentric networks in what are arguably China's two most important mega-city regions: the Yangtze River Delta (YRD) and the Pearl River Delta (PRD). To this end, we deployed a methodology that allowed the analysis of the shifting spatial organization of mega-city regions through the lens of the headquarters–branches linkages of corporations; that is, we explored the mega-city regions' constituent urban networks by looking at the ownership linkages running from a corporation's headquarters to the corporation's branches. In the process, this research extended and refined the statistical tools that are often deployed to measure polycentricity. Our results suggest that in both the YRD and the PRD there are more and more linkages interconnecting the mega-city region. The two regions share the following features: the general level of polycentricity is increasing, even though the concentration of headquarters is also increasing; and the growth of the general level of polycentricity mainly originates from higher levels of network density. There are, however, also fundamental differences between the YRD and the PRD: firms in the PRD are more likely to set up branches beyond the prefectures' boundaries, which results in higher levels of network density than in the YRD; there is a relatively 'flatter' intercity network in the YRD compared to the PRD, in which there are more firms' links interconnecting the four major cities (Guangzhou, Shenzhen, Dongguan and Foshan), rather than other small and medium-size cities; and there has been a significant shift in the YRD whereby Nanjing and Hangzhou now attract more branches than Shanghai, whereas there is no obvious equivalent change taking place in the PRD.

This chapter is adapted from: Zhao, M., Derudder, B., Zhong, Y., & Junhao, H. (2016). Polycentric development in China's megacity regions, 2001–08: a Comparison of the Yangtze and Pearl River Deltas. *Die Erde*, under review.

5.1 Introduction

In recent decades, geographers have observed that as global economic integration proceeds, an extensive archipelago of large city regions is coming into being (e.g. Petrella, 1995; Veltz, 1996; Sassen, 2001; Newman & Thornley, 2011; Reades & Smith, 2014; Timberlake et al., 2014). Leading geographer Allen Scott (2001), for instance, coined the term 'global city regions' to indicate that a number of large-scale metropolitan areas are increasingly functioning as the spatial foundations of the global economy that has been taking shape since the end of the 1970s, while influential empirical studies have been carried out by Hall & Pain (2006), who explored the polycentric networks of eight mega-city regions in Europe.

In China, the multifaceted growth dynamics of global city regions present a number of challenges to researchers and policymakers alike. In the recent planning document 'New Path of Urbanization (2015-2020)' for China, the central government envisions mega-city regions as a functional whole, instead of any single megacity, to accommodate the linkages emerging from migrants from rural areas. Although the literature on mega-city regions in China has been referred to extensively ever since Hall (1999) recognized the megacities of the Yangtze River Delta (YRD) and the Pearl River Delta (PRD), the study of city networks has only recently started. Furthermore, analysing city regions from the perspective of corporate structures has become a hot topic in China (Zhang & Wang, 2008; Tang & Zhao, 2010; Luo, 2010; Lu et al., 2012; Zhao et al., 2013; Yuan, Wei & Chen, 2014; Yeh, Yang & Wang, 2015).

However, most of these studies mainly paid attention to the major cities in China at one time point and almost ignored the evolution of horizontal corporate networks among city regions (Derudder, Taylor & Hoyler et al., 2010; Zhao, Liu & Derudder, 2015; Yeh, Yang & Wang, 2015; Zhang & Kloosterman, 2016). Since a comparison of the changes in city regions would provide a better understanding of the evolution of city regions (Hall & Pain, 2006; Florida, Gulden & Mellander, 2008; LeGates, 2014; Liu, Derudder & Wu, 2016), we propose to analyse polycentric developments in city regions in China. As an empirical study parallel to the comparison study of eight mega-city regions in Europe (Hall & Pain, 2006), we also paid more attention to the changes in typical city regions in China.

5.2 Review polycentrism

5.2.1 General research on polycentric city regions

Although a global city or world city defines the external relations of city regions, the organization of polycentric networks is the main feature of city regions from the perspective of its internal spatial logic. Scott (2001: 814) paid little attention to the analysis of the internal spatial organization of global city regions, and simply points out that they 'represent an outgrowth of large metropolitan areas – or contiguous sets of metropolitan areas – together with surrounding hinterlands of variable extent which may themselves be sites of scattered urban settlements.' The ensuing challenge of describing and analysing the shifting 'internal' spatial organization of global city regions has resulted in a rapidly evolving urban–regional literature. In the event, a plethora of concepts have been devised, whereby 'polycentric mega-city regions' (PMCRs; see Hall & Pain, 2006) has emerged as the favoured term. Obvious examples include large metropolitan regions such as the German Rhine–Ruhr region – a conurbation extending from Dortmund–Bochum–Essen–Duisburg in the north to the urban areas of Monchengladbach, Düsseldorf, Cologne and Bonn in the south (see Münter, 2011) – and the Dutch Randstad region, which is a conurbation comprising the four largest Dutch cities (Amsterdam, Rotterdam, The Hague and Utrecht) and the surrounding areas (see Van Oort et al., 2010). Both metropolitan regions are obvious examples of the key tenets of this literature, in that the complexity of their 'internal' spatial organization is either explicitly or implicitly related to the increased insertion of some (or all) of their constituting parts in external (i.e. non-regional) networks.

To date, the empirical focus of research on PMCRs has been firmly on city regions in northwest Europe and, albeit to a lesser degree, North America. For instance, a vast number of scientific papers on this topic have emerged from the POLYNET project. The purpose of POLYNET was to compare and analyse the polycentricity of eight emerging European mega-city regions. As regards the 'reality' of polycentricity, the basic criticism has been that a dense, urbanized region with multiple cities of varying sizes in close proximity to each other does not by definition point to the presence of polycentricism and its purported advantages. Or, as Meijers (2008) has aptly put it: 'Summing small cities does not make a large city' (see also Meijers and Burger, 2010). Current research has therefore continue to work on a more through empirical substantiation of the concept of polycentrism (Kloosterman and Musterd, 2001; Parr, 2004; Turok and Bailey, 2004). According to Meijers (2008), a region can only be considered polycentric when there are strong functional linkages between different nodes across the region. He thus coins the term 'relational polycentricity' or 'functional polycentricity' as opposed to 'morphological polycentrism', which more simply points to the co-existence of different more or less important cities in a region without the necessity of having interactions between these (Meijers, 2007). That is to say, the study of urban networks is of importance for measuring the polycentric development of city regions in current literature.

5.2.2 Research on polycentric city region in China

The literature on polycentric city regions has been referred to extensively in Chinese academic research ever since it was first introduced from Western academia (Tang & Zhao, 2010; Zhao et al., 2014; Yeh et al., 2014). However, comparative studies of the evolution of urban networks in city regions in China have been thin on the ground. Hence, the purpose of this research is to contribute to this literature by analysing the shifting polycentric network of the YRD and the PRD. These shifts were assessed for 2001–08, a period of increased global connectivity for China in general and its mega-city regions in particular (Derudder et al., 2010; Yeh et al., 2014; Timberlake et al., 2014; Zhao, Liu & Derudder et al., 2016; Zhang & Kloosterman, 2016). Although the city regions of the YRD and the PRD have major urban eye-catchers such Shanghai, Guangzhou and Shenzhen (Derudder et al., 2010; Zhao, Liu & Derudder et al., 2016), both city regions are in fact densely urbanized regions with cities located nearby and, to varying degrees, functionally integrated.

In the era of globalization, most local governments in China compete with each other to attract more firms, and especially their headquarters, from all over the world to maintain their connections with the government at different levels (Fan et al., 2007; Li et al., 2008; Pan & Xia, 2014). Policymakers seem always interested in each other's regional development experiences, and most them used to compete with each other for potential investment from the external world. During this process it was natural for them to compare the regional differences resulting from the aspects of society and geography. More directly, observing firms' performance in the context of contemporary China is popular among scholars (Pan & Xie, 2014; Jiang & Nie, 2014; Xia & Walker, 2015). For instance, there has been research to find the relationship between firm performance and ownership type across regions (Jiang & Nie, 2014; Xia & Walker, 2015). Based on these current research gaps and planning practicing needs, this study focuses on analysing the polycentric progress of typical mega-city regions in China. The evolution of both the degree of centrality and the topological structures was analysed. This was the main purpose of the research.

5.3 Data and methods

5.3.1 Study area

The YRD and the PRD city regions are recognized as potentially the most top-tier world city regions in China. They are also the two prospective Chinese mega-city regions identified by Hall (1999). That is to say, the spatial structures of the YRD and the PRD are closer to Hall's initial definition of megacity, although Beijing–Tianjin–Heibei (BTH) is also listed by the central government of China as a top-tier world city region in the 'New path of urbanization for China (2015–2020)'. The significant regional disparity within the BTH, indicated by poor areas around Beijing, would have resulted in unclear results had it been compared with the PRD and the YRD, where such differences are relatively small. Therefore, this research focused on comparing the development of polycentricity in the two more typical city regions, the YRD and the PRD.

There are 16 above prefecture-level cities in the YRD, which is made up of eight prefecture regions in Jiangsu Province, seven prefecture regions in Zhejiang Province and the whole area of Shanghai Municipality. Of these above prefecture-level cities, Nanjing, Wuxi, Changzhou, Suzhou, Nantong, Yangzhou, Zhenjiang and Taizhou–JS are in Jiangsu province, and Hangzhou, Ningbo, Jiaxing, Huzhou, Shaoxing, Zhoushan and Taizhou–ZJ are in Zhejiang Province. There are nine cities in the PRD (Guangzhou, Shenzhen, Foshan, Zhuhai, Dongguan, Jiangmen, Huizhou, Zhongshan and Zhaoqing), all of which are in Guangdong Province (Figure 5.1).

Figure 5.1 Location of city regions in the YRD and PRD

Table 5.1 presents the basic features of cities in the YRD and the PRD in 2008. It shows that cities in the PRD are relatively smaller than those in the YRD in terms of area and population. And most cities in the YRD have higher fixed assets investments, which is mainly related to the infrastructure projects dominated by the central or local governments, as a proportion of regional GDP, than those in the PRD, whereas the development of cities in the PRD is more likely related to the import and export trade with the external world. In general, cities in the YRD have an economic geography with more features of a state-owned economy and a less dense population than cities in the PRD.

Table 5.1 Basic features of city regions in the YRD and PRD in 2008 (sources: Statistical yearbook of Yangtze and Pearl River Deltas, Hong Kong and Macau 2009)

City region	Cities	Area (km^2)	GDP (Billion Yuan)	Population (Million)	FAI (Billion Yuan)		FDI (Billion US Dollars)	Import and export (Billion US Dollars)
					All	State owned		
YRD	Shanghai	6341	1369.8	18.88	482.95	229.6	10.08	322.14
	Nanjing	6582	377.5	7.59	215.42	48.6	2.37	40.59
	Wuxi	4788	442.0	6.11	187.70	34.9	3.17	56.03
	Changzhou	4385	220.2	4.41	144.82	21.8	2.04	17.63
	Suzhou	8488	670.1	9.13	261.12	33.6	8.13	228.53
	Nantong	8001	251.0	7.15	150.54	12.0	2.94	16.69
	Yangzhou	6634	157.3	4.47	95.00	12.7	1.51	6.18
	Zhenjiang	3847	140.8	3.04	71.85	12.3	1.20	7.46
	Taizhou_JS	9411	196.5	5.74	75.96	16.0	0.24	13.81
	Hangzhou	16596	478.1	7.97	198.05	73.4	3.31	48.07
	Ningbo	9816	396.4	7.07	172.82	48.8	2.54	67.84
	Jiaxing	3915	181.5	4.23	100.68	19.7	1.36	19.83
	Huzhou	5818	103.5	2.82	52.52	7.7	0.80	5.59
	Shaoxing	8256	222.3	4.64	91.33	9.9	0.77	23.83
	Zhoushan	1440	49.0	1.05	33.94	16.9	0.16	6.05
	Taizhou_ZJ	5797	139.4	4.64	90.05	10.9	1.05	6.34
PRD	Guangzhou	7434	821.6	10.18	210.15	79.7	3.62	81.97
	Shenzhen	1953	780.7	8.77	146.43	49.0	4.03	299.96
	Zhuhai	1688	99.2	1.48	37.23	12.6	1.14	46.84
	Foshan	3848	433.3	5.95	123.06	11.6	1.81	42.21
	Jiangmen	9541	128.1	4.14	37.82	4.4	0.92	13.16
	Zhaoqing	14856	71.6	3.80	32.63	5.4	0.86	3.81
	Huizhou	11158	129.0	3.93	58.87	16.5	1.35	29.75
	Dongguan	2465	370.3	6.95	94.31	9.6	2.45	113.30
	Zhongshan	1800	140.9	2.51	44.50	6.0	0.75	25.91

Note: FAI=fixed assets investments, FDI= foreign directed investment.

5.3.2 Data sources

There are diverse types of flows between cities: actual connections (e.g. airline networks: Smith & Timberlake, 2001), virtual connections (e.g. internet backbone networks: Zoon, 2001; Townsend, 2001) and indirect connections, in the form of spatial corporate organizations (Pred, 1977; Taylor, 2001; Anderson & Beckfield, 2004). As Timberlake et al. (2014) have argued, cities are sites of ongoing human activity and repositories of the history of this activity (Timberlake et al., 2014). Hence, urban networks should be seen as the interaction of agents' activities among cities. According to this view, spatial corporate organizations have also been used to indicate indirect flows between cities (Pred, 1977; Taylor, 2001; Anderson & Beckfield, 2001). On the other hand, employment by corporate organizations in city regions in China is closely related to the process of urbanization (Yuan, Wei & Chen, 2014; Lin, Li & Yang et al., 2014; Li, Deng & Wang, 2014; Fang

& Lin, 2015). Therefore, this research used the firms' networks to explore the polycentric process of city regions in the YRD and the PRD.

Various data sources can be used when analysing the networks of spatial corporate organizations between cities. The most popular was put forward by Taylor (2001), who calculated the connections between cities by using the offices of advanced producer services firms. According to Taylor's (2001) Interlocking Network Model (INM), there are connections not only between headquarters and branches, but also between branches. For instance, Derudder and Taylor (2013) used this method in their empirical study of Chinese cities' networks. However, the relatively 'flatter' and empirically richer intercity network emerging from this model is perhaps also the model's shortcoming (Liu & Derudder, 2013).

Another type of firms' connections takes ownership links in the corporate organization of firms as the cities' connections, which is suggested by Alderson & Beckfield (2004, 2010) and Rozenblat and Pumain (2007). The linkage between cities is solely defined as the connection between headquarters and branches, as it is often assumed that large firms are more likely to establish branches and thus form intercity linkages (see, however, Godfrey & Zhou, 1999). That is, urban networks are defined by looking at the ownership linkages running from headquarters to other parts of the firm, as these linkages represent 'a direct interaction between the city where the headquarters are located and the city where the subsidiary is owned' (Rozenblat & Pumain, 2007, p. 131; see also Alderson & Beckfield, 2004; Liu & Derudder, 2013). In this approach, the urban network specification is very straightforward: it results in an asymmetric (from headquarters city to subsidiary city) and valued (number of ownership linkages) intercity matrix. This approach, however, does not go beyond what is strictly supported by the available data. That is, it is assumed that the headquarters–subsidiary relations of Fortune 500 companies are more tangible than other possible inter-urban relations in firm networks, which require far more conjecture.

To circumvent this problem, this research extends the sample of enterprises to include most medium-size prefecture cities in addition to the major cities, such as Beijing and Shanghai (Tang & Zhao, 2010; Jin, 2010). By locating the headquarters and branches of all the enterprises in China, as many connections between cities as possible were established. Specifically, we found the branches' location information on the enterprises list, and then determined the directional headquarters–branch links between cities according to the location information of the corresponding enterprises' headquarters. This method is suitable for China, which has a large number of medium-size cities attracting only a few Fortune 500 companies or multinational producer services firms. It should be emphasized that this method not only avoids the problem that the relations between branches is relatively 'flatter' and empirically richer (Liu & Derudder, 2013), but is also closer to Scott's (1982) definition of enterprise flows between cities.

To analyse this type of spatial linkages of city regions, this study uses data on enterprises drawn from the enterprises list and various institutions. Specifically, we used information on the geography of firms located in the YRD and the PRD provided in the publicly available company directories in 2001 and 2008 published by Ebuy Information Ltd (http://www.ebuywww.net.cn/). For each firm with more than a single presence in a certain place, the research examined whether this involved a legal ownership link as suggested by the terms 'subsidiary', 'agency' or 'branch'. From this perspective, a mega-city region's constituent urban networks were explored by looking at the ownership linkages running from a corporation's headquarters to other branches of the firm. This resulted in 4352 and 28,881 pairs of headquarters–branch links across the PRD in 2001 and 2008, respectively, and in 33,180 and 100,399 pairs of such links across the YRD in 2001 and 2008, respectively.

5.3.3 Measuring functional polycentricity

In the empirical study, by taking into consideration the spatial properties of a world city's or global city's controlling function (Friedman, 1982; Sassen, 2001) and defining the number of headquarters and branches as the outdegree centrality (ODC) and the indegree centrality (IDC), respectively, in the corresponding city, this connection can also show the inequality of the productive network of interregional enterprises as put forward by Diken (2000), namely, there are differences between controlling and being controlled in the system of production. That is to say, branches are subordinate departments established for enterprises' operation in other places, and the spatial ownership of headquarters–branches' links turn into the geography of controlling and being controlled.

Then the ownership links T_{ij} represent the number of enterprises with headquarters in city *i* and branches in city *j* among all of *n* cities. The corresponding ODC of city *i* is O_i and the IDC I_i can be calculated as follows:

$$O_i = \sum_{j=1}^{n} T_{ij} \qquad (5-1)$$

$$I_i = \sum_{j=1}^{n} T_{ji} \qquad (5-2)$$

The total number of city-dyads between cities *i* and *j* can be defined as (T_{ij}+T_{ji}). It should be noted that it is common for headquarters and its branches to be located in the same region. Thus, we used the term self-containment proposed by Hall & Pain (2006). Specifically, e_{ii} is the number of headquarters–branches' links in the same prefectural region, so the self-containment of each city *i* is defined as:

$$SC_i = \frac{e_{ii}}{(O_i + I_i + e_{ii})} \qquad (5-3)$$

In the above formula, self-containment SC_i ranges from 0 to 1 and reflects the level at which a city participates in an interaction network. The higher the self-containment, the lower the level of a city's interaction in the network.

Hall & Pain (2006) used the term network density to reflect the interaction level of an entire network. Green (2007) formally defined this term as:

$$\Delta = \frac{L}{L_{max}} \qquad (5-4)$$

L is the sum of all intercity connections in a network, L_{max} is the maximum value of possible functional connections, and Δ ranges from 0 to 1. The higher the network density, the more eminent the intercity interaction of the whole network.

When it comes to measuring polycentricity, Hall & Pain (2006) first statically analyse the array differences of net nodes for morphological polycentricity, which means a region consisting of different important cities at large (Liu, Derudder & Wu, 2016). σ_F is the standard deviation of the value of net nodes, so the polycentric degree of node hierarchy is:

$$P(F,N) = 1 - \frac{\sigma_F}{\sigma_{F_{max}}} \qquad (5-5)$$

In the above formula, the value of $P(F,N)$ also ranges from 0 to 1. When the standard deviation of the value of net nodes is 0, morphological polycentricity reaches its maximum value 1, which means that the value of all the nodes in the network is the same. Based on the network density and difference of net nodes, Hall & Pain (2006) present the formula to measure the special functional polycentricity:

$$P_{SF}(N) = (1 - \frac{\sigma_F}{\sigma_{F_{max}}}) \cdot \Delta \qquad (5-6)$$

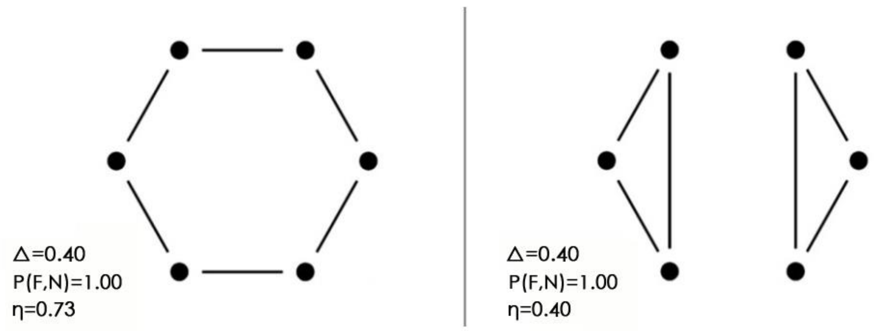

Figure 5.2 Network efficiency of possible patterns

What needs to be pointed out is that Hall & Pain (2006) and Green (2007) used data on dense commuting flows, while this study uses ‘flow’ data stemming from enterprise’s headquarters and branches. Thus, this kind of ‘sparse’ flow might result in the absence of connections in the city-dyads. If one calculates according to formulas (5-4) and (5-5), another problem arises, namely that of the efficiency of connections between cities. As Figure 5.2 shows, there are six nodes and six edges for both the left- and the right-hand diagrams, implying a similar level of network density in two city regions according to Green’s (2007) formula. Meanwhile, there is no hierarchical difference between these two patterns because each node of the two city regions possesses the same degree, which means the level of polycentricity is exactly the same as the definition of Green (2007). The above suggests that network density cannot completely reflect the cities’ connection in a sparse network and the typological structures: in Figure 5.2, all the nodes in the left-hand diagram are connected in a circle, and each node can be linked with other nodes directly or indirectly; whereas the six nodes in the right-hand diagram consist of two separate triangles. It is obvious that the city regions in the right-hand diagram are actually two unconnected regions. In order to detect the typological structures of sparse networks, the authors refer to Latora’s (2001, 2003) research, which introduces global network efficiency in graph theory and supplements the measurement of network density:

$$\eta = \frac{1}{n(n-1)/2} \sum_{i=1}^{n} \sum_{j=1}^{n} {d_{ij}}^{-1} \qquad (5-7)$$

In the above formula for global network efficiency, d_{ij} is the paths between nodes i and j, d_{ij} is ∞ when there is no suitable between two nodes, corresponding d_{ij}^{-1} is 0. Global network efficiency η ranges from 0 to 1; when two arbitrary nodes of the network are linked together, a regular network will form and the global efficiency reaches the maximum value 1. In the case of Figure 5.2, although both the network density and the standard deviation of the nodes are the same, there are prominent differences in global network efficiency.

On the basis of the above, the formula for measuring the functional polycentricity of mega-city regions (5-6) is:

$$P_{SF}(N) = \left(1 - \frac{\sigma_F}{\sigma_{F_{max}}}\right) \cdot \Delta \cdot \eta \qquad (5-8)$$

Further more, σ_F^{out} and σ_F^{in} are the standard deviation of ODC and IDC, respectively, and σ_{Fmax}^{out} and σ_{Fmax}^{in} are the maximum values of the standard deviation of ODC and IDC, respectively. Thus, the general functional polycentricity, $P_{GF}(N)$, in network connection can be calculated by averaging the polycentricity of ODC and IDC:

$$P_{GF}(N) = \frac{{P_F}^{out}(N) + {P_F}^{in}(N)}{2} \qquad (5-9)$$

Considering that the maximum possible value of ODC and IDC is 1, the general polycentricity $P_{GF}(N)$ will be smaller than 1.

5.4 Results

5.4.1 Rising levels of connectivity

First, we took the number of enterprises with headquarters–branches relations as the value of city-dyads between cities, and then compared the similarities and differences between the networks of both city-regions. During 2001–08, the corporate network of the two city regions slowly evolved into a closely connected polycentric network. In 2008, the city-dyads between cities were more common and the number of ownership links increased greatly, which makes the connection between cities more obvious in the YRD and the PRD. The self-containment of each city basically decreased to different degrees, which indicates the improvement of the degree of regional integration of the city regions.

Furthermore, the city-regions have different network states and development tendencies. In the YRD (see Figure 5.3), all cities increased their relative levels of connectivity in the period 2001–08. Shanghai, Suzhou, Hangzhou, Nanjing, Suzhou, etc. formed the strongest city-dyads in the YRD. In both Jiangsu province and Zhejiang province, the number of connections between most cities and the regional primary city (Shanghai) or provincial capital (Nanjing or Hangzhou) is higher than for other city-dyads in the respective provinces (Tang & Zhao, 2010). Firms' networks in Shanghai have the largest self-containment (93.2%), and the number of enterprises with headquarters in Shanghai is much higher than in other cities.

As for the spatial evolution from 2001 to 2008, the total ownership links in the YRD increased from 30,983 to 86,577, and the ratio of cross-regional linkages increased from 8.0% to 9.6%. This can be attributed to a combination of new firms headquartered in Shanghai with multiple presences in the YRD and/or the further branching out of firms already headquartered in these other cities. Second, however, it is clear that Shanghai continues to be the starting point for the overwhelming majority of business links throughout the region. Shanghai has strong connections with the other cities in the YRD, especially the emerging secondary cities like Hangzhou, Nanjing and so on; Shanghai–Hangzhou is still the strongest dyad as regards connections (1607 connected enterprises). Although the difference in node degree between Suzhou and other small or medium-size cities was relatively small in 2001, by 2008 Suzhou had 1504 links with Shanghai, ranking it second as regards connectivity. Generally speaking, the connections between cities are becoming more numerous and demonstrate a polycentric networks structure in the YRD.

Table 5.2 Number of headquarters and branches in the YRD and the PRD in 2001 and 2008

City region	Cities	Headquarters		Branches	
		2001	2008	2001	2008
YRD	Shanghai	1115	7142	474	1381
	Nanjing	202	1129	306	2174
	Wuxi	88	635	159	1029
	Changzhou	50	377	58	411
	Suzhou	127	679	320	1916
	Nantong	68	430	84	556
	Yangzhou	44	254	31	297
	Zhenjiang	25	128	28	275
	Taizhou-JS	15	89	40	314
	Hangzhou	199	1428	363	2162
	Ningbo	180	983	151	1225
	Jiaxing	24	110	50	563
	Huzhou	21	99	21	245
	Shaoxing	16	145	41	361
	Zhoushan	23	80	23	173
	Taizhou-ZJ	16	114	64	740
PRD	Guangzhou	183	1558	263	2403
	Shenzhen	230	2883	119	949
	Zhuhai	58	434	46	282
	Foshan	23	359	59	662
	Jiangmen	15	92	17	146
	Zhaoqing	5	42	5	90
	Huizhou	25	164	31	317
	Dongguan	50	459	25	939
	Zhongshan	30	250	54	453

It should be noted that the ODC reflects the number of headquarters located in Shanghai: the city's status of controlling and demanding, as indicated by the number of headquarters, has been strengthened. Yangzhou and Ningbo turned into cities with an ODC less than that of IDC in 2001–08. The self-containment of each city in the YRD declined, indicating that the level of regional integration improved; Shanghai has the highest self-containment (84.1%) and still had the most headquarters in 2008, while Nanjing had the largest number of branches. What needs to be noticed is that in 2008, the IDC of all cities, except Shanghai, was larger than that of their ODC. The number of cities' linkages in the PRD (Figure 5.4) increased greatly, as it did in the YRD, and the total number of firms' links rose from 619 to 6241. Guangzhou and Shenzhen had the largest number of connectivities; Zhuhai, Zhongshan, Foshan and Dongguan also had large numbers of connections. The two cores, Guangzhou and Shenzhen, had the highest connectivity (220 links), and Zhaoqing and Jiangmen had the lowest. Compared to the obvious hierarchy in connectivity, the differences in cities' self-containment (i.e. the portion of firms with branches in local hinterlands) are small, mainly ranging from 57% to 81%. The distribution of enterprises' headquarters and branches were concentrated in the two major cities (Guangzhou and Shenzhen). The ODC of Shenzhen, Zhuhai and Dongguan was higher than their IDC, whereas other cities focused on the inflow of enterprises' branches.

Figure 5.3 The urban networks and self-containment in the YRD in 2001 and 2008

The overwhelming dominance of Guangzhou and Shenzhen in 2008 is more obvious: the number of cross-regional linkages between both cities increased significantly (to more than 3800 connections between firms), and the connections with Dongguan and Foshan also developed quickly because more firms are involved in the spatial organization of headquarter–branch linkages. Hence, dense connections mainly exist in the four core cities. It should be noted that all cities had an increased number of connections in 2008 in some instance. Headquarters and branches between Guangzhou and Shenzhen still made this the strongest city-dyad in the PRD, while those between Shenzhen and Dongguan made them the second strongest city-dyad. The self-containment of each city declined and in 2008 ranged from 40% to 60%; Foshan was still the most self-contained.

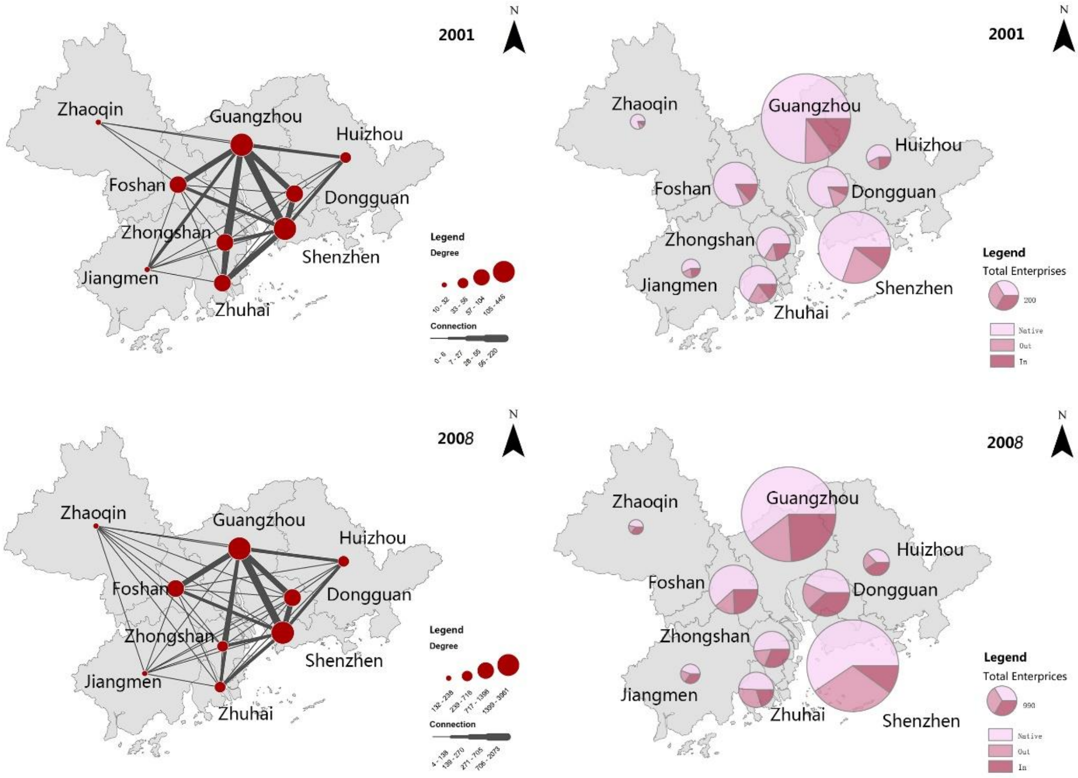

Figure 5.4 The urban networks and self-containment in the PRD in 2001 and 2008

As for the network evolution of the city regions from 2001 to 2008, the main differences concerned the city region's degree of polycentricity. The city region in the YRD tended to form a more mature and balanced polycentric network structure, whereas the difference in node degree centrality in the PRD increased gradually and the hierarchy is more obvious, because the relatively weaker connectivity of small or medium-size cities in the PRD (except for Shenzhen, Guangzhou, Dongguan and Foshan) contribute less to the development of a polycentric network.

5.4.2 Different levels of network density

The result of the analysis of network density for both city regions is shown in Table 5.3. The network density of the PRD was always larger than that of the YRD, and the intercity interactive connection was prominent in 2001–08. By 2008, the network density of both city-regions had increased to varying degrees. The interactive degree of the PRD was still stronger; the network density of the YRD had doubled.

Regarding network density, the YRD had more obvious interactive connections across regions and its level of network density doubled between 2001 and 2008. This means that firms in the PRD were more likely to set up branches beyond the prefecture's boundary, which resulted in a higher level of network density in the PRD than in the YRD. The reason is that the self-containment of each region in the PRD was usually lower than that in the YRD.

Table 5.3 Indices indicating polycentricity in the YRD and the PRD in 2001 and 2008

Indices		YRD		PRD	
		2001	2008	2001	2008
Network Density: Δ		0.071	0.160	0.158	0.276
Network Efficiency: η		0.846	0.946	0.903	1.000
Morphological Polycentricity: $P_F(N)$	Headquarter	0.785	0.778	0.775	0.738
	Branch	0.886	0.913	0.756	0.784
General functional Polycentricity: $P_{GF}(N)$		0.050	0.128	0.109	0.210

5.4.3 Higher levels of network efficiency

The results for network efficiency for the two city regions are shown in Table 5.3. In 2001, the network efficiency of the corporate network in the PRD was higher than that in the YRD. There were also some city-dyads that were very weak in both city regions in 2001. By 2008, the network efficiency of the two city regions had grown; especially the cities in the PRD have developed more powerful connections. Meanwhile, the ownership links in the YRD also got much denser and the value of network efficiency exceeded 0.9. This suggests that the firms' connections of the two city regions had developed into a closely connected regional network.

The entire network efficiency increased dramatically between 2001 and 2008. During this period, the connections among small- or medium-size cities gradually increased (see figures 5.3 & 5.4), and this led to the improvements of the network efficiency at the level of the city region. All of the cities in the network of the PRD in 2008 had direct connections, which produced a maximal level of network efficiency. The tendency for network efficiency to improve each year is advantageous to the further development of the two city regions into world-class city regions, which is the planning goal of the 'New path of urbanization' in China.

5.4.4 Shifting morphological polycentricity

Table 5.3 shows the result of the analysis of the morphological polycentricity, indicated by $P_F(N)$, of the two city regions. In 2001, the ODC's morphological polycentricity in the YRD was at a relatively lower level than that of the IDC, which implies that the IDC had a flatter distribution of nodes. In the same year, the PRD's morphological polycentricity was less marked and the difference in node degree centrality was greater than that in the YRD, i.e. the distribution of corporations' spatial activities in the PRD suggests a more imbalanced geography. In 2008, the morphological polycentricity of nodes in the IDC is different from that in the ODC in both city regions: the morphological polycentricity of branches is more marked, while the headquarters tend to be clustered in a few main cities. Generally speaking, the development of the morphological polycentricity of the branches was prominent, while the decline of the morphological polycentricity of the ODC reflected a tendency of a clustering of enterprises' headquarters.

5.4.5 Increasing general functional polycentricity

The results of the analysis of general functional polycentricity, $P_{GF}(N)$, of the two city regions are shown in Table 5.3. In 2001, the $P_{GF}(N)$ in the PRD (0.128) was stronger than that in the YRD. In 2008, the $P_{GF}(N)$ of the PRD (0.210) was still stronger, although the $P_{GF}(N)$ of the YRD had improved a lot.

Regarding the evolution of the city regions' $P_{GF}(N)$ between 2001 and 2008, the PRD maintained its good polycentric momentum, which nearly doubled. The four major cities of Shenzhen, Guangzhou, Foshan and Dongguan became the main centres of the polycentric city region in the PRD; the YRD witnessed a more rapid increase in $P_{GF}(N)$, which jumped from 0.050 to 0.109 – a value that is nearly 2 times larger than it was in 2001. It should also be noted that in both city regions, the growth in the general functional polycentricity mainly originated from higher levels of network density.

5.5 Discussion

In this research, we explored the shifting spatial organization of the Yangtze River Delta (YRD) and the Pearl River Delta (PRD) through the lens of recent research on polycentricity. Based on a review of the current state of affairs in this literature, this research developed comprehensive methodologies to compare the shifting spatial organization of city regions through the lens of enterprises' headquarters–branch links. That is, urban networks were defined by looking at the ownership linkages running from headquarters to other parts of the firm, as these linkages represent 'a direct interaction between the city where the headquarters are located and the city where the subsidiary is owned' (Alderson & Beckfield, 2004; Rozenblat & Pumain, 2007; Zhao & Duo, 2013). Following this definition, this research also improved the statistical tools for measuring polycentricity, as initially proposed by Hall & Pain (2006) and Green (2007), to suit this class of urban networks in China. We then carried out a comparison to evaluate the evolution of polycentricity in the two typical mega-city regions, the YRD and the PRD.

Comparing the change in spatial organization of the YRD and PRD allowed us to discuss the unfolding functional–spatial architecture of the two mega-city regions in general: 1) The general functional polycentricity in both regions is increasing, even though the concentration of headquarters is also increasing; and 2) The growth in the general level of polycentricity mainly originates from higher levels of network density; that is, the self-contained headquarters–branches' relations in most regions is now weakening.

The fundamental differences between these two city regions include: 1) Firms in the PRD are more likely to set up branches beyond the prefectures' boundary and this results in a higher level of network density in the PRD than in the YRD; 2) There is a relatively 'flatter' intercity network in the YRD than in the PRD, in which there are more firms' links interconnecting the four major cities (Guangzhou, Shenzhen, Dongguan and Foshan), rather than other small and medium-size cities; and 3) There has been a significant shift in the YRD whereby Nanjing and Hangzhou have become the cities that attract more branches than Shanghai; no obvious equivalent change is taking place in the PRD.

For the evolution of both city-regions, the dominance of the regional gateway city (Shanghai and Shenzhen, respectively) is still significant, but the goal of regional planning is not to reduce the status of these major cities. The polycentric city-region is seen as an ideal regional model, even though there is no solid evidence regarding its efficiency and it is still a controversial issue (Kloosterman & Musterd, 2001; Parr, 2004). Although most local governments of small or medium-size cities usually compete with each other to attract more firms to maintain the connections (Fan et al., 2007; Li et al., 2008; Xia, 2014), the strength of economic agglomeration in megacities cannot be ignored (Wang, 2010; Gu, 2012). Above all, small and medium-size cities are more likely to be faced with the awkward situation that few leading firms want to establish their headquarters in such cities.

The results of this empirical study also suggest that the two city regions follow different pathways towards polycentricity. Although denser urban networks have facilitated regionalization in terms of the increasing involvement of non-state actors (Luo, Shen & Chen, 2010), the level of integration in the YRD is relatively lower because of its higher number of state-owned companies (Zhang & Wu, 2006; Xu & Yeh, 2010). Along with other results on the relationship between firm performance and ownership type across regions (Jiang & Nie, 2014; Xia & Walker, 2015), this suggests that a relatively higher ratio of private companies in the YRD will promote a higher level of network density and efficiency there.

On the other hand, in the planning documents of 'New path of Urbanization in Guangdong (2014-2015)', it is proposed to expand the area of city region in the PRD because it is relatively smaller than the city region in the YRD. However, our findings indicate that most enterprises are locating their branches in the four large cities rather than in small or medium-size cities in the PRD. This means that companies still intend to organize production networks within several main cities. Thus, policymakers should also pay attention to the current reality of economic gaps within the PRD, instead of simply enlarging the size of the city region.

References

Alderson, A. S., Beckfield, J., & Sprague-Jones, J. (2010). Intercity relations and globalisation: the evolution of the global urban hierarchy, 1981—2007. *Urban Studies, 47*(9), 1899-1923.

Alderson, A. S., & Beckfield, J. (2004). Power and position in the world city system, *American Journal of Sociology, 109*(4), 811-851.

Beaverstock, J. V., Smith, R., & Taylor, P. J. (1999). A Roster of World Cities. *Cities, 16*(6), 445-458.

Godfrey, B. J., & Zhou, Y. (1999). Ranking world cities: multinational corporations and the global urban hierarchy. *Urban Geography, 20*(3), 268-281.

Burgalassi, D. (2010). *Defining and measuring polycentric regions: the case of Tuscany*. MPRA Paper 25880, University Library of Munich, Germany.

Castells, M. (1996). *The Rise of the Network Society*. Oxford: Blackwell.

Derudder, B., Taylor, P. J., Hoyler, M., Ni, P., Liu, X., Zhao, M., Shen, W., & Witlox, F. (2010). Measurement and interpretation of the connectivity of Chinese cities in the world city network. *Chinese Geographical Sciences, 23*, 261-273.

Derudder, B., Taylor, P. J., Ni, P., Vos, A. D., Hoyler, M., Hanssens, H., Bassens, D., Huang, J., Witlox, F., Shen, W., & Yang, X. (2010). Pathways of change: shifting connectivities in the world city network, 2000—08. *Urban Studies, 47*(9), 1861-1877.

Fan, J. P. H., Wong, T. J., & Zhang, T. (2007). Politically connected CEOs, corporate governance, and post-IPO performance of China's newly partially privatized firms. *Journal of Financial Economics, 84*(2), 330-357.

Fang, T., & Lin, C. (2015). Minimum wages and employment in China. *IZA Journal of Labor Policy, 4*(1), 1-30.

Florida, R., Gulden, T., & Mellander, C. (2008). ‘The rise of the mega-region', *Cambridge Journal of Regions, Economy and Society, Economics, 57*(1), 203–216.

Green, N. (2007). Functional Polycentricity: A formal definition in terms of social network analysis. *Urban Studies, 44*(11), 2077-2103.

Gu, C. (2012). On the fundamental features of modern urbanization in China. *Urban Insight*. (3),12-19. (in Chinese)

Hall, P. (1999). *Planning for the mega-city: a new eastern Asian urban form. Perspectives on 21st Century Urban Development: Sustainable Eastern and Western Cities in the New Millennium*, Aldershot.

Hall, P. (2001). Global City Regions in the Twenty-first Century. In: Scott, A.J. (ed.). *Global City Regions*. Oxford, UK: Oxford University Press, 59-77.

Hall, P., & Pain, K. (2006). *The Polycentric Metropolis: Learning from Mega-city Regions in Europe*. London: Earthscan.

Hanssens, H., Derudder, B., Van Aelst, S., & Witlox, F. (2014). Assessing the functional polycentricity of the mega-city-region of central Belgium based on advanced producer service transaction links. *Regional Studies, 48*(12), 1939-1953.

Hoyler, M., Kloosterman, R. C., & Sokol, M. (2008). Polycentric puzzles–emerging mega-city regions seen through the lens of advanced producer services. *Regional Studies, 42*(8), 1055-1064.

Jin, Z. (2010). On structural properties of transnational urban network based on multinational enterprises network in China: As the case of link with South Korea. *Geography Research, 29*(9), 1670-1682. (in Chinese)

Kloosterman, R., & Musterd, S. (2001). The polycentric urban region: towards a research agenda. *Urban Studies, 38*(2), 623-633.

Lambooy, J. G. (1998). Polynucleation and economic development: the Randstad. *European Planning Studies, 4*(4), 457-466.

Lang, R. E., & Dhavale, D. (2005). Beyond megalopolis: exploring America’s new megalopolitan geography. *Metropolitan Institute Census Report Series, 46*(3), 5–6.

Latora, V., & Marchiori, M. (2001). Efficient Behavior of Small-World Networks. *Phys. Rev. Lett, 87*(19), 1-4.

Latora, V., & Marchiori, M. (2003). Economic small world behavior in weighted networks. *The*

European Physical Journal B-Condensed Matter and Complex Systems, *32*(2), 249-263.

LeGates, R. T. (2014). Visions, scale, tempo, and form in China's emerging city-regions. *Cities, 41*, 171-178.

Li, H., Meng, L., Wang, Q., & Zhou, L. (2008). Political connections, financing and firm performance: Evidence from Chinese private firms. *Journal of Development Economics, 87*(2), 283–299.

Li, J., Deng, J., Wang, K., Li, J., Huang, T., Lin, Y., & Yu, H. (2014). Spatiotemporal patterns of urbanization in a developed region of eastern coastal China. *Sustainability*, 6(7), 4042-4058.

Limtanakool, N., Dijst, M. J., & Schwanen, T. (2007). A theoretical framework and methodology for characterising national urban systems on the basis of flows of people: empirical evidence for France and Germany. *Urban Studies, 44*(11), 2123-2145.

Limtanakool, N., Schwanen, T., & Dijst, M. (2009). Developments in the Dutch urban system on the basis of flows. *Regional Studies, 43*(2), 179-196.

Lin, G. C., Li, X., Yang, F. F., & Hu, F. Z. (2014). Strategizing urbanism in the era of neoliberalization: State power reshuffling, land development and municipal finance in urbanizing China. *Urban Studies, 52* (11), 1962-1982.

Lu, X., Ma, X., & Li, G. (2012). Spatial Pattern of Regional City Network Based on International Advanced Producer Services' Layout in Pearl River Delta. *Economic Geography*, *32*(4), 50-54. (in Chinese)

Luo, Z. (2010). Study on the Functional Polycentricity of Yangtze River Delta. *Urban Planning International, 25*(1), 60-65. (in Chinese)

Luo, X., Shen, J., & Chen, W. (2010). Urban networks and governance in city-region planning: state-led region building in Nanjing city-region, China. *Geografiska Annaler, 92*(4), 311–326.

Meijers, E. J, & Burger, M. J. (2010). Spatial Structure and Productivity in U.S. Metropolitan Areas. *Environment and Planning A, 42* (6), 1383-1402.

Meijers, E. J. (2007). *Synergy in Polycentric Urban Regions: Complementarity, organizing capacity and critical mass*. Thesis Delft University of Technology, Delft, the Netherlands.

Meijers, E. J. (2008). Measuring Polycentricity and its Premises. *European Planning Studies*, 16 (9), 1313-1323.

Mellander, C., Florida, R., & Gulden, T. (2008). The rise of the mega-region. *Cambridge Journal of Regions, Economy and Society, 57*(1), 459-476.

Münter, A. (2011). Germany's polycentric metropolitan regions in the world city network. *Raumforschung und Raumordnung, 69*(3), 187-200.

Newman, P., & Thornley, A. (2011). *Planning world cities: globalization and urban politics*. Palgrave MacMillan.

Pain, K. (2008). Examining 'core-periphery' relationships in a mega-city region: the case of London and South East England. *Regional Studies, 42*(8), 1161-1172.

Parr, J. (2004). The Polycentric Urban Region: A Closer Inspection. *Regional Studies, 38*(3), 231–240.

Petrella, R. (1995). *A global agora vs. gated city-regions*. New Perspectives Quarterly, Winter, 21-22.

Pred, A. (1977). *City Systems in Advanced Economies.* London: Hutchinson.

Reades, J., & Smith, D. A. (2014). Mapping the 'space of flows': the geography of global business telecommunications and employment specialization in the London mega-city-region. *Regional Studies, 48*(1), 105-126.

Rozenblat, C., & Pumain, D. (2007). *Firm linkages, innovation and the evolution of urban systems*. In Taylor, P. J., Derudder, B., Saey, P., Witlox, F. (Eds.). *Cities in globalization: practices, policies and theories,* Oxon, Routledge.

Sassen, S. (2001). *Global City: New York, London, Tokyo*. New Jersey: Princeton University Press.

Scott, A. J. (2001). Globalization and the rise of city-regions. *European Planning Studies, 9*(9), 813-826.

Tang, Z., & Zhao, M. (2010). Economic globalization and transformation of urban system in the Yangtze River Delta Region: Interlocking network and value-added hierarch. *Urban Planning Forum*, (1), 29-34. (in Chinese)

Taylor, P. J., M. Evans, D., & Pain, K. (2008). Application of the interlocking network model to mega-city-regions: measuring polycentricity within and beyond city-regions. *Regional Studies, 42*(8), 1079-1093.

Taylor, P. J. (2001). Specification of the World City Network. *Geographical Analysis, 33*(2), 181-194.

Taylor, P. J., & Pain, K. (2007). Polycentric mega-city regions: exploratory research from

Western Europe, in the Healdsburg research seminar on megaregions. In: Todorovich, P. (ed.). *Lincoln Institute of Land Policy and Regional Plan Association*, Healdsburg, 59-67.

Timberlake, M., Wei, Y. D., Ma, X., & Hao, J. (2014). Global cities with Chinese characteristics. *Cities, 41*, 162-170.

Turok, I., & Bailey, N. (2004). The theory of polynuclear urban regions and its application to central Scotland. *European Planning Studies*, *12*(3), 371-389.

Townsend, A. M. (2001). Network cities and the global structure of the internet. *American Behavioral Scientist*, *44*(10), 1697-1716.

Van Oort, F., Burger, M. J., & Raspe, O. (2010). On the economic foundation of the urban network paradigm: Spatial integration, functional integration and economic complementarities within the Dutch Randstad. *Urban Studies*, *47*(4), 725-748

Vasanen, A. (2012). Functional polycentricity: examining metropolitan spatial structure through the connectivity of urban sub-centres. *Urban Studies*, *49*(16), 3627-3644.

Veltz, P. (1996). *Mondialisation, Villes et Territoires: L'Economie d'Archipel*. Paris: Presses Universitaires de France.

Xia, F., & Walker, G. (2015). How much does owner type matter for firm performance? Manufacturing firms in China 1998–2007. *Strategic Management Journal*, *36*(4), 576-585.

Pan, F., & Xia, Y. (2014). Location and agglomeration of headquarters of publicly listed firms within China's urban *system*. *Urban Geography*, *35*(5), 757-779.

Jiang, T., & Nie, H. (2014). The stained China miracle: Corruption, regulation, and firm performance. *Economics Letters*, *123*(3), 366-369.

Xu, J., & Yeh, A. G. (Eds.). (2010). *Governance and planning of mega-city regions: An international comparative perspective*. Routledge.

Yeh, A. G., Yang, F. F., & Wang, J. (2014). Producer service linkages and city connectivity in the mega-city region of China: a case study of the Pearl River Delta. *Urban Studies, 52*(13) 2458-2482.

Yuan, F., Wei, Y. D., & Chen, W. (2014). Economic transition, industrial location and corporate networks: Remaking the Sunan model in Wuxi City, China. *Habitat International, 42*, 58-68.

Zhang, X., & Kloosterman, R. C. (2016). Connecting the 'workshop of the world': intra-and extra-service networks of the Pearl River Delta City-Region. *Regional Studies, 50*(6), 1069-1081.

Zhang, J., & Wu, F. (2006). China's changing economic governance: Administrative annexation and the reorganization of local governments in the Yangtze River Delta. *Regional Studies, 40*(1), 3-21.

Zhao, M., Liu, X., Derudder, B., Zhong, Y., & Shen, W. (2015). Mapping producer services networks in mainland Chinese cities. *Urban Studies, 52*(16), 3018-3034.

Zhao, M., & Duo, D. (2013). Complex Network Features of Mega City Region. *Journal of South China University of Technology (Natural Science Edition), 41*(6), 108-115.

Zook, M. A. (1999). Old hierarchies or new networks of centrality? The global geography of the internet content market. *American Behavioral Scientist, 44*(10), 1679-1696.

Wang, X. (2010). Urbanization path and city scale in China: an economic analysis. *Economic Research Journal*, *10*, 20-32. (in Chinese)

Chapter 6: Examining the transition processes in the Pearl River Delta polycentric mega-city region through the lens of corporate networks

Abstract: This chapter presents an analysis of the shifting spatial organization of the Pearl River Delta (PRD), a large-scale urbanized region bordering Hong Kong and including major cities such Guangzhou and Shenzhen alongside a range of other fast-changing cities and towns. Our methodology measures and compares the different networking components of the PRD's spatial organization, and uses data on the geography of firms' networks as visible in the links between locations of headquarters and subsidiaries in 2001, 2008 and 2013. We examine if there has been a shift towards integrated polycentricity in the unfolding spatial organization of this 'workshop of the world' through functional polycentricity and a typology of the geographies of links. Results suggest complex interaction process in the PRD that network interaction significantly increased in 2001-08, and slightly declined in 2008-13 (with the exception of manufacturing links, which are increasingly commanded from headquarters in Guannei, Shenzhen). We argue that the PRD is increasingly characterized by a functional polycentric and cross-regional interaction pattern for market-oriented sectors, albeit that more regionalized, networks continue dominate in sectors with higher proportions of state owned enterprises.

This chapter is adapted from: Zhao, M., Derudder, B., Huang, J. (2016). Examining the transition processes in the Pearl River Delta polycentric mega-city region through the lens of corporate networks. *Cities*, accepted.

6.1 Introduction

The purpose of this paper is to contribute to the literature on the emergence of polycentric mega-city regions (PM-CRs), tentatively defined here as large regions with multiple, functionally connected urban nuclei at their core. To this end, we present an analysis of the shifting spatial organization of the Pearl River Delta (PRD) between 2001 and 2013 (based on cross-sections for 2001, 2008, and 2013), an era of increased global connectivity for the PRD at large (Schoon, 2014; Timberlake et al., 2014; Yeh et al., 2015; Zhang & Kloosterman, 2016; Liu et al., 2016). Although the PRD has major urban eye-catchers in the form of Guangzhou and Shenzhen, the region as a whole is densely urbanized with a range of larger and smaller cities that are proximately located and – as we will show – increasingly functionally integrated.

In recent decades we have witnessed increased scholarly attention for polycentric developments in booming urbanized regions in China (Wu, 1998; Lin, 2001; Seto et al., 2003; Yeh et al., 2015; Zhang & Kloosterman, 2016; Zhao et al., 2015; Liu et al., 2016), and this paper aims to contribute to this literature by assessing the polycentric spatial organization of the Pearl River Delta (PRD). Almost two decades ago, Mogridge and Parr (1997) already identified the PRD as one of the fastest-developing metropolitan regions in eastern Asian, a view later confirmed by Hall (1999). In terms of planning practices in China, it can be noted that policymakers have always been interested in the functional linkages among cities in the PRD. At the scale of prefecture regions, urban networks in the PRD have been outlined in the 'Planning for a new path of urbanization in Guangdong province (2014–2020)' and 'Planning for the whole territory of the Pearl River Delta (2015–2020)'. The two documents verified the functions of Shenzhen, Guangzhou, Dongguan, and other cities. It was found that Shenzhen has the highest degree of headquarters in the networks. However, functional links among central and non-central sub-regions in the PRD have not yet been researched intensively.

At the same time, the desire of local government officials to attract firms' branches from outside the prefecture regions has become increasingly important in an era of economic globalization. For instance, in the 'Thirteenth economic & social planning of Shunde (2015–2020)' it is stated that government officials in Shunde, a non-central sub-region in the prefecture region of Foshan, want to improve the industrial cooperation with Panyu in Guangzhou rather than with the central city of Foshan. In line with this desire of local governments, some managers of private enterprises in Shunde are also seeking government permits to set up branches in sub-regions in Guangzhou in order to expand their markets. The (potentially) rising importance of functional links across prefecture boundaries has not been systematically considered in empirical research on the city networks in the PRD (Chen, Ma, Li et al., 2013; Tong, Tao, Li et al., 2014; Yeh, Yang, Wang et al., 2014; Zhang & Kloosterman, 2016).

Hence the starting point of this paper is that finer-grained analyses of urban networks including prefectures' sub-regions may enhance our understanding of a range of (polycentric) urbanization processes in mega-city regions (Zhou, 2016). In our reading, previous studies often ignored prefectures' 'internal geographies' as these prefectures' central cities are often assumed to dominate the development of the entire region, with non-central sub-regions having little chance to command or even attract economic activity viz. other prefectures. This then results in a Christaller-like central place pattern in each prefecture region, an effect that can be likened to a system of water pumps with pipelines continually absorbing economic resources from a prefecture's non-central sub-regions to its central city (Zhou & Hu, 1992; You et al., 2005; Wang et al., 2015). In such a context, prefecture-level analyses focusing central cities may seem warranted. However, a range of rescaling processes has implied that different levels of government have become involved in competition for attracting investment by harnessing economic activity within its own administrative boundaries (Ma & Wu, 2005; Wu, 2015). The net result may be that regional and local development may increasingly be driven by economic interaction outside of prefectures (Xue & Wu, 2015), a process that would be reflected in an interaction pattern composed of functionally connected spatial units. The purpose of this chapter is to explore finer-grained geographical changes in these functional interaction patterns. To this end, we will analyse shifting patterns of polycentricity in the PRD through the lens of corporates' networks. In our analysis, we will also pay attention to possible differences emerging from firms being active in different sectors. Given this focus, we will mainly deal with the region's urban networks rather than with how these changing geographies may or may not be harnessed by urban planning or regional governance, topics that have been addressed extensively in the academic literature (e.g. Zhou & Hu, 1992; Ye, 2014; Wang et al., 2015; Wei, 2015; Wu, 2015; Xue & Wu, 2015).

Our approach for measuring corporate networking in the PRD is loosely based on the quantitative approach for studying urban networks presented in Alderson & Beckfield (2004) and Zhao et al. (2015). In this approach, connections between headquarters and the different branches of large corporations are conceptualized as the basic components of cities' links. To assess whether and these links may or may not produce polycentric developments, we use a combination of measures functional polycentricity and classifications of the different links according to their spatial dimension. The remainder of this chapter is organized as follows. The next section further introduces the relevant theoretical background and research context. This is followed by a discussion of the methodology and data, after which we present our results. The chapter is concluded with an overview of our main findings, which may serve as an agenda for future research.

6.2 Research background

6.2.1 Polycentric mega-city regions et al.

Many urban scholars have argued that as globalization proceeds, an extensive archipelago of large-scale urbanized regions is coming into being (Scott, 2001; Newman & Thornley, 2011; Harrison and Hoyler, 2015). Scott (2001), for instance, has argued that regions embodying 'an outgrowth of large metropolitan areas – or contiguous sets of metropolitan areas – together with surrounding hinterlands of variable extent which may themselves be sites of scattered urban settlements' increasingly function as the backbone of the global economy.

The challenge of describing and analysing the shifting 'internal' spatial organization of such large-scale urbanized regions has resulted in a fast-evolving literature. In the event, a plethora of terms has been put forward, with 'polycentric mega-city regions' (PMCRs, see Hall & Pain, 2006) and 'Polynuclear Urban Regions' (PURs, see Turok & Bailey, 2004) being amongst the favoured concepts. Exploring the similarities and differences between these concepts is beyond the scope of this research, and we therefore use these terms in their most general guise – obvious examples then include large metropolitan regions such as South East England, the German Rhine-Ruhr region, the Dutch Randstad region and the 'Flemish diamond' in central Belgium. These metropolitan regions are obvious examples of the key tenets of the PM-CR/PUR literature in that the complexity of their spatial organization is either explicitly or implicitly related to there being multiple important and well-connected urban nuclei within the region. For example, Taylor et al. (2008) have argued that a polycentric organization around one or major 'global cities' seems to be (or become) a general feature of large-scale urbanized regions in Western Europe: in their research, they consistently observe a new scale of expansion and integration of economic activity at the regional level so that emerging mega-city regions are enveloping previously separate cities, as well as promoting growth in settlements not previously deemed to be 'major cities'.

The dominant assumption when making sense of polycentric urban regions is that such a spatial structure allows capitalizing on the different specializations in the region at large through efficient cross-regional infrastructures and/or the knowledge exchanges these facilitate (De Goei & Burger, 2010). Put differently: the assumption is that polycentricity in a region yields advantages because external economies are not restricted to a single urban core, but shared among a collection of relatively proximate, functionally well-connected cities. Meijers and Burger (2010) have corroborated this hypothesis based on an analysis of how differences along the monocentricity/polycentricity continuum affect regional economy in the United States.

At the same time, however, Burger et al. (2011) remind us that not all urbanized regions are experiencing an unambiguous shift toward a polycentric spatial structure. They furthermore emphasize that polycentricity is a heterogeneous spatial process that can take different forms (see also de Goei et al., 2010), pointing to the importance of a clear definition of 'polycentricity': they show how 'monocentricity' and 'extreme polycentricity' should be treated as ideal-typical extremes of a continuum, whereby in-between situations can cover a multifaceted set of processes unfolding in different directions, at different paces, and at different scales. This implies that polycentricity should be approached as a heterarchic concept consisting of multiple tendencies (see also Van Meeteren et al., 2015). And finally, polycentricity in and by itself is a multiplex phenomenon in that – irrespective of the measurement framework – different types of activities may be associated with different levels of polycentricity (Burger et al., 2014b). In other words: in order to fruitfully engage with this elusive concept, one needs to be very clear about what it entails in conceptual and empirical terms in any research project.

6.2.2 Conceptualising polycentricity

Below we provide a summary of the key conceptual points of attention when engaging in research on regional polycentricity. The overview obviously does not do justice to the broad range of insights that have been developed over the past few years. Rather, the key point is to show how our analytic framework relates to the conceptual state-of-the-art.

In conceptual terms, the main insight developed in recent years is that the presence of a dense, urbanized region with multiple cities of varying sizes located in close proximity does not by definition point to the presence of polycentricity and its purported advantages. Or, as Meijers (2008) aptly put it: 'Summing small cities does not make a large city'. Recent research has focused on a more thorough substantiation of the concept, which has led to the following points of attention. First, a region can only be considered polycentric when there are strong functional links between the different nodes. To this end, Meijers (2008) coins the term 'functional polycentricity' as opposed to 'morphological polycentrism' with the latter simply pointing to the presence of a set of more or less important cities in a region without the necessity of having interactions between these (for more details, see also Meijers, 2005 and 2007; De Goei et al., 2009) (see figure 6.1a).

Furthermore, and second, Meijers (2007) distinguishes between 'vertical' and 'horizontal' networking in the study of functional polycentrism cf. Camagni & Salone, 1993). Vertical urban networks are built up by inter-linked nodes from different ranks, with some nodes dominating the others during exchange (e.g. Christaller-like central place systems, see figure 6.1b). Horizontal urban networks, in contrast, are built up by linked nodes of more or less the same rank without any clear-cut dominance during exchange (see figure 6.1c).

Third, it has been argued that urban networks are being upscaled (van Oort et al., 2010; Shearmur & Doloreux, 2015; Hanssesn et al., 2014). Spatial interaction may thus increasingly stretch across regions and/or administrative areas, producing functional interdependencies across wider areas. Thus although networks of cities obviously often develop within a limited geographic area (Hall & Pain, 2006), these connections may also becoming less prone to distance decay and/or regional-administrative boundaries (see figure 6.1d). The geographical result of this pattern is also related to the idea that different levels of government will attract firms by harnessing economic activity from outside their own administrative area (Ma & Wu, 2005; Wu, 2015).

Each of these insights will be used in our analytical framework in that (1) our data is link-based; (2) discerns different types of links depending on nodes' position in the hierarchy; and (3) considers the geographical position of nodes.

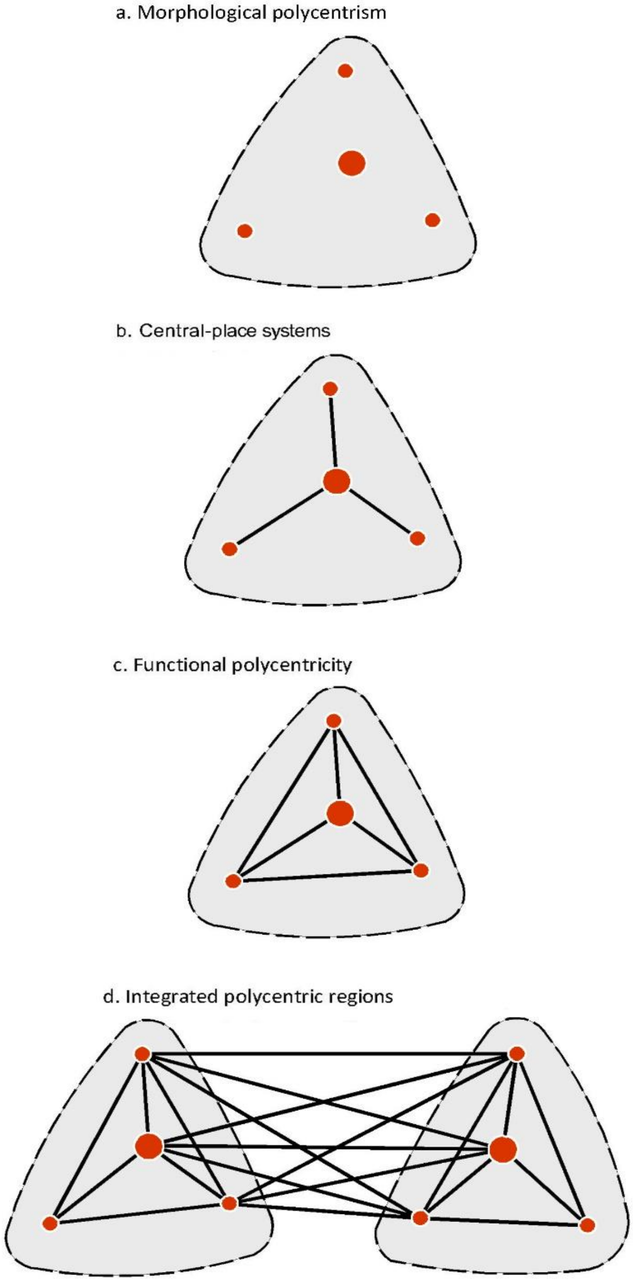

Figure 6.1 Conceptual patterns of polycentric regions

6.2.3 Analysis of polycentricity in the PRD

In this chapter, we contribute to a growing body of literature analysing the economic transition and urban transformation of the PRD (Yeh, Yang, Wang, 2015). Focusing on the rising levels of economic globalization and urbanization in this ‘workshop of the world’, scholars have analysed the expansion of the urban form and the spatial restructuring of land use patterns in the PRD (Seto & Kaufmann, 2003; Li & Yeh, 2004; Chen, Zheng, Guan et al., 2011; Ge et al., 2011). In terms of the transformation of the urban form in the PRD, Vogel, Savitch, Xu et al. (2010) have argued that economic globalization contributes to a more spatially decentralized urban form in the PRD. In addition, Lin (2001) has shown that the growth of spatial interaction outside the central cities has not led to a reduction of regional economic inequality in the PRD. However, to the best of our knowledge few (if any) empirical studies have focused on the (possibly: changing) relationship between central and non-central sub-regions.

In parallel, there has also been a growing interest in research on urban networks in the PRD. Tong, Tao, Li et al. (2014) used a modified gravity model to characterize the city linkages within the PRD. Chen, Ma, Li et al. (2013) found that the structure of intercity passenger traffic flows in the PRD suggest a spatial structure of a gradient hierarchy and a polycentric distribution. They also confirmed that leapfrog contact networks are formed among the central sub-regions. Furthermore, Yeh, Yang, Wang et al. (2014) have shown that the rapid growth of producer services in the PRD has been a crucial contributor to the formation of the regional network besides the manufacturing activities. However, these results do not reveal the transition of the spatial patterning of the different networks in the context of central and non-central sub-regions in the PRD.

6.3 Data and methods

6.3.1 Study area

Administratively, the PRD consists of nine ‘prefecture-level regions’, each with a major city at their core: Guangzhou, Shenzhen, Zhuhai, Dongguan, Foshan, Huizhou, Jiangmen, Zhaoqing and Zhongshan (Table 6.1). And the two dominant cities of Guangzhou and Shenzhen, in terms of population and economic output, can also receive favourable policies (i.e. economic zones, tax subsidies of Nansha and Qianhai, political ranking of officials etc.) from the central government in China. Irrespective of there being at least 9 ‘major’ cities, the Pearl River Delta as a whole is actually a complex urbanized region with population dynamics and massive land-use transformation in the intermediate zones surrounding and in-between the major metropolitan centres. Geographically, these trends can be captured by each of the ‘prefecture-level regions’ being sub-divided in a central city sub-region and a number of non-central city sub-regions in which a number of ‘smaller’ cities and towns are located. It is this framework we will use in our analyses. Figure 6.2 outlines the basic geographical framework used in in this chapter.

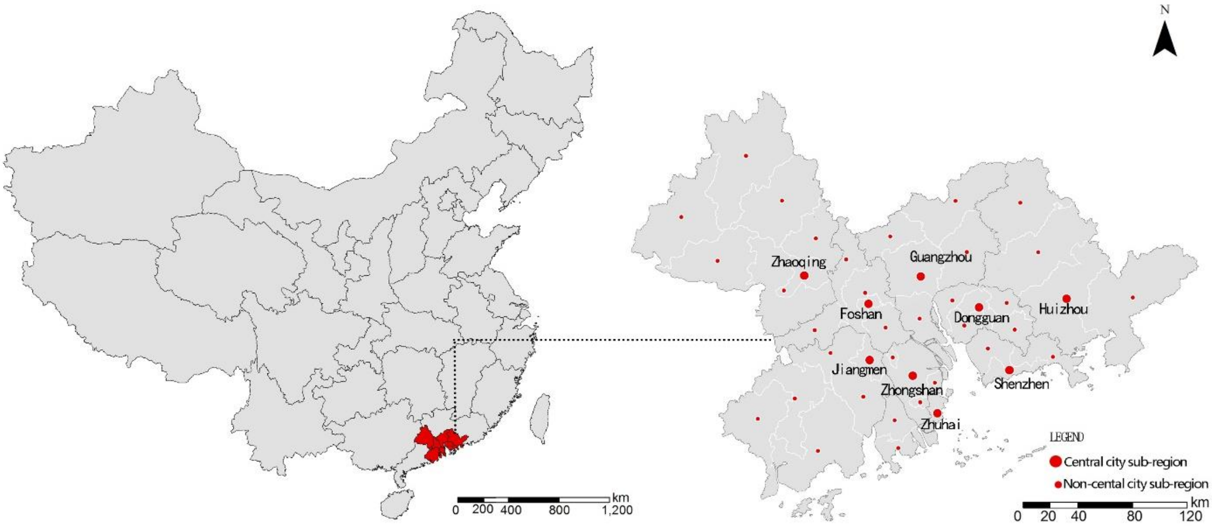

Figure 6.2 Location of prefectures and their sub-regions in the PRD[9]

Table 6.1 Area, population and GDP of prefecture-level regions in 2001 and 2013 (sources: Statistical yearbook of Guangdong 2002/2014)

Indices	Area (km^2)	Population (Thousand)		GDP (Billion Chinese yuan)	
		2001	2013	2001	2013
Guangzhou	7263	9942.0	12926.8	268.6	1542
Shenzhen	2050	7008.8	10628.9	195.5	1450
Zhuhai	1653	1235.4	1590.3	36.7	166.2
Dongguan	2465	6445.8	8316.6	57.9	549
Foshan	3868	5337.7	7295.7	106.8	701
Huizhou	10655	3216.1	4700.0	48.0	267.8
Jiangmen	9443	3956.8	4497.6	61.5	200
Zhaoqing	15056	3373.1	4022.1	41.1	166
Zhongshan	1800	2363.3	3173.9	36.3	263.9
Total	54253	42879	57151.9	852.4	5305.9
Growth			33.3%		522.5%

9 Some sub-regional boundaries have changed over the research period, albeit that prefecture-level boundaries have remained stable. For example, Guangming was separated from Shenzhen's Bao'an sub-region in 2007. Different operationalizations of the sub-regions implies that we are facing different spatial units in different periods. To tackle this, we devised a consistent set of 9 central city sub-regions and 34 non-central city sub-regions (totalling 43). The county-level administrative boundaries as they were in 2004 were used to delineate our sub-regions. There have been no changes in terms of the prefecture-level geographies of the PRD during 2001-13.

Although this a priori delineation of spatial units has all the bearings of the 'modifiable area(l) unit problem', there are in our view a number of reasons to assume that, in the PRD context, Figure 6.2 produces a reasonable territorial framework for capturing polycentric developments. The most important reason is that, in the Chinese context, administrative boundaries often reflect concrete planning realities and thus become available proxy for assessing spatial patterns. This two-tiered regionalization – prefecture-level regions that are subdivided in central cities and non-central city sub-regions – is commonly used in planning documents, for example the 'Master Plan for Dongguan (2015-2030)' and the 'Master Plan for Zhongshan (2010-2020)'.

6.3.2 Data sources

Our analysis is based on ownership links L_{ij} in the corporate organization of firms. To produce the data matrix of areal associations, we used information on the geography of firms located in the PRD drawn from the publicly available company directories provided by Ebuy Information Ltd (http://www.ebuywww.net.cn/) in Beijing and Emage Company Ltd (http://www.emagecompany.com/) in Shenzhen[10]. The data points (2001, 2008, and 2013) were chosen for two reasons: (i) China's role in the global economy has been strongly shaped since the country joined WTO in 2001 and (ii) has also been hit by the global economic crisis in 2008-09.

Table 6.2 Basic features of firms' links in the PRD

Indices		2001	2008	2013	Growth in 2001-08	Growth in 2008-13
Total firms		2015	9356	8823	364.3%	-5.7%
Employees engaged		105787	454777	586418	329.9%	28.9%
Ownership	State owned	561	1242	1082	121.4%	-12.9%
	Collectively owned	229	194	266	-15.3%	37.1%
	Private companies	461	3347	3810	626.0%	13.8%
	Foreign invested	282	1717	986	508.9%	-42.6%
	Joint-stock	228	1243	1270	445.2%	2.2%
	Other	254	1613	1409	535.0%	-12.6%
Sector	Manufacturing	195	788	1674	304.1%	112.4%
	Technology & construction	177	746	570	321.5%	-23.6%
	Transportation & communication	246	1616	1131	556.9%	-30.0%
	Trade & catering service	655	2052	1656	213.3%	-19.3%
	Finance & insurance	342	1735	1641	407.3%	-5.4%
	Real estate	45	608	486	1251.1%	-20.1%
	Leasing & professional business	271	1324	1211	388.6%	-8.5%
	Administration & social service	84	487	454	479.8%	-6.8%

10 As pointed out by the reviewer, the resulting data quality is not perfect, but they are in line with existing research (Chen et al., 2009; Tang & Zhao, 2010).

For each firm with more than a single presence in the PRD, we examined whether this involved a legal ownership link as suggested by the terms ‘subsidiary’, ‘agency’, or ‘branch’. This resulted in 2015, 9356 and 8823 pairs of headquarter-subsidiary links across the PRD in 2001, 2008 and 2013 respectively (see Table 6.2).

The companies can be divided into 8 sectors, according to the 4-digit code of the Chinese Standard Industrial Classification (CSIC 1994 & 2002). The number of connections rises significantly during 2001-08 for most sectors, followed by a small drop in 2008-13 except for manufacturing (see Table 6.2). Importantly, the number of foreign firms setting up branches drops 42.6% after the onset of the global economic crisis in 2008-09.

The changes in the number of firms can be related to the life span of companies in China. According to research reports from Beijing Evening News (2013), most small firms in China close down after an average of 2.5 years, while large corporations last for more than 7–years. There is no research about the lifespan of branches in China but the branch offices should not last no more than firms. In our datasets, most of the branch offices are medium or small firms, since the average number of employees of firms in 2001, 2008 and 2013 was 52.50, 48.61 and 66.46, respectively. 92.96% of the 2,015 firms that existed in 2001 had closed down by 2008, which is indicative of only 10% of private enterprises in China surviving for more than 3 years in their original format (Wang, 2006). In the meantime, 48.33% of 9,356 companies that existed in 2008 had closed down by the end of 2013. This reflects the shorter timespan between both data points, but also that the life span of companies in China has gradually improved in the last decade (see Cheng, 2010; Chen et al., 2009; Wu, 2015).

6.3.3 Measuring polycentricity and interaction

Although China-focused research on polycentric city regions has been booming in recent years (Tang & Zhao, 2010; Luo, 2010; Lu et al., 2012; Zhao et al., 2015), to date this research has not really linked up with the state of the art in conceptual and empirical research on polycentricity. We therefore seek to extend this literature by drawing on recent insights as set out in the literature review. Our approach for analysing the spatial organization of the PRD in the context of the PC-MR literature consists of analysing the shifting geographies of headquarter-subsidiary networks. Although this approach is reminiscent of the work of *inter alia* Taylor et al.’s (2008) research based on the ‘interlocking network model’, our framework is slightly different. That is, whereas in the interlocking network model the mere co-presence of a firm in any pair of places is assumed to be sufficient to assume the presence of flows, here we adopt a more restricted stance as advanced in the research of Alderson & Beckfield (2004) and Zhao et al. (2015). In this approach, attention is given to firms’ spatial organization as visible in their legal structure: firm ownership relations are interpreted as areal links L_{ij} between a firm headquartered in sub-region i with a branch office in sub-region *j*. These ownership links L_{ij} are at the basis of our measurement framework.

At the nodal level, we can use the ownership links L_{ij} to calculate two basic network centrality measures, i.e. outdegree centrality (representing the number of outgoing links L_{ij} from firms headquartered in *i*) and indegree centrality (representing the number of incoming links L_{ji} to branches located in *i*). The total connectivity (or degree centrality) of a node is then calculated by aggregating outdegree and indegree.

To assess polycentricity, we analyse the nature of the increasing connectivity of erstwhile non-well connected nodes in general, but also at the overall changes in the outline of the networks. Following Hall & Pain (2006) and Green (2007), the polycentricity in headquarter–subsidiary links can be expressed as:

$$P_{SF}(N) = (1 - \frac{\sigma_F}{\sigma_{F_{max}}}) \cdot \Delta \qquad (6-1)$$

With $P_{SF}(N)$ ranging from 0 to 1 for sector N; σ_F the standard deviation of degree centrality; σ_{Fmax} is the standard deviation of degree centrality in a two-node network where one node has zero connectivity and the other node has the maximum possible value; and Δ is the density of the network defined as the ratio between the observed connections *L* and the theoretical maximum of connections L_{max} in the city region (Hall & Pain, 2006; Green, 2007; Liu et al., 2016),

$$\Delta = \frac{L}{L_{max}} \qquad (6-2)$$

The general level of functional polycentricity is then given by:

$$P_{GF}(N_1, N_2 \dots N_n) = \frac{1}{n} \cdot \sum_{1}^{n} \alpha_i \cdot P_{SF}(N_i) \qquad (6-3)$$

Where α_i are the weights of sector i in defining a city's functionality as per Table 6-2.

In order to explore the geographical nature of the links across regions, we categorize them into five types that in different ways speak to Meijers' (2007) distinction between 'vertical networks' and 'horizontal networks'. The links inside a prefecture-level region can take on two forms: (i) type A is a link between a central city and a non-central city sub-region; and (ii) type B is a link between any pair of two non-central city sub-regions (Figure 6.3a).

Second, links between prefecture-level regions can be classified into three types: (iii) type C is a link between two central cities; (iv) type D is a link between a central city and a non-central city sub-region; and (v) type E is a link between two non-central city sub-regions (Figure 6.3b). Burger et al.'s (2011) observation of polycentricity being a heterogeneous spatial process that can have different forms is reflected here in that the different kinds of shifts in the relative balance between the five types of links can be interpreted as pointing to the emergence of a PC-MR. However, in general terms this would imply a shift away from type A/B connections (see figure 6.1d).

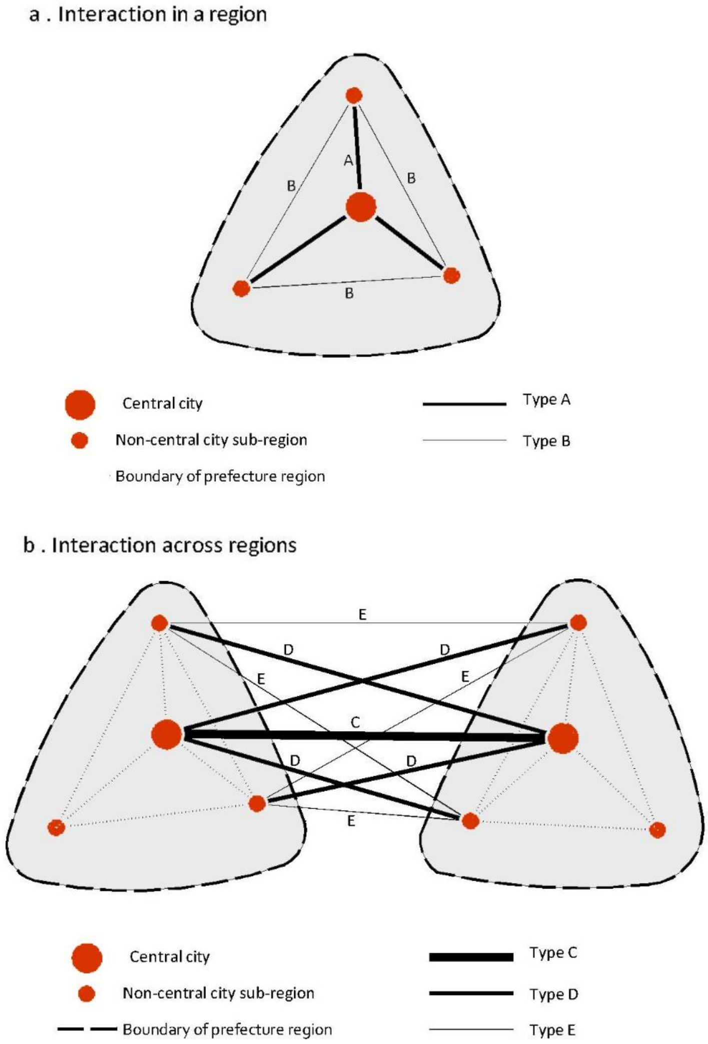

Figure 6.3 Five types of possible linkages

To formally test the evolution of the 5 types of connections, we compare the ratios of these links by sector. If R_A, R_B…R_E represent the number of connections of each type, we can define cross-regional interaction for each sector N's network as:

$$I_{SC}(N) = 1 - (R_A + R_B) \qquad (6-4)$$

The general cross-regional interaction of $I_{GC}(N)$ can be defined as the average of all sectors' networks:

$$I_{GC}(N_1, N_2 \dots N_n) = \frac{1}{n}\sum_{1}^{n} I_{SC}(N_i) \qquad (6-5)$$

6.4 Results

6.4.1 A more balanced, but shifting pattern of connectivity

We begin with a discussion of the rankings and distributions of degree centralities in the PRD (Figure 6.4 and Tables 6.3). Collectively, the maps in Figure 6.4 clearly show that (1) the density of links has intensified and (2) their geographical scope has broadened between 2001 and 2013. In 2001, only a limited number of centrally located sub-regions were well connected. A clear strengthening of links and a concomitant geographical extension is visible in 2008, and by 2013 most of the PRD's sub-regions have become integrated in a complex web of links. Only the most western, north-western and eastern sub-regions of the PRD remain relatively poorly connected.

Not only have *more* sub-regions become integrated in the PRD's corporate networks, the distribution of connectivities has also become 'flatter'. Although all of the PRD's sub-regions are increasingly enmeshed in corporate networks, it is above all previously less connected nodes that have gained additional connectivity. This is shown by the evolution of the general level functional polycentricity (see Table 6.3), which gradually rises from 0.393 in 2001, to 0.439 in 2008, and further to 0.514 in 2013. Similar evolutions can be observed for the indegree and outdegree centrality distributions. Unsurprisingly, functional polycentricity of outdegree centrality in 2008 and 2013 is consistently smaller than the indegree centrality, suggesting that outgoing links from headquarter locations – although somewhat spreading out within the PRD over time – remain more concentrated than incoming links into branch locations.

The relative balance between outgoing and incoming links also has a particular geography to it. This geography is shown in figure 6.4b through the use of different labels based on the more prevalent type of centrality. In addition to outdegree centrality prevalence being and remaining confined to the central parts of the PRD (Guangzhou, Shenzhen, Foshan and Dongguan in particular, in spite of shifts amongst these four prefecture-level regions), the major pattern is that it is a limited number of central-city nodes that stand out. Central Guangzhou and Guannei (Shenzhen) – a special territorial unit in the Shenzhen region in the context of the 'open door policy' since 1980s and the de facto central area of the Shenzhen region – are the major sites for links from corporate headquarters in 2013.

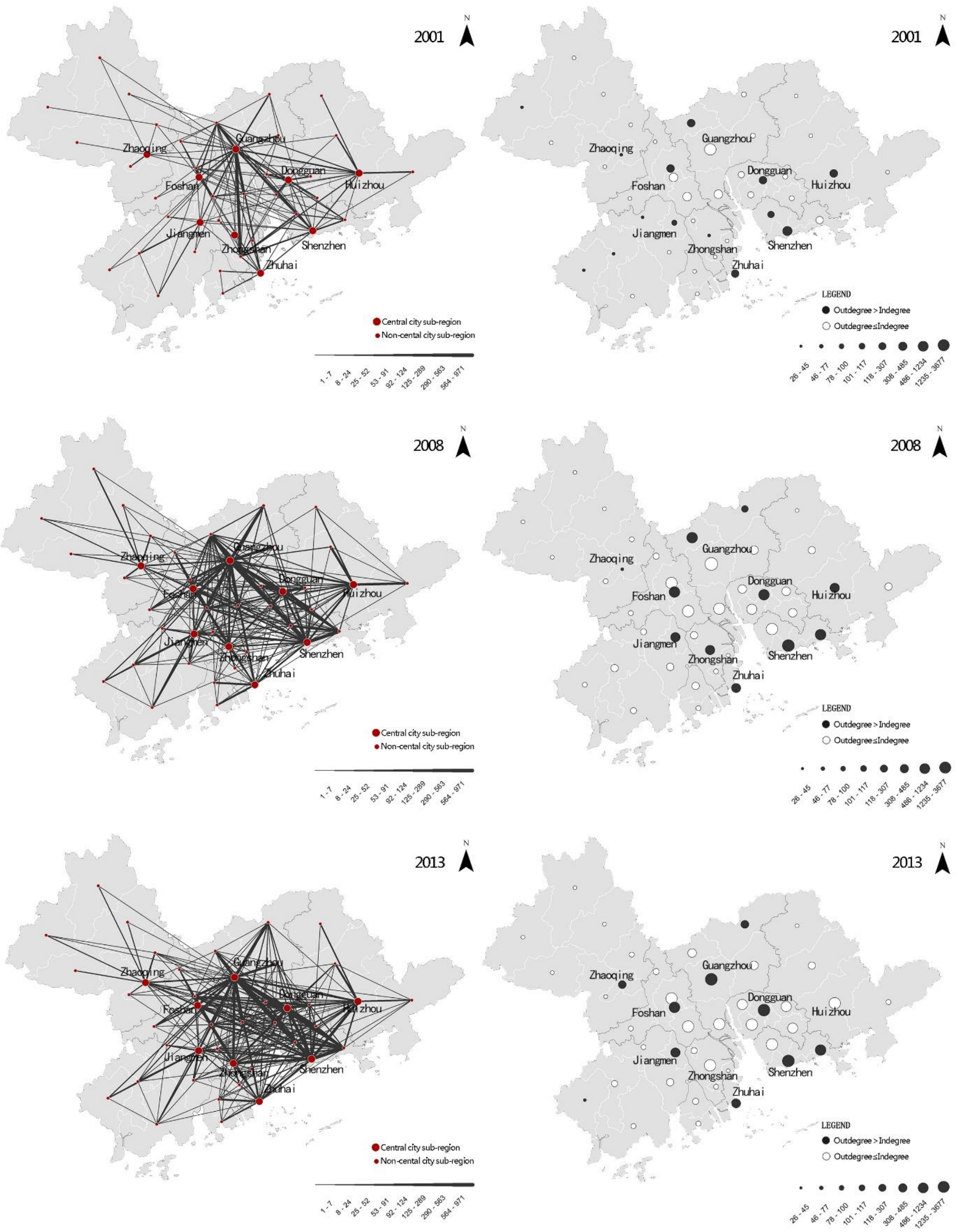

Figure 6.4 Linkages and centrality of sub-regions in the PRD in 2001, 2008 and 2013

Table 6.3 General level functional polycentricity in 2001, 2008 and 2013

	2001	2008	2013
$P_{GF}(N)$, outdegree	0.391	0.434	0.506
$P_{GF}(N)$, indegree	0.394	0.444	0.521
$P_{GF}(N)$, total degree	0.393	0.439	0.514

6.4.2 Evolution of the different types of connections

The increasing connectivity and levels of polycentricity mask geographical sifts as shown by the uneven evolution of the different types of connections. Although the 'vertical networks' of type A connections remain dominant, their relative importance declines (along with type B connections), especially in 2008-2013: while the number of intra-regional links declines and even produces a small overall decline in connectivity, the number of inter-regional links keeps growing (see Table 6.4). This indicates a shift in the 'use' of the PRD, which not only becomes more polycentric in general term but appears to evolve into a regional system of multiple centres that are connected by complex interactions. The net result is that the $I_Gc(N)$ value for the PRD as a whole rises from 0.426 in 2001 to 0.486 in 2013.

Table 6.4 Number of linkages per type of connection and general cross-regional interaction (2001, 2008, 2013)

	2001	2008	2013	Growth in 2001-08	Growth in 2008-13
Type A	1115	5141	3853	361.1%	-25.1%
Type B	58	434	374	648.3%	-13.8%
Type C	408	2093	2412	413.0%	15.2%
Type D	355	1427	1826	302.0%	28.0%
Type E	79	261	358	230.4%	37.2%
Total	2015	9356	8823	364.3%	-5.7%
$I_{GC}(N)$	0.426	0.405	0.486	—	—

To explore differences of the types of links across the 9 regions, we can further observe the distribution of the number of links for each region. In 2001 and 2008, type A links are dominant in all regions, after which they start decreasing. Regions such as Foshan, Zhuhai, Huizhou and Zhaoqing, in particular are increasingly enmeshed in cross-regional interaction in 2001, with Zhuhai and Zhongshan even having more type C than type A connections by 2013. By 2013, $I_{GC}(N)$ defined exceeds 0.5 for 5 out of 9 regions indicating that the extra-regional linkages are now more prevalent than intra-regional linkages.

For each sectoral connection, the ratio of each type to the sum of all links was also calculated to compare the shifting process of interaction in the PRD (see table 6.5). The bold numbers in table 6.5 indicate the type with the largest share in the respective sector. In 2001, type A connections were far stronger in all sectors than any other connections. In 2013, this type lost its dominant status in most sectors, except in the transport & communication, finance & insurance, real estate, and administration & social service sectors. Type C connections were the more important type in 2013 (ratio among all sectors: 27.3%).

Table 6.5 Ratio of linkages per type of connection for each sector (2001, 2008, 2013)

2001	Type A	Type B	Type C	Type D	Type	Total	N
Manufacturing	53.3	5.1	11.8	20.0	9.7	100	194
Technology & construction	44.6	1.7	16.9	29.9	6.8	100	167
Transport & communication	56.1	0.8	22.8	16.7	3.7	100	249
Trade & catering service	51.0	3.4	22.9	19.5	3.2	100	659
Finance & insurance	84.8	1.2	10.8	3.2	0.0	100	228
Real estate	51.1	8.9	15.6	22.2	2.2	100	47
Leasing & professional business	38.7	3.3	33.6	20.7	3.7	100	275
Administration & social service	50.0	4.8	16.7	20.2	8.3	100	10
Total	55.3	2.9	20.2	17.6	3.9	100	1913
2008	Type A	Type B	Type C	Type D	Type	Total	N
Manufacturing	60.3	11.8	8.6	13.1	6.2	100	788
Technology & construction	35.7	5.6	31.5	22.9	4.3	100	493
Transportation & communication	56.6	3.7	19.1	17.8	2.9	100	1911
Trade & catering service	46.7	4.9	27.5	17.3	3.6	100	2052
Finance & insurance	84.0	0.7	10.0	4.8	0.5	100	2117
Real estate	67.1	6.1	13.2	12.5	1.2	100	608
Leasing & professional business	32.1	4.0	40.1	21.9	1.9	100	1324
Administration & social service	48.7	7.8	27.3	12.3	3.9	100	253
Total	54.9	4.6	22.4	15.3	2.8	100	10033
2013	Type A	Type B	Type C	Type D	Type	Total	N
Manufacturing	23.5	3.8	30.5	32.9	9.4	100	1674
Technology & construction	35.6	7.5	35.8	18.4	2.6	100	373
Transportation & communication	44.6	5.3	25.9	22.0	2.2	100	1295
Trade & catering service	25.7	2.8	34.7	29.6	7.2	100	1656
Finance & insurance	83.2	0.7	10.8	4.9	0.3	100	2348
Real estate	62.1	6.8	18.5	11.9	0.6	100	476
Leasing & professional business	32.5	4.5	41.0	20.0	2.0	100	1221
Administration & social service	58.8	13.4	14.8	10.8	2.2	100	197
Total	43.7	4.2	27.3	20.7	4.1	100	9695

More significantly, type A had the largest share (84.8%) in finance & insurance in 2001, and declined a little (to 83.2%) in this sector in 2013. Manufacturing links were more often in the pattern of type D, between central and non-central sub-regions of different prefecture-level regions, in 2013. Industrial location policies laid down in the regional planning policy documents should thus reflect an increasingly complex reality with major evolutions outside of central cities and being steered from outside the own region. Coupled with the relative rise of non-central city sub-regions across the prefectural boundaries this implies that emerging planning policy measures aimed at the dispersal of manufacturing activities (*Shuang zhuan yi,* 双转移) in the PRD have either materialised or are unfolding.

6.4.3 Shift analysis by sector

To shed more detailed light on the complexity of different types networks, we explore the (evolution of the) geographies of the different links for each sector. For each sector, functional polycentricity is on the rise in the period 2001-13 (see figure 6.5). However there are major differences across sectors and between time periods. Functional polycentricity for technology & construction, transportation & communication, finance & insurance and real estate is at its peak in 2008. Manufacturing has the highest level of special functional polycentricity in 2013 and this sector, followed by trade & catering service, and transportation & communication.

Finally, we present a longitudinal analysis for the share of cross-regional links defined by I_{SC}(N) for each sector (see figure 6.5). The gradually enlarged area of shaded part in the radar charts indicates the rising share of connections across regions in PRD. The most significant shift comes from manufacturing and trade & catering service, which exhibit stronger cross-regional interaction. However, real estate and administration & social services have witnessed shrinking process in terms of their inter-regional interaction in 2013. More generally, those sectors dominated by state-owned enterprises (SOEs) finance & insurance and administration & social service in particular, retain a regional connectivity patterns reflecting administrative the continued relevance of distance decay and/or administrative boundaries. The formation of cross-regional links is therefore not only complex in geographical terms, but is also constituted by different and diverging processes where regionality continues to play a major role: rather than an unequivocal shift from vertical to horizontal urban networks (Camagni & Salone, 1993), we see a hesitant shift with uneven geographical and sectoral dimensions attached to it.

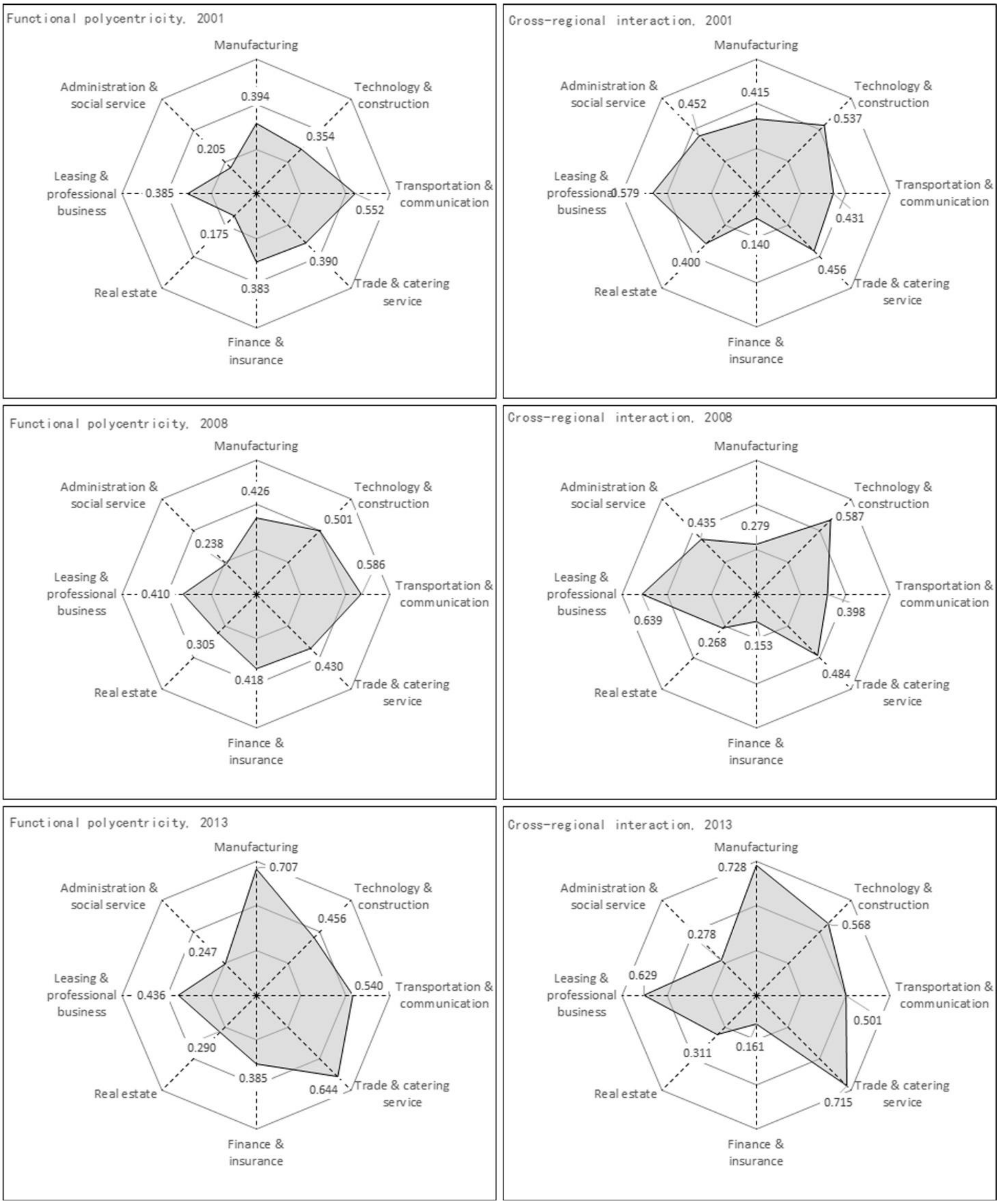

Figure 6.5 Shift of special functional polycentricity and cross-regional interaction in the PRD

6.5 Discussion and conclusion

In this chapter, we have explored the shifting spatial organization of the Pearl River Delta (PRD) through the lens of research on polycentric mega-city regions (PMCRs). Based on a review of the current state of affairs in this literature, we have devised an empirical framework for exploring economic integration through polycentric developments that has the following key features. First, we have assessed polycentricity in its functional guise by drawing on flow data, in this case headquarter-subsidiary relations across space. Second, to address shifts towards polycentricity and integration, we combined a straightforward description of the evolution of connectivity patterns with a functional polycentricity analysis and an analyses of differential growth patterns for different types of links. Polycentricity is not an absolute end state and can come in different guises, and we therefore approached it as a general concept that may consist of very different developments.

Comparisons of the spatial organization of the PRD in 2001, 2008 and 2013 revealed the rising complexity of the functional integration of the PRD. Our results suggest a fast rising of these networks in 2001-08, with growth stalling for most sectors in 2008-13 except for manufacturing. However, in the latter period there is an expansion of inter-regional links, producing rising levels of functional polycentricity. This process is uneven, with regions such as Zhuhai and Zhongshan and above all firms active in market-oriented sectors be(com)ing more involved in cross-regional links. The PRD continues undergoing economic restructuring, and new challenges since 2014 are reshaping this city region. For example, many firms including large corporations such as Huawei (*Huawei*, *华为*) and ZTH Holding (*Zhongxing*, *中兴*) are planning to set up branches outside of Shenzhen in early 2016. Hence, further research is necessary to reveal the evolution of firms' networks in the PRD.

In this Chapter, it was shown that headquarters–branch connections also reflect the impacts of the state-owned economy. Among different sectors, those dominated by state-owned enterprises (SOEs), and particularly finance & insurance and administration & social services, retain a regional connectivity pattern that reflects the continued relevance of distance decay and/or administrative boundaries. This leads to another argument, namely that the state, in the form of SOEs, should not have so much power in the regional economy and should allow more room for the development of private firms. After all, private companies can have a higher performance (Jiang & Nie, 2014; Xia & Walker, 2015) and denser cross-regional networks than SOEs, which are always faced with more limits on setting up branches because they are tightly controlled by governments. Although SOEs conduct both social and economic affairs, this study found that they make a smaller contribution to the regional network interaction in city regions compared to other firms. After all, the number and affairs of SOEs controlled by central or local governments should be kept at a suitable ratio to ensure the social functions in China. What that ratio should be, however, is beyond the scope of this dissertation. While industries that are relevant to the country's natural resources will continue to be controlled by the state (Krug & Libman, 2015).

References

Alderson, A. S., & Beckfield, J. (2004). Power and position in the world city system. *American Journal of Sociology, 109*(4), 811-851.

Burger, M. J., de Goei, B., van der Laan, L., & Huisman, F. J. M. (2011). Heterogeneous development of metropolitan spatial structure: evidence from commuting patterns in English and Welsh city-regions, 1981–2001. *Cities*, *28*(2), 160-170.

Burger, M. J., & Meijers, E. J. (2012). Form follows function? Linking morphological and functional polycentricity. *Urban Studies*, 49(5), 1127-1149.

Burger, M. J., Meijers, E. J., & Van Oort, F. G. (2014a). Regional spatial structure and retail amenities in the Netherlands. *Regional Studies, 48*(12), 1972-1992.

Burger, M. J., Van der Knaap, B., & Wall, R. S. (2014b). Polycentricity and the multiplexity of urban networks. *European Planning Studies*, *22*(4), 816-840.

Camagni, R.P., & Salone, C. (1993). Network urban structures in northern Italy: elements for a theoretical framework. *Urban Studies, 30*(30), 1053-1064.

Chen, W., Ma, X., Li, G., Luan, X. F., & Li, G. (2013). Characteristics of regional city connection's spatial pattern based on intercity passenger traffic flow in Pearl River Delta. *Economic Geography, 33*(4), 38-45. (in Chinese)

Chen, X. H., Cao, Y., & Yue-Ru, M. A. (2009). Life cycle of small and medium-sized enterprises based on external environmental perspective—empirical research that takes 5 metropolises including Shenzhen as samples. *Systems Engineering - Theory & Practice, 29*(1), 64-72.

Chen, Y., Li, X., Zheng, Y., Guan, Y., & Liu, X. (2011). Estimating the relationship between urban forms and energy consumption: a case study in the Pearl River Delta, 2005–2008. *Landscape & Urban Planning*, *102*(1), 33–42.

Chen, Z. (2010). Wang Jianxiang: Average life span of medium and small companies is 2.9 years. *Enterprise reformation and management*, (5), 83-83. (in Chinese)

De Goei, B., & Burger, M. J. (2010). Functional polycentrism and urban network development in the greater south east, United Kingdom: evidence from commuting patterns, 1981–2001. *Regional Studies*, *44*(9), 1149-1170.

Derudder, B. (2006). On conceptual confusion in empirical analyses of a transnational urban network. *Urban Studies*, *43*(11), 2027-2046.

Florida, R., Gulden, T., & Mellander, C. (2008). The rise of the mega-region. *Social Science Electronic Publishing*, *1*(3), 459-476.

Green, N (2007) Functional Polycentricity: A Formal Definition in Terms of Social Network Analysis, *Urban Studies, 44*(11), 2077-2103.

Hall, P., & Pain, K. (2006). *The polycentric metropolis: learning from mega-city regions in Europe*. London: Earthscan.

Hall, P. (1999). *Planning for the mega-city: a new eastern Asian urban form. Perspectives on 21st Century Urban Development: Sustainable Eastern and Western Cities in the New Millennium*, Aldershot.

Hanssens, H., Derudder, B., Van Aelst, S., & Witlox, F. (2014). Assessing the functional polycentricity of the mega-city-region of Central Belgium based on advanced producer service transaction links. *Regional Studies*, *48*(12), 1939-1953.

Harrison, J., & Hoyler, M. (2015). Megaregions: foundations, frailties, futures. *Megaregions: Globalization's New Urban Form*, 1-28.

Krug, B., & Libman, A. (2015). Commitment to local autonomy in non-democracies: Russia and China compared. *Constitutional Political Economy, 26*(2), 221-245.

Li, X., & Yeh, A. G. O. (2004). Analyzing spatial restructuring of land use patterns in a fast growing region using remote sensing and GIS. *Landscape & Urban Planning, 69*(4), 335-354.

Lu, X., Ma, X., & Li, G. (2012) Spatial pattern of regional city network based on international advanced producer services' layout in Pearl River Delta. *Economic Geography, 32*(4), 50-54. (in Chinese).

Lin, G. C. (2001). Metropolitan development in a transitional socialist economy: spatial restructuring in the Pearl River Delta, China. *Urban Studies, 38*(3), 383-406.

Liu, X., Derudder, B., & Wu, K. (2016). Measuring polycentric urban development in China: an intercity transportation network perspective. *Regional Studies*, *50*(8), 1302-1315.

Lu, X., Ma, X., & Li, G. (2012) Spatial Pattern of Regional City Network Based on International Advanced Producer Services' Layout in Pearl River Delta. *Economic Geography*, *32*(4), 50-54. (in Chinese).

Luo, Z. (2010) Study on the Functional Polycentricity of Yangtze River Delta. *Urban Planning International*, *25*(1), 60-65. (in Chinese).

Ma, L., & Wu, F. (2005). Restructuring the Chinese city: diverse processes and reconstituted spaces. In Ma, L., & Wu, F. (Eds.), *Restructuring the Chinese City*. London: Routledge.

Meijers, E. (2007). From central place to network model: theory and evidence of a paradigm change. *Tijdschrift Voor Economische En Sociale Geografie*, *98*(2), 245–259.

Meijers, E. (2008). Summing small cities does not make a large city: polycentric urban regions and the provision of cultural, leisure and sports amenities. *Urban Studies*, *45*(11), 2323-2342.

Mogridge, M., & Parr, J. B. (1997). Metropolis or region: on the development and structure of London. *Regional Studies*, *31*(2), 97-115.

Newman, P., & Thornley, A. (2011). *Planning world cities: globalization and urban politics*. Palgrave Macmillan.

Pred, A. R. (1977). *City Systems in Advanced Economies: Past Growth, Present Processes and Future Development Options*. London, Hutchinson.

Schoon, S. (2014). Chinese strategies of experimental governance. The underlying forces influencing urban restructuring in the Pearl River Delta. *Cities*, *41*(s1), 194-199.

Scott, A. J. (2001). *Global City-Regions: Trends, Theory, Policy*, Oxford: Oxford University Press.

Seto, K. C., & Kaufmann, R. K. (2003). Modeling the drivers of urban land use change in the Pearl River Delta, China: integrating remote sensing with socioeconomic data. *Land Economics*, *79*(1), 106-121.

Shearmur, R., & Doloreux, D. (2015). Central places or networks? Paradigms, metaphors, and spatial configurations of innovation-related service use. *Environment & Planning A*, *47*(7), 1521-1539.

Tang, Z., & Zhao, M. (2010). Economic globalization and transformation of urban system in the Yangtze River Delta Region: Interlocking network and value-added hierarchy. *Urban Planning Forum*, (1), 29-34. (in Chinese).

Taylor, P. J., Evans, D. M., & Pain, K. (2008). Application of the interlocking network model to mega-city-regions: measuring polycentricity within and beyond city-regions. *Regional Studies*, *42*(8), 1079-1093.

Timberlake, M., Wei, Y. D., Ma, X., & Hao, J. (2014). Global cities with Chinese characteristics. *Cities*, *41*(s1), 162-170.

Tong, D., Liu, T., Li, G., & Yu, L. (2014). Empirical analysis of city contact in Zhujiang (Pearl) River Delta, China. *Chinese Geographical Science*, *24*(3), 384-392.

Turok, I., & Bailey, N. (2004). The theory of polynuclear urban regions and its application to central Scotland. *European Planning Studies*, *12*(3), 371-389.

Van Meeteren, M., Poorthuis, A., Derudder, B., & Witlox, F. (2015). Pacifying Babel's Tower: A scientometric analysis of polycentricity in urban research. *Urban Studies*, (ahead-of-print).

Van Oort, F., Burger, M., & Raspe, O. (2010). On the economic foundation of the urban network paradigm: spatial integration, functional integration and economic complementarities within the Dutch Randstad. *Urban Studies*, *47*(4), 725-748.

Vasanen, A. (2013). Spatial integration and functional balance in polycentric urban systems: a multi‐scalar approach. *Tijdschrift Voor Economische En Sociale Geografie*, *104*(4), 410-425.

Vogel, R. K., Savitch, H. V., Xu, J., Yeh, A. G. O., Wu, W., & Sancton, A. (2010). Governing global city regions in China and the West. *Progress in Planning, 73*(1), 1-75.

Wang, W. (2006). *Different thinking about the management innovation of small and medium private enterprises (SMPEs) of China*. http://www.seiofbluemountain.com . (in Chinese)

Wang, Y., Wang, C., Hong, J, & Nian, M. (2015). Natural resources, administration hierarchy and development of China. Management *World*: (1), 41-50. (in Chinese).

Wei, Y. D. (2015). Spatiality of regional inequality. *Applied Geography, 61*, 1-10.

Wu, F. (1998). Polycentric urban development and land-use change in a transitional economy: the case of Guangzhou. *Environment and Planning A*, *30*(6), 1077-1100.

Wu, F. (2015). *Planning for growth: Urban and regional planning in China*. Routledge.

Wu, Y. (2015). Secrets for longer life span of companies. *Corporate culture*, (5), 71-73. (in Chinese)

Yeh, A. G., Yang, F. F., & Wang, J. (2015). Producer service links and city connectivity in the mega-city region of China: A case study of the Pearl River Delta. *Urban Studies, 52*(13), 2458-2482.

Ge, Y., Cao, F., Du, Y., Lakhan, V. C., Wang, Y., & Li, D. (2011). Application of rough set-based analysis to extract spatial relationship indicator rules: An example of land use in Pearl River Delta. *Journal of Geographical Sciences*, *21*(1), 101-117.

Xue, D., & Wu, F. (2015). Failing entrepreneurial governance: from economic crisis to fiscal crisis in the city of Dongguan, China. *Cities*, *43*, 10-17.

Ye, L. (2014). State-led metropolitan governance in China: Making integrated city regions. *Cities*, *41*, 200-208.

Yeh, A. G. O., Yang, F. F., & Wang, J. (2015). Producer service links and city connectivity in the mega-city region of China: A case study of the Pearl River Delta. *Urban Studies, 52*(13), 2458-2482.

You, X., Wei, Q., Li, K., & Tang, F. (2005). Development problems at prefecture and city level in Guangdong from the view angle of administrative division. *Planners*. (11), 72-7. (in Chinese).

Zhang, X., & Kloosterman, R. C. (2016). Connecting the 'workshop of the world': intra-and extra-service networks of the Pearl River Delta City-Region. *Regional Studies, 50*(6), 1069-1081.

Zhao, M., Zhong, Y., & Xu, G. (2015). Polycentric progress of the three major city regions in China, 2001-2009. *Economic Geography, 35*(3). (in Chinese).

Zhou, Y., & Hu, D. (1992). A questionnaire survey for the economic impact of 'prefecture city jurisdiction over counties'. *Economic Geography*. (1), 8-14. (in Chinese).

Zhou, Y. (2016). *Discussing urban agglomeration as the main form of urbanization*. http://www.planning.org.cn/report/view?id=140. (in Chinese).

Chapter 7: Conclusions: main results and future issues

7.1 Introduction

As firms are widely viewed as actors underlying the formation of intercity networks, this study focused on the characteristics of connections in mainland China through the lens of spatial corporate organizations. In the process, the various chapters focused on the research gaps: first, few studies have noted the complexity of urban geographies in firms' networks in China beyond the major cities of Beijing and Shanghai; second, limited attention has been paid to the intensified features of urban networks using different methods; and third, the impacts of globalization and political hierarchy on the urban networks have been insufficiently explored. This study addressed four aspects of these issues:

- The geographies of corporate spatial organization in the national urban system were examined, and two mega-city regions of the Yangtze River Delta (YRD) and the Pearl River Delta (PRD) were extensively researched.
- Diverse algorithms for more adequately measuring city-dyads in networks were explored according to the specific context of regional development.
- The impacts of China's political system, in the form of state-owned firms, on the urban networks were revealed.
- The landscape of urban networks in China, which have been strongly reshaped during the process of globalization, were explored at both the national and the regional scale.

7.2 Overview of the main results

The answers to the research questions are presented in Chapters 2–6. Each research question was addressed in two or three chapters, because the various impacts of the state-owned economy or of globalization on urban networks can be revealed by different methods or at different geographical scales.

In Chapter 2, it was shown that China is now being opened up not only through the well-established gateway of Hong Kong, but also through major transnational intercity connections centred on Beijing and Shanghai (Taylor et al., 2014). The emerging dominance of a select triad of Chinese cities in the office networks of PS firms is evident. The study confirmed a hierarchical structure in the Chinese urban network of PS firms by means of the interlocking network model.

Unsurprisingly, Beijing and Shanghai are at the top of this hierarchy, but their dominance is less apparent than that revealed in the global analysis. Moreover, unlike other studies that assert that Shanghai has surpassed Beijing in the world city system, our analysis suggests that Beijing leads in the national urban network. Second, the hierarchies of the banking and insurance servicing networks are flatter than those of law, advertising and consultancy, which are more influenced by market factors. The banking and insurance sectors are more dominated by state-owned enterprises that have branches all over the country and generate a large amount of intercity connectivity in the interlocking network model (INM). Third, there is a geographic concentration of network connectivity in eastern China, and in coastal China a triangle is formed by three highly interconnected urban clusters: Beijing–Tianjin–Hebei (BTH), the Yangtze River Delta (YRD) and the Pearl River Delta (PRD). It should also be noted that a significant amount of industrial specialization occurred in cities in the YRD in 1996–2005 and in the PRD in 2000–2010 (Zhao, 2012; Zhao & Duo, 2013). And according to the 2000 and the 2010 census, the three mega-clusters attracted more migrants from other regions in 2000–10.

In Chapter 3, a complementary method of measuring asymmetric connections – that of bipartite network projection of resource allocation – was applied to reflect the imbalanced geography of PS firms in the global economy. The location strategies of firms, which are always influenced by local governments seeking investments, are regarded as a process of recommendation. In this process, PS offices are considered to be the scarce resources to be allocated in the bipartite network. In addition, connections between two cities in a city network may indicate an asymmetric flow. By analysing asymmetrical edge weight between cities, we divided the city network of multi-locational PS firms into core cities and periphery cities. On this basis, we made an arithmetic reduction to 106 Chinese cities. By the statistical analysis of asymmetry between each pair of city-dyads, gateway cities and periphery cities were distinguished within China's urban system of PS firms under the model of the recommendation system of location choices. The results also suggest that typical provincial capitals tend to link with cities that accommodate firms with widely dispersed offices.

In Chapter 4, we proposed another method for measuring urban networks by using the locational strategies of PS firms. Specifically, we performed the traverse computation of individual firms throughout the entire process and applied a combination of geographical space and the firm's hierarchy. We thus avoided the information loss associated with the projection from a two-mode firm–city database to a one-mode city–city database, and thereby understood the actual social network linkage process. In the presented empirical interpretation of two large metropolitan areas in China (i.e. the YRD and the PRD), the improved combining geographic and hierarchical features model (CGHM) algorithm revealed clear hierarchical and geographical characteristics and better described the spatial structure of intercity producer servicing networks. More importantly, we were able to use the network analysis indicators (i.e. node degree, closeness, betweenness, in-degree and out-degree) to broaden the research perspective on PS networks.

In Chapter 5, we explored the shifting spatial structures of the YRD and the PRD through the lens of companies' spatial organization. Based on a review of the current state of affairs in the relevant literature, we developed comprehensive methodologies to compare the polycentric development of city regions through the lens of enterprises' headquarters–branch links. We also improved the statistical tools for measuring polycentricity, as initially proposed by Hall & Pain (2006) and Green (2007), to suit this class of urban networks in China. Comparing the change in spatial organization of the YRD and the PRD allowed us to discuss the unfolding functional–spatial architecture of the two mega-city regions. The results indicate that the general level of polycentricity in both regions is increasing, even though the concentration of headquarters is also increasing, while the growth in the general level of polycentricity mainly originates from higher levels of network density. And there are fundamental differences between these two city regions. For instance, firms in the PRD are more likely to set up branches beyond the prefectures' boundary, and this results in a higher level of network density compared to the YRD.

In Chapter 6, the shifting network interaction of the PRD was explored through the lens of research on polycentric mega-city regions (PMCRs). Based on a review of the current state of affairs in this literature, we devised an empirical framework for exploring economic integration through polycentric developments. First, we assessed polycentricity in its functional guise by drawing on flow data, in this case headquarters–subsidiary relations across space. Second, to address shifts towards polycentricity and integration, we combined a straightforward description of the evolution of connectivity patterns with a functional polycentricity analysis and an analysis of differential growth patterns for different types of links.

7.3 Further discussion

1) Urban geographies of networks in China

We provided a detailed description of the urban geographies of urban networks in China in Chapters 2, 5 and 6. In Chapter 2, we did not attempt to explain the entrenched geographical inequality of socioeconomic development in China (Zhang & Kanbur, 2005), but argued that these geographic disparities have been shaping China's PS provision in multiple ways. On the one hand, although the country's tertiary economy is expanding rapidly, manufacturing remains a crucial sector in China's export-oriented economy and serves as the major 'feeder' for producer services (PS) firms. While a good part of the global advanced producer service provision is associated with financial and business transactions that have nothing to do with manufacturing production, China's PS firms are less advanced in the sense that many of these services are strongly integrated with industrial bases. Accordingly, PS firms cluster in the more industrialized eastern part of China.

Moreover, in contrast to previous observations that advanced PS firms usually cluster in large global cities, China's PS firms related to manufacturing tend to cater to the country's smaller industrial cities. This is reflected in the more even distribution of urban connectivity in eastern China, which has urban regions that abound with small industrial cities.

In Chapter 5, a comparison of the development of polycentric networks in the two city regions showed that the dominance of the regional gateway city (Shanghai and Shenzhen, respectively) is still significant in the YRD and the PRD. Although most local governments of small or medium-size cities compete with each other to attract more firms to maintain connections (Fan et al., 2007; Li et al., 2008; Xia, 2014), the strength of economic agglomeration in larger cities cannot be ignored (Wang, 2010; Gu, 2012). This means that small and medium-size cities are more likely to face the situation that few leading firms want to establish their headquarters in these places.

In Chapter 6, comparisons of the spatial organization of the PRD in 2001, 2008 and 2013 revealed the increasing complexity of the functional integration of the PRD. The results suggest the rapid growth of these networks in 2001–08, with growth stalling for all sectors except manufacturing in 2008–13. However, the latter period saw the expansion of interregional links, leading to higher levels of functional polycentricity. Chapter 6 also showed that polycentricity is not an absolute end state and can come in different guises, and that we should approach it as a general concept that can consist of very different developments.

2) Diversified methods for mapping urban networks

Various data sources and methods can be used to analyse the networks of spatial corporate organizations between cities. According to Taylor's (2001) interlocking network model (INM), there are connections not only between headquarters and branches, but also between branches. We therefore used the INM to explore the urban network in mainland China through the lens of PS firms. However, the relatively 'flatter' and empirically richer intercity network emerging from this model is perhaps also the model's shortcoming (Liu & Derudder, 2013).

We also applied two other algorithms to explore the connections within urban systems in China. In Chapter 3, we presented a complementary method, inspired by the network of resource allocation dynamics (Zhou, Ren & Medo, 2007), and used it to extract the hidden information of two mode networks. In this process, PS offices are looked upon as the scarce resources to be allocated in the bipartite network. It should be noted that richer information can only be revealed when compared with the results of Taylor's (2001) interlocking network model. Therefore this algorithm should supplement the INM rather than be used as a totally new methodology. This does not mean that the INM, which is used to map urban networks, should now be replaced by the network of resource allocation dynamics, but it can be combined with LRM for a better understanding of urban networks in China.

In Chapter 4, it was noted that case studies still exhibit room for improvement in the related research. And the empirical analysis using the CGHM method, proposed by Henanman & Derudder (2013), was based on only two city regions, whereas theoretically a minimum of three city regions are needed to ensure that the algorithm can calculate intercity PS networks adequately. Moreover, the CGHM algorithm is not perfect owing to the limitations of its assumptions, such as the issue of spatial scaling and firms' hierarchy. Further, the algorithm takes account of the 'region' in the model, which means that the choice of geographical units greatly influences the model results.

In Chapters 5 and 6, in addition to the bipartite network of PS firms, another approach regards ownership linkages in the corporate organization of firms as the cities' connections. The linkage between cities is solely defined as the connection of headquarters and branches, as it is often assumed that large firms are more likely to establish branches and thus form intercity linkages (Godfrey & Zhou, 1999). In this approach, the urban network specification is very straightforward: it results in an asymmetric (from headquarters city to subsidiary city) and valued (number of ownership linkages) intercity matrix. It could be also argued that such links are more suitable to reflect the urban networks in China, since there are fewer connections of PS offices compared with many more links between the headquarters and the branches of all companies, located in the small-sized cities in the developing regions.

Generally speaking, deductive analyses carried out using any theoretical model rest on the model's hypotheses; hence, the structure of city networks is also constrained by the calibration model of the basic data. That is to say, the external spatial characteristics of a city network depend on the actual sample type, which is indicative of a complicated macro-level system. Therefore, the internal and external spatial relations of an urban system in China cannot simply be determined by using one or two theoretical models.

3) Impacts of state-owned economy on urban networks

In Chapter 2, it was argued that local governments in China play a decisive role in the development of the state-processed regional economy. Since capital is a major factor in the economic growth of Chinese cities, local governments use financial tools to regulate the economy (Gu & Zou, 2012). For instance, they can support certain state-owned enterprises (SOEs) by controlling banks (Jiang & Li, 2006). Most SOEs can obtain loans from local banks or the central government, and such loans are often guaranteed by the local government. This means that some enterprises are more dependent on the local financial network (Lin & Li, 2001). This applies especially to those located in central or western China, where state-controlled banks wield a lot of power in the local financial markets (Gu & Zou, 2012).

In Chapter 3, a comparison of the degree of centrality between the locational recommendation model (LRM) and the interlocking network model (INM) provided further results for the urban geographies of intercity networks. It confirmed that the development of most provinces still relies on their capital cities having an abundance of state-owned enterprises. In most provinces, PS companies set up offices only in the provincial capitals, whereas other, smaller cities in the periphery areas accommodate several offices of state-owned banks, even though these banks mean poor efficiency for the local economy (Boyreau-Debray, Cull, Dollar, Honohan & For, 2003).

Chapter 5 showed that denser urban networks have facilitated regionalization in terms of the increasing involvement of non-state actors (Luo, Shen & Chen, 2010), and that the level of integration in the YRD is relatively lower than that in the PRD because of the former's larger number of state-owned companies (Zhang & Wu, 2006; Xu & Yeh, 2010). Along with other results on the relationship between firm performance and ownership type across regions (Jiang & Nie, 2014; Xia & Walker, 2015), this study showed that a relatively higher ratio of private companies in the YRD will promote a higher level of network density and efficiency there.

In Chapter 6, it was shown that headquarters–branch connections also reflect the impacts of the state-owned economy. Among different sectors, those dominated by state-owned enterprises (SOEs), and particularly finance & insurance and administration & social services, retain a regional connectivity pattern that reflects the continued relevance of distance decay and/or administrative boundaries. This leads to another argument, namely that the state, in the form of SOEs, should not have so much power in the regional economy and should allow more room for the development of private firms. After all, private companies can have a higher performance (Jiang & Nie, 2014; Xia & Walker, 2015) and denser cross-regional networks than SOEs, which are always faced with more limits on setting up branches because they are tightly controlled by governments.

Although SOEs carry out both social and economic activities, this study found that they make a smaller contribution to the regional network interaction in city regions compared to other firms. The reason lies in the fact that commands from the administrative departments to SOEs are not necessarily right. Hence, the number and affairs of SOEs controlled by central or local governments should be kept at a suitable ratio to ensure the social functions in China. What that ratio should be, however, is beyond the scope of this dissertation.

4) Impacts of globalization on urban networks

Because of the national regulation of the Chinese state-processed economy and the location strategies of global APS firms, the geography of global APS in China reflects the limited selection of cities. And the Chinese urban network created by APS firms cannot be studied as a subnetwork of GaWC's global network, but needs an empirical study based on a wide range of leading APS in the Chinese market.

Chinese cities' external relations with the global network were revaluated in Chapter 2. This dissertation argued that, local and global circuits of servicing intertwine in the sense that the degree to which individual localities are involved in global production networks would affect the locational strategies of PS firms in the Chinese market (Liu & Dicken, 2006; Derudder et al., 2013). This is exemplified by the distribution of the foreign banks in China. Given that foreign banks' services and locations are affected by the aforementioned spatially explicit policies, foreign firms cluster in China's most open and globally connected cities along the Eastern seaboard. Local PS firms' development is also affected by localities' involvement in the global capital circulation. For example, the economic take-off of the Pearl River Delta and Yangtze River Delta is propelled by the regions' connections with overseas Chinese capital from Hong Kong and Taiwan, as well as the opportunities to be locked in the global manufacturing system (Peck & Zhang, 2013).

Many urban scholars have argued that as globalization proceeds, an extensive archipelago of large-scale urbanized regions is materializing (Scott, 2001; Newman & Thornley, 2011; Harrison & Hoyler, 2015). Scott (2001), for instance, argued that regions embodying 'an outgrowth of large metropolitan areas – or contiguous sets of metropolitan areas – together with surrounding hinterlands of variable extent which may themselves be sites of scattered urban settlements' increasingly function as the backbone of the global economy. To verify this argument, the urban networks of city regions in the PRD were explored in Chapter 6. Specifically, the data points of 2001 and 2008 were chosen for reasons related to globalization. We found that the number of connections increased significantly for most sectors in 2001–08; this was followed by a small drop in 2008–13 (except for manufacturing). Importantly, the number of foreign firms setting up branches dropped significantly after the onset of the global economic crisis in 2008–09. As the GDP in the PRD continued to rise in 2008–13, it can be argued that the evolution of urban networks indicated by headquarters–branch links could more clearly reflect the real impacts of globalization on the economy of China.

In the last three decades, FDI and exports have played important roles in the development of urbanization and industrial processes in China. In recent years, more and more companies have begun to invest in western countries, although they have been faced with many difficulties in this process (Silk & Malish, 2006; Gatai, 2009; Ito, Iwata & Mckenzie, 2014). The strategy of One Road One Belt in recent years shows that the central government still wants to benefit from contacts with the rest of the world. But what the enterprises can get in the era of globalization is not clear because of the complex condition of the world economy of today.

7.4 Avenues for future research

The following are recommendations for future research.

Further mathematical work could uncover more details about the restructuring of urban networks in China. Although which algorithms or data sources are the most suitable for analysing intercity networks continues to be a matter of debate among urban scholars, it is possible that academic research will continue to make improvements. Innovations resulting from the continuing research into PS networks might include questionnaires and interviews within PS firms. Future studies should aim to clarify the mechanism underlying the formation of city connections and to make conclusive improvements to the various algorithms on the basis of those findings.

Since 2014, a great number of factories have been facing economic challenges, which might bring about changes in the urban networks of different sectoral firms in mainland China. For example, Shenzhen's top government official felt uneasy because a number of top technology firms were ready to move their headquarters out of this booming southern metropolis (China Daily, 2016). And many firms, including large corporations such as Huawei (*Huawei*, *华为*) and ZTH Holding (*Zhongxing*, *中兴*), are planning to set up branches outside of Shenzhen in early 2016, because of increasing housing prices. Hence, it is necessary to explore the evolution of networks since 2014 through the lens of corporate spatial organization.

We argued in this dissertation that the empirical approach to understanding urban and regional structures, as exemplified in the current research, should be complemented with qualitative investigations, which would provide insights into non-systematic local contexts as well as phenomena that are not readily quantifiable. As a case in point, a lot of producer servicing functions in China have been performed not through formal corporate activities, but through informal interpersonal networks (*Guanxi*). To deal with this phenomenon, comprehensive interviews should be conducted in future research.

Finally, the empirical results of future research should be targeted at policymakers. In the recent planning document ‘New Path of Urbanization (2015-2020)’ for China, the central government anticipates mega-city regions as a whole, rather than any single megacity, accommodating migrants from rural areas. And employment by corporate organizations in city regions in China is closely related to the process of urbanization (Yuan, Wei & Chen, 2014; Lin, Li & Yang et al., 2014; Li, Deng & Wang, 2014; Fang & Lin, 2015). At the same time, the strategy of One Road, One Belt combined with the opportunities provided by the Asian Infrastructure Investment Bank might really help firms in China. It also means that more detail about the economic connections between China and other countries should be provided, since local governments still want to attract more enterprises from all over the world. Therefore, future research should continue researching the firms' networks to explore the network process of more city regions in China rather than just the two city regions in the YRD and the PRD.

References

Bassens, D., Derudder, B., & Witlox, F. (2010). Searching for the Mecca of Finance: Islamic Financial Services and the World City Network, *Area, 42*(1), 35–46.

Boyreau-Debray, G., Cull, T. T. R., Dollar, D., Honohan, P., & For, S. J. W. (2003). Financial intermediation and growth: Chinese style. *Social Science Electronic Publishing*, 1-46.

Fang, T., & Lin, C. (2015). Minimum wages and employment in China. *IZA Journal of Labor Policy, 4*(1), 1-30.

Gattai, V. (2009). Dissecting Chinese ODI: Dragon multinationals in Italy. *Department of Political Economics Working Paper. Milan: Milan Bicocca University*.

Godfrey, B. J., & Zhou, Y. (1999). On ranking world cities: multinational corporations and the global urban hierarchy. *Urban Geography, 20*(3), 268-281.

Green, N. (2007). Functional Polycentricity: A Formal Definition in Terms of Social Network Analysis, *Urban Studies, 44*(11), 2077-2103.

Gu, S., & Zou, Y. (2012). The role of the local government in the financial development of the western region: A study based on Panel Data Model. *Modern Economic Science. 34*(6), 63-69. (in Chinese)

Hall, P., & Pain, K. (2006). *The polycentric metropolis: learning from mega-city regions in Europe*. London: Earthscan.

Harrison, J., & Hoyler, M. (2015). Megaregions: foundations, frailties, futures. *Megaregions: Globalization's New Urban Form*, 1-28.

Henanman, S., & Derudder, B. (2013). An alternative approach to the calculation and analysis of connectivity in the world city network. *Environment & Planning B, 41*(3), 392-412.

Ito, T., Iwata, K., Mckenzie, C., Marcus Noland., & Urata, S. (2014). China's impact on the rest of the world: Editors' overview. *Asian Economic Policy Review, 9*(2), 163–179.

Jiang, T., & Nie, H. (2014). The stained China miracle: Corruption, regulation, and firm performance. *Economics Letters*, *123*(3), 366-369.

Lai, K. (2012). Differentiated markets: Shanghai, Beijing and Hong Kong in China's financial centre network, *Urban Studies, 49*(6), 1275–1296.

Li, J., Deng, J., Wang, K., Li, J., Huang, T., Lin, Y., & Yu, H. (2014). Spatiotemporal patterns of urbanization in a developed region of eastern coastal China. *Sustainability, 6*(7), 4042-4058.

Lin, G. C., Li, X., Yang, F. F., & Hu, F. Z. (2014). Strategizing urbanism in the era of neoliberalization: State power reshuffling, land development and municipal finance in urbanizing China. *Urban Studies, 52* (11), 1962-1982.

Liu, X., & Derudder, B. (2013). Analyzing urban networks through the lens of corporate networks: a critical review. *Cities, 31*(2), 430-437.

Luo, Z. (2010). Study on the Functional Polycentricity of Yangtze River Delta. *Urban Planning International, 25*(1), 60-65. (in Chinese)

Luo, X., Shen, J., & Chen, W. (2010). Urban networks and governance in city-region planning: state-led region building in Nanjing city-region, china. *Geografiska Annaler, 92*(4), 311–326.

Newman, P., & Thornley, A. (2011). *Planning world cities: globalization and urban politics*. Palgrave MacMillan.

Silk, M., & Malish, R. (2006). Are Chinese companies taking over the world. *Chi.j.intl L,* (7), 105.

Scott, A. J. (2001). Globalization and the rise of city-regions. *European Planning Studies, 9*(7), 813-826.

Taylor, P. J. (2001). Specification of the World City Network. *Geographical Analysis*, *33*(2), 181-194.

Taylor, P. J., Derudder, B., Hoyler, M., Ni, P., & Witlox, F. (2014) City-dyad Analyses of China's Integration into the World City Network. *Urban Studies, 51*(5), 868-882.

Xia, F., & Walker, G. (2015). How much does owner type matter for firm performance? Manufacturing firms in China 1998–2007. *Strategic Management Journal*, *36*(4), 576-585.

Xu, J., & Yeh, A. G. (2010). *Governance and planning of mega-city regions: An international comparative perspective*. Routledge.

Yuan, F., Wei, Y. D., & Chen, W. (2014). Economic transition, industrial location and corporate networks: Remaking the Sunan model in Wuxi City, China. *Habitat International, 42*, 58-68.

Zhang, J., & Wu, F. (2006). China's changing economic governance: Administrative annexation and the reorganization of local governments in the Yangtze River Delta. *Regional Studies*, *40*(1), 3-21.

Zhang, X., & Kloosterman, R. C. (2016). Connecting the 'workshop of the world': intra-and extra-service networks of the Pearl River Delta City-Region. *Regional Studies*, *50*(6), 1069-1081.

Zhao, M. (2012). The evolution of urban function in Yangtze River Delta region in the process of globalization. *Economic Geography, 32*(3), 50-56.

Zhao, M., & Duo, D. (2013). Complex Network Features of Mega City Region. *Journal of South China University of Technology (Natural Science Edition), 41*(6), 108-115.

Zhou, T., Ren, J., & Medo, M. (2007). Bipartite network projection and personal recommendation, *Physical Review E, 76*(4), 046115.

Summary

Starting from the vantage point that firms can be viewed as key actors in the (re)production of intercity networks, this dissertation explores the characteristics of intercity connections in Mainland China through the lens of spatial corporate organization. In the process, this study focuses on four main topics:

- The geographies of corporate spatial organization in the national urban system are examined, focusing on the mega-city regions of the Yangtze River Delta (YRD) and the Pearl River Delta (PRD) in particular. This reveals a hierarchical structure in the Chinese urban network of producer services firms, with the level of polycentricity in both mega-city regions being on the rise.

- Diverse algorithms for more adequately measuring city-dyads in urban networks are explored against the background of the specific context of regional development. In addition to the interlocking network model, alternative algorithms are devised and applied.

- The impact of China's political system on the urban networks is studied in depth. It is shown that local governments in China play a decisive role in the development of a state-processed regional economy. It also confirms that the development of most Chinese provinces still relies on their capital cities hosting an abundance of state-owned enterprises.

- The landscape of urban networks in China has been strongly reshaped because of increasing global economic integration in general and China's role therein in particular. Foreign firms cluster in China's most open and globally connected cities along the Eastern seaboard, albeit that the number of foreign firms setting up branches dropped significantly after the onset of the global economic crisis in 2008–09 in the PRD.

Based on the different findings drawn from the analysis of these four topics, this dissertation presents some avenues for further research on mapping urban networks in China.

Samenvatting

Het startpunt van dit proefschrift is de vaststelling dat ondernemingen kunnen gezien worden als sleutelactoren in de (re)productie van stedelijke netwerken. Tegen deze achtergrond wordt in het proefschrift een analyse gemaakt van de karakteristieken van de interstedelijke netwerken op het vasteland van China door de bril van de ruimtelijke organisatie van ondernemingen. De studie focust daarbij meer specifiek op vier onderwerpen:

- De geografieën van de organisatie van ondernemingen in het Chinese nationale stedelijke systeem worden onderzocht, met een specifieke focus op de megastad-regio's van de Yangtze Rivier-Delta (YRD) en de Parelrivier-Delta (PRD). Dit brengt een hiërarchische structuur naar voor in het Chinese stedelijke network van productieve-dienstenfirma's, waarbij de mate van polycentriciteit in beide megastad-regio's toeneemt.

- Diverse algoritmes om een meer adequate inschatting te maken van stedenparen in netwerken worden geanalyseerd, en dit tegen de achtergrond van de specifieke context die regionale ontwikkeling aanreikt. Ter aanvulling van het 'interlocking network model' worden alternatieven opgesteld en toegepast.

- De impact van China's politiek systeem op stedelijke netwerken wordt in detail bestudeerd. Er wordt aangetoond dat locale overheden in China een cruciale rol spelen in de ontwikkeling van een door de staat gecoproduceerde regionale economie. Het bevestigt eveneens dat de ontwikkeling van de meeste Chinese provincies nog steeds steunt op de aanwezigheid van overheidsondernemingen in hun hoofdstad.

- Het landschap van stedennetwerken in China wordt sterk beïnvloed door toenemende mondiale economische integratie in het algemeen en China's belangrijke rol daarin in het bijzonder. Buitenlandse ondernemingen clusteren in China's meest open en mondiaal geconnecteerde steden langs de oostkust, zij het dat die buitenlandse ondernemingen in afnemende mate vestigingen openen in de PRD sedert de mondiale economische crisis van 2008-9.

Op basis van de verschillende bevindingen die naar voor kwamen in de analyse van deze vier onderwerpen, presenteren de conclusies van het proefschrift een aantal mogelijke pistes voor verder onderzoek over het in kaart brengen van stedennetwerken in China.

Curriculum Vitae (Bibliography)

Miaoxi Zhao was born in Xaingtan, Hunan Province, China. He obtained a Bachelor’s (2002) and a Master’s Degree (2005) in Urban Planning from Tongji University (Shanghai, China). Prior to moving to Ghent in 2015 to pursue his research on urban networks in Mainland China, he has been employed as a researcher at the South China University of Technology (SCUT, Guangzhou) for 6 years. Most of his research is in the domain of urban planning and urban geography, with a particular focus on understanding urban China in the context of a globalizing network society. He has published more than 50 papers in peer-reviewed journals, 4 of which in leading English-language journals, including Urban Studies and Cities. He has attended 6 international conferences and workshops, where he presented some of the research carried out in the context of his doctoral research. In the last two years, he has filed 12 patents, including 3 international patents on the technologies supporting urban design through data mining.

Starting from the vantage point that firms can be viewed as key actors in the (re) production of intercity networks, this dissertation explores the characteristics of intercity connections in Mainland China through the lens of spatial corporate organization.

This study addressed four aspects: 1) The geographies of corporate spatial organization in the national urban system were examined, and the mega-city regions were extensively researched; 2) Diverse algorithms for more adequately measuring city-dyads in networks were explored according to the specific context of regional development; 3) The impacts of China's political system, in the form of state-owned firms, on the urban networks were revealed; 4)The landscape of urban networks in China, which have been strongly reshaped during the process of globalization, were explored at both the national and the regional scale. This dissertation also presents some avenues for further research on mapping urban networks in China.

SEG research unit
Social and Economic Geography

geografie vakgroep
Universiteit Gent

UNIVERSITEIT GENT