FDI and Technological Upgrading in Chinese Cities: Externalities of Foreign Expansion Process and Industrial Structures

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London July 2017

Statement of Originality

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Abstract

Technological upgrading, as the key engine of Chinese economic development, does not take place in isolation, but is largely dependent on access to external knowledge sources. FDI has long been regarded as an external knowledge source because of its intra- and intercity technological spillovers. Meanwhile, both foreign expansion time-based characteristics and industrial structures could affect technological upgrading, but there is a heated debate about whether they enhance FDI spillovers in host cities. In this PhD thesis, I integrate these two streams of literature into a theoretical framework, and hope to investigate how foreign expansion time-based characteristics and industrial structures moderate both intra- and intercity relationships between inward FDI and technological upgrading in Chinese cities. Moreover, I link cluster theory to FDI spillovers, and establish a theoretical model in which government and market orientations can affect knowledge transfers and disseminations between domestic and foreign firms. Overall, this research aims to extend the existing literature by bridging literature of FDI spillovers, foreign expansion process, and industrial structures from a contingency perspective. It deepens our understandings about both intra- and intercity dimensions of FDI technological spillovers in explaining host city technological upgrading. Based on specific panel datasets from the Chinese Urban Statistical Yearbooks and the Annual Industrial Survey Database, I adopt Pooled OLS and Spatial Durbin Model to explore intra- and intercity externalities of foreign expansion process and industrial structures in FDI spillovers. My results indicate that FDI spillovers contribute to both intra- and inter-city technological upgrading in China. Irregular foreign expansion process diminishes FDI spillovers within a given city, but facilitates intercity knowledge dissemination. Cities with a high degree of related variety can reap benefits from FDI technological spillovers. However, such empirical results may change between different urban groups, Beijing-Tianjin-Hebei and Shanghai-Yangtze River Delta respectively. Therefore, the findings of this PhD thesis not only provide convincing evidence for the debate regarding the relationship between FDI and host city technological upgrading, but also highlight government and market orientations to assist with policy making in the future.

Acknowledgement

First and foremost, I would like to express the deepest appreciations to my supervisors, Dr. Lutao Ning and Prof. Gulnur Muradoglu, who have spent countless hours to help me in academic research teaching, guidance the direction of PhD research and carefully read the thesis. I have known Lutao when I was the exchange student at Queen Mary University of London at final year of undergraduate. He encouraged and leaded me to the academic world. During the postgraduate life at LSE, Lutao accepted me as his PhD student and helped me apply the QM-CSC scholarship. During the three-year PhD project, he did not only help me to build the faith in academic works, but also provided me with guidance in both research and career planning. I am extremely grateful to your responsible and invaluable supervisions and kindness. Moreover, I would also like to express sincere gratitude to my second supervisor, Prof. Gulnur Muradoglu. Thank you for your invaluable comments and supports for my PhD research, and it is helpful for my academic works in the future. I also appreciate the time you devoted to regular meetings during my PhD life.

Second, I would like to take this opportunity to thank scholars at conferences and workshops during my PhD life. I would like to express special appreciation to Frances Bowen and Deven Bathia, who were the examiners of my first year progression meeting. Thank you for your support and advice in my PhD project. Special thanks to the QM-CSC scholarship and School of Business Management for providing me with the necessary financial support during my PhD studies. Otherwise, it would not have been possible to successfully finish my PhD.

Finally, I am extremely grateful to my parents, Youjun Wang and Mei Qin. They always understand me and encourages me during very difficult times in my PhD life. I would also like to thank my best friends and colleagues: Qian Liu, Chong Nie, Diqian Xiao, Songzhi Liu, Yu Cheng, Chunyang Zhou, Shuyan Wang, Rulin Wang, Jingzhu Chen, Yaxing Wu, Yaping Lang, Yuanyuan Liu, Xueying Lv, Yang Hu, Shichen Wang, Xin Pan, Zhihui Bi, Duanjinyu Yin, Lei Yang and Li Dai for your supports and encouragements.

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List of Abbreviations

CCP: China Communist Party

FDI: Foreign direct investment

GDP: Gross domestic production

IPR: Intellectual property right

LM Test: Lagrange Multiplier Test

MNEs: Multinational enterprises

NBS: National Bureau of Statistics of the People's Republic of China

R&D: Research and development

OLS: Ordinary least square

OECD: Organization for Economic Co-operation and Development

PRC: the People's Republic of China

SAR: Spatial Lag Model

SEM: Spatial Error Model

S&T: Science and technology

SDM: Spatial Durbin Model

SEZs: Special economic zones

SMEs: Small and medium enterprises

SOEs: State-owned enterprises

SIC code: Standard Industrial Classification code

TFP: Total factor productivity

VIF: Variance Inflation Factors

WTO: World Trade Organization

Chapter 1 Introduction

1.1. Backgrounds and Motivations

Over the last three decades, China, as the largest emerging economy, has experienced relatively rapid economic development, and continued to open itself wider to the outside world. Since the beginning of the 21st century, China's annual GDP growth rate has remained at over 9%, and it has become the second largest economic entity in the world. By the end of 2016, foreign investment in actual use had reached 126.3 billion US dollars in China, an increase of 5.6% compared to the previous year (Li, 2016). More importantly, the Chinese central government has prioritised the development of cities. This is because cities are at the forefront of economic growth and technological innovation, and are also the key nodes of knowledge sharing and transfer (Simmie, 2003). Hence, the developmental level of cities will determine directions of Chinese economic growth in the future.

Technological upgrading is widely recognised as one of the key engines of regional economic growth, and cities are closely intertwined with R&D activities (Ning et al., 2016, Simmie, 2003). Since the late 1970s, China has accelerated its technological upgrading, and devoted itself to facilitating its economic growth increasingly relying on S&T developments (Ning, 2009, Fu, 2008). However, the existing literature has demonstrated that regional discrepancy is common in emerging economies (Prevezer et al., 2013, Li et al., 2013). In China, which is a large country, technological developments are also not evenly distributed, but are mainly concentrated in particular eastern and coastal cities. These metropolises, such as Beijing, Shanghai and Shenzhen etc. are the innovation centres of large geographic regions, and they drive technological upgrading both within and across the urban boundaries. By contrast, the knowledge stocks in most inland cities are still too weak to support their technological demands, so it is necessary for them to seek external knowledge sources (Pang, 2009).

During recent years, an increasing number of studies have shifted their research focus from a national level to an aggregate city level, in order to investigate specific urban technological upgrading mechanisms. They argue that cities are the loci of creative and innovative activities (Florida, 2008, Montgomery, 2008). This is because the majority of national intellectual resources (e.g. creative talents, universities and research institutions) are concentrated in cities, and have become the key drivers of technological breakthroughs (Acs, 2002, Florida, 2002). New and high-tech industries emerge first in cities, enabling the expansion of both the scale and scope of industrial agglomerations across various suppliers, distributors and customers (Duranton and Puga, 2001). Moreover, cities can create a stable and energetic business environment to facilitate interactions across industries and firms, and facilitate technology transfer and dissemination (Rosenthal and Strange, 2004, Tappeiner et al., 2008). From the spatial perspective, cities are not isolated geographic areas, but are closely interlinked with each other through several "pipelines" e.g. social networks, and forward and backward linkages (Ning et al., 2016, Bathelt et al., 2004). Knowledge spillover effects can spread from one city to others in close geographic proximity. Urban technological upgrading is thereby dependent upon sources from both the local areas and the adjacent cities (Usai, 2011). Based on empirical evidence from developed countries, cities are ideal research settings to investigate the mechanisms of technological innovation and upgrading (Shearmur, 2012).

The existing literature has argued that technological upgrading and progress does not take place in isolation, but is largely dependent on access to external knowledge sources (Chesbrough, 2013, Enkel et al., 2009). Due to the relatively weak internal knowledge stocks in emerging economies such as China, external technological sources appear to be especially crucial. Inward FDI (thereafter FDI) contributes greatly to technological upgrading in the host city, as domestic firms can reap the benefits of its technological spillovers. Foreign investments result in the transfer and dissemination of advanced technology and managerial patterns through interactions with local actors such as firms, universities and research institutions (Crespo and Fontoura, 2007, Fu and Gong, 2011, Fu et al., 2011). As indicated above, knowledge sharing and transfer can take place both within and across cities through intercity “pipelines”. In the same vein, FDI technological spillover can also spread from an FDI receiving area to geographically adjacent cities (Ning et al., 2016). However, few scholars have considered such spatial effects of FDI on regional technological upgrading (Ouyang and Fu, 2012, Doh et al., 2008, Blonigen et al., 2007). The existing empirical results regarding the relationship between FDI and host city technological upgrading are mixed and inconclusive (Aitken and Harrison, 1999, Liu et al., 2000).

One of the key reasons for such mixed results is that FDI spillovers are greatly contingent upon a set of determinant factors including host regional effects and the characteristics of the FDI activities (Crespo and Fontoura, 2007). Therein, foreign expansion time-based characteristics and industrial structures have been identified as having an effect on the interactions and communications between local and foreign firms in host cities, but such a situation is overlooked in much of the existing literature. On the one hand, FDI expansion is not an instantaneous process, but takes place over time from the initial entry to completing the establishment of subsidiaries (Wang et al., 2012a). During such a complex development process, local firms also spend time interacting with MNEs, and carefully recognise and assimilate external knowledge sources (Wang et al., 2017). The intensity of the interactions between domestic firms and MNEs varies when time-based characteristics of foreign entry change. Based on evidence on the industrial level, FDI spillovers depend not only on the degree of foreign presence, but also on the foreign expansion process (Wang et al., 2012a). Pace and rhythm have been identified as two representative time-based features that can be used to indicate the degree of speed and irregularity of the FDI expansion process, respectively (Wang et al., 2012a, Vermeulen and Barkema, 2002).

On the other hand, because urban distinctive industrial structures can help domestic firms to access external knowledge from MNEs, FDI spillovers in cities also play a key role in local technological upgrading (Ning et al., 2016). Diversified industrial structures foster interactive opportunities across firms and industries in spatial proximity, as the compositions of different sectors help to draw upon a variety of knowledge sources (Quatraro, 2010). Firms in cities with a diversified industrial structure are likely to reap the benefits of ideas exchanges and knowledge spillovers, leading to technological upgrading (Beaudry and Schiffauerova, 2009). However, some scholars are of the opposite opinion, that industrial diversification diminishes FDI spillovers, as it creates a vibrant and unstable business environment, which hinders the interactions between local and foreign firms (Ning et al., 2016).

One of the key reasons for such a heated debate is that the majority of the prior studies have overlooked the externalities of inter-industry cognitive distance in FDI spillovers. In other words, it is necessary to move beyond the notion of industrial diversity, and classify it into two specific dimensions, namely related and unrelated variety. Firms in two industries that share technologically related knowledge stocks (related variety) can interact more frequently and effectively, and facilitate technological transfer and dissemination. Unrelated variety refers to an industrial composition consisting of sectors sharing limited complementary competences, where each sector is technologically isolated with the others (Boschma and Iammarino, 2009, Frenken et al., 2007). But this type of industrial diversity captures a portfolio-effect that spreads the risks across irrelevant industries, and reduces vulnerability in terms of technological upgrading in cities (Castaldi et al., 2015, Nooteboom, 2000, Brachert et al., 2011). So far, the prior literature has mainly investigated industrial diversity externalities in FDI technological spillovers (Ning et al., 2016, Wang et al., 2014), but no studies have focused specifically on the effects of related and unrelated diversity in technological upgrading. To my knowledge, little is known about the externalities of related and unrelated variety in host city FDI spillovers, and there is even less evidence regarding emerging economies.

More importantly, cluster theory argues that with the trend of increasing economic globalisation, the regionalisation process is still significant in creating competitive advantage for technological upgrading (Zhou and Xin, 2003, Bathelt et al., 2004). This is because place-specific factors and resources can enhance the competitive advantage within a geographic region, which cannot be easily duplicated or matched by distant rivals in other regions (Asheim and Isaksen, 2002). China is the largest emerging economy, and its provinces are even larger than most European countries (Ning et al., 2016). Provincial level analysis often overlooks the effects of urban heterogeneity in FDI spillovers, and provides limited evidence about intercity interactions between domestic and foreign firms from a spatial perspective. Moreover, cities, as international and national nodes in knowledge sharing and transfer, are closely interlinked in terms of both complementarities and commonalities (Simmie, 2003). Therefore, specific regional clusters, e.g. urban groups, can possess unique technological upgrading mechanisms that exhibit some insightful understandings of host city FDI spillovers. Government and market orientations are often identified as two representative determinant factors in technological upgrading, as they affect technology transfer and dissemination in cities (Chung, 2013, Mani, 2002). Governments often control the direction of urban technological upgrading by implementing a set of administrative means (e.g. financial subsidies, tax concessions and research grants) to facilitate R&D activities (Hsu and Chiang, 2001, Mani, 2002, Franzel, 2008). By contrast, market orientations focus on the maximisation of R&D efficiency to satisfy customers' demands and reduce the risks in the technological upgrading process (Atuahene-Gima, 1996).

1.2. Statement of Purposes

In this PhD thesis, the main research purpose is to investigate the intra- and inter-regional externalities of the foreign expansion process and industrial structures in FDI spillovers based on evidence from Chinese cities. Several themes are investigated with the aim of expanding the FDI spillover literature on host cities. First, this thesis examines spatial FDI spillovers in technological upgrading, which has seldom been considered in previous research (Ouyang and Fu, 2012, Blonigen et al., 2007). Technological upgrading sources are localised both within and across cities, as urban regions are closely interlinked through several "pipelines" e.g. supplier chains and worker mobility (Usai, 2011, Moreno et al., 2005a, Ning et al., 2016). These "pipelines" can disseminate newly created and advanced knowledge to local firms through intercity interactions with MNEs (Ning et al., 2016). I posit that FDI spillovers are not strictly bounded within an aggregate city level, but can spread to other regions in close spatial proximity. This thesis therefore extends the FDI spillover theoretical framework from both the intra- and inter-city perspectives.

Second, I explore the externalities of foreign expansion pace and rhythm in Chinese cities, in order to enhance the understanding of the determinant factors in FDI spillovers with a contingency perspective. Prior studies have mainly focused on FDI spillovers in regard to their dependence on host regional issues such as absorptive capacity and infrastructure facilities etc., but have neglected the time-based characteristics of the foreign expansion process (Ferragina and Mazzotta, 2014, Fu, 2008, Crespo and Fontoura, 2007). Only a small number of researchers have discussed the effects of FDI expansion pace and rhythm within an individual firm or sector (Vermeulen and Barkema, 2002, Wang et al., 2012a). They argue that MNEs that adopt rapid and irregular FDI expansion are likely to encounter time compression diseconomies and have poorer financial performance (Vermeulen and Barkema, 2002). I take a further step and examine how foreign expansion pace and rhythm affect FDI spillovers within and across host cities. The FDI spillover literature can thereby be linked to the time compression diseconomies argument at an aggregate city level, to help us to better understand technological upgrading within a geographic region rather than an isolated firm.

Third, this thesis investigates the externalities of both related and unrelated variety in FDI spillovers. Due to differences in interindustry cognitive distance, a diversified industrial structure can either enhance or hinder technology sharing and transfer (Frenken et al., 2007). The prior literature has not differentiated the effects of related and unrelated variety in FDI spillovers, which has led to mixed empirical results regarding the relationship between FDI and technological upgrading in host cities. In order to explain how different types of industrial diversification affect FDI spillovers, I link the notion of "interindustry cognitive distance" to knowledge spillovers between foreign and local firms. I hope to demonstrate that interindustry cognitive proximity (related variety) is likely to foster opportunities in inter-firm communications and interactions, and enhance FDI technological spillovers. Unrelated variety hinders knowledge flows and transfers in host cities due to limited interindustry complementary and shared competences. Furthermore, I also examine the externalities of related and unrelated variety in spatial FDI spillovers, in order to identify how industrial structures affect technological upgrading in neighbouring cities. To my knowledge, this thesis provides the first empirical evidence of the spatial externalities of related and unrelated variety, and will help us to obtain a clearer understanding of intercity FDI spillovers.

Fourth, I link FDI spillovers to specific Chinese urban groups by examining the externalities of the foreign expansion process and industrial structures in FDI spillovers, and thereby contribute to the understanding of technological upgrading mechanisms under both government and market orientations. Cluster theory argues that regionalisation is still significant in regard to creating competitive advantage for technological upgrading, because place-specific resources and factors can enhance knowledge sharing and transfer within a geographic region (Asheim and Isaksen, 2002). Through a comparison analysis based on both nationwide and urban group level datasets, this PhD thesis moves beyond the widely accepted argument of the positive relationship between FDI and technological upgrading, and proposes that FDI knowledge spillovers are contingent upon the government and market orientations within the specific clusters, namely urban groups. Moreover, it also addresses how the government and market orientations can affect the externalities of the foreign expansion process and industrial structures differently in regard to FDI spillovers from a regional context perspective, thereby contributing to the spatial FDI spillover literature.

1.3. PhD Thesis Outlines

This PhD thesis addresses both the intra- and inter-city externalities of foreign expansion time-based characteristics and industrial structures based on evidence from China. Figure 1 illustrates the overall research framework of this thesis.

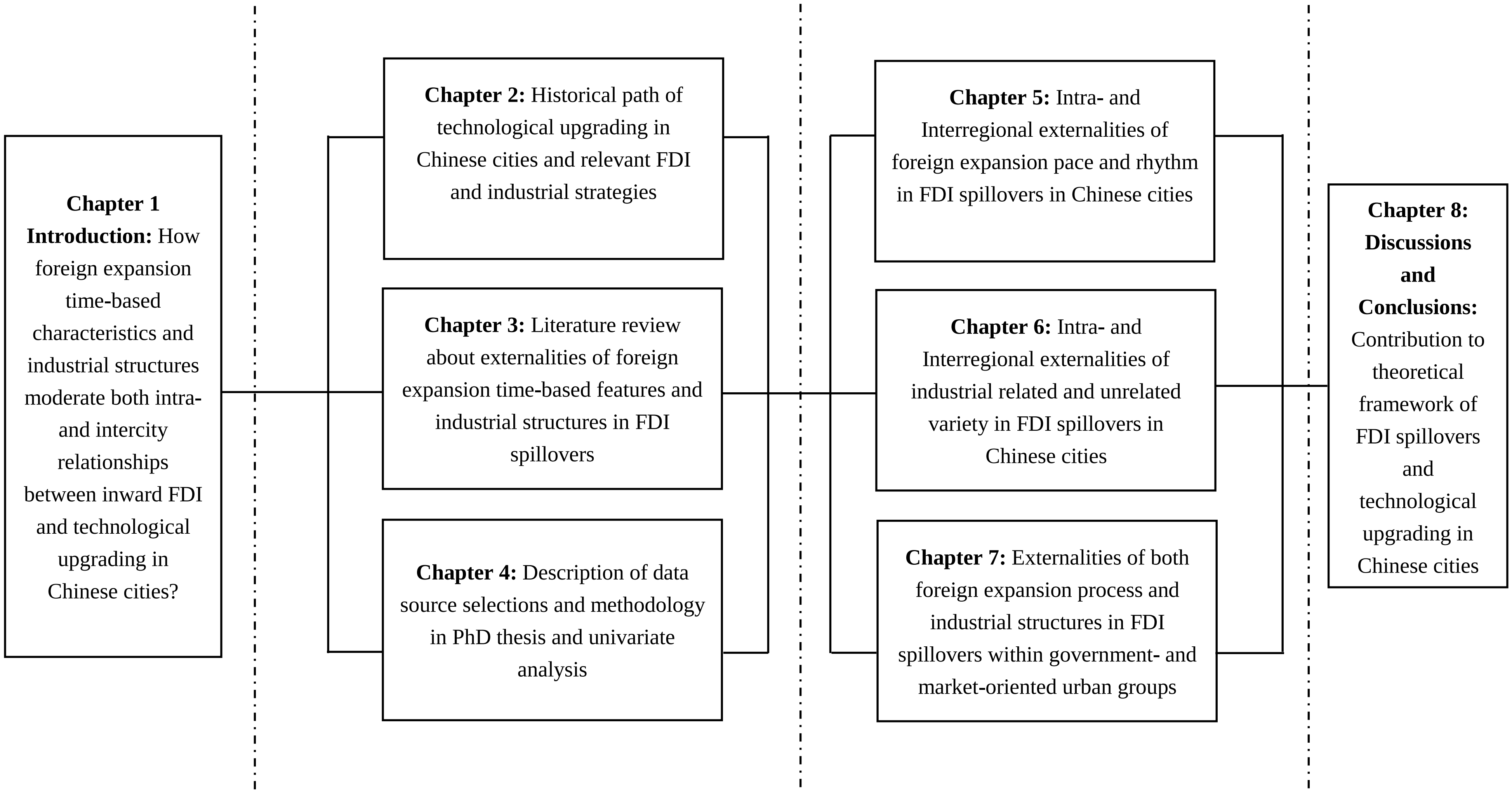

Figure 1 Overall research framework of the PhD thesis

This section systematically introduces the PhD research outline. The remainder of this thesis is organised as follows: First, Chapter 2 reviews the historical background of Chinese technological upgrading, as well as urban FDI and industrial development strategies. It expatiates on the technological developments in Chinese cities over four periods: 1949-1957, 1958-1977, 1978-2000, and 2001-the present. The main objective of Chapter 2 is to provide an overview of the Chinese science and technology (S&T) developmental path, and explain why cities are ideal regional settings in which to understand FDI spillovers in regard to technological upgrading.

Specifically, China basically resumed its S&T activities in most cities, and set up a strict state-led technological upgrading mechanism during the period of 1949-1957. It also adopted a heavy industry and national defence-oriented strategy in terms of urban industrialisation, which was supported in particular by 156 USSR assistance projects during the same period. From 1958 to 1977, China experienced plenty of difficulties in both S&T and industrial development, because some of its policies deviated from the actual urban conditions. From 1978-2000, China simultaneously accelerated foreign technological imports and industrial structure adjustments, enabling cities to become the frontline of innovation. In the 21st century, China has accelerated its transformation from an industrial structure to a knowledge-based one, and enhanced foreign entry controls in cities. This has highlighted the importance of synergy innovation across cities, and the aim is to build up indigenous technological capabilities through the marketisation reform.

Chapter 3 is the literature review. It systematically discusses both theoretical and empirical findings regarding FDI spillovers, the foreign expansion process and industrial structures in technological upgrading from previous studies, and helps to provide a solid theoretical framework for the PhD research. The first section in this chapter discusses knowledge spillover rationales in urban technological upgrading, and explains the importance of interactions in technology transfer and dissemination. The second section focuses on FDI spillovers in host city technological upgrading. It first analyses five FDI spillover channels, namely demonstration and imitation effects, labour mobility, competition, exports, and forward and backward linkages. In line with the rationale of regional knowledge spillovers, technology transfers and diffusions of FDI also exhibit a spatial effect in terms of neighbouring city level technological performance. The third section discusses the role of two specific time-based features of the foreign expansion process, namely pace and rhythm, in FDI spillovers. The fourth section analyses the mechanism of industrial related and unrelated variety in city level knowledge spillovers, and discusses their impacts on technological upgrading. Related and unrelated variety are found to affect technological performance in different ways, but prior research has scarcely investigated their role in FDI spillovers. Finally, the fifth section emphatically elaborates cluster technological upgrading from the regional context perspective, and indicates that place-specific factors play an important role in FDI spillovers. It first defines (regional) clusters, and then analyses cluster mechanism in technology transfer and diffusion. Based on two specific dimensions, it discusses the roles of both the government and market orientations in cluster technological upgrading, and also previous empirical cluster studies.

Chapter 4 introduces the data sources and methodology adopted in the PhD thesis, as well as the overall research design. The objectives of this chapter are to establish appropriate datasets and select a research methodology according to the requirements in the subsequent empirical analysis. First, it introduces four hierarchies within the Chinese regional administrative system, namely provinces, prefectural cities, counties, and villages, and emphatically elaborates the geographic distribution of Chinese cities. It then introduces two specific databases adopted in the PhD thesis, *Chinese Urban Statistical Yearbooks,* and *The Annual Industrial Survey Database*, respectively. In line with the specific research questions, it systematically expatiates on the dataset processing, the definitions of the variables, the estimation methods, and the univariate analysis in Chapters 5, 6, 7. Hence, it provides an empirical research framework for the PhD thesis.

Chapter 5 investigates both the intra- and inter-city externalities of inward FDI in technological upgrading. It also aims to find out how foreign expansion pace and rhythm affect FDI spillovers both within and across Chinese cities. Based on the panel data of 244 Chinese cities over the period 2004-2011, the estimation results demonstrate that FDI spillovers exert a significantly positive impact on technological upgrading both within and across cities. Focusing on foreign expansion time-based characteristics, a rapid foreign expansion process in neighbouring cities can significantly promote local technological upgrading. It also enhances FDI spillovers across cities. By contrast, irregular and unstable foreign expansions negatively moderate FDI technological spillovers in the FDI recipient city, but directly facilitate technological upgrading in neighbouring regions.

Chapter 6 investigates the roles of industrial related and unrelated variety in both intra- and inter-city FDI spillover effects, in order to determine how they affect technological upgrading within and across Chinese cities. In this chapter, I integrate the firm-level data sample from *The Annual Industrial Survey Database* into a panel city level dataset, consisting of 239 cities over the period

2001-2009. The empirical results once again confirm the positive effects of foreign presence in regard to technological upgrading both within and across cities. Focusing on the industrial structures, both related and unrelated variety directly promote technological upgrading in the local areas. From a spatial perspective, only related variety in adjacent cities has a spatial effect on local technological upgrading, but it significantly diminishes FDI spillover across cities.

Chapter 7 aims to investigate the intra- and inter-city externalities of inward FDI, the foreign expansion process and industrial structures in technological upgrading within both government and market-oriented Chinese urban groups. Using the panel datasets from two specific clusters, namely the Beijing-Tianjin-Hebei and Shanghai-Yangtze River Delta Urban Groups, this chapter replicates both the pooled OLS and ML spatial regressions from the previous two chapters. Our results show that FDI spillovers exert entirely different impacts on technological upgrading between the two clusters. Due to place-specific factors and resources, both industrial structures and the foreign expansion process also have distinctive impacts on FDI spillovers. The findings of this chapter further contribute to a deeper understanding of cluster technological upgrading mechanisms.

Chapter 8 is the final chapter of the PhD thesis and its objective is to summarise the research. First, I summarise each of the preceding chapters and discuss the empirical findings, as well as propose some policy suggestions for central and local authorities to consider. Then, in the next section, the theoretical contributions are presented. Finally, I emphatically state the research limitations of the PhD thesis, and make several recommendations for future studies.

Chapter 2 Historical Path of Technological Upgrading in Chinese Cities

Before the systematic literature review, this chapter introduces the historical path of technological upgrading in Chinese cities, and relevant FDI and industrial strategies. This will help me to better explain the concrete reasons why I chose Chinese cities as the research setting in this thesis, and illustrate their unique characteristics, which differ from those in developed economies.

Nowadays, urbanisation is one of the most critical worldwide social phenomena in terms of labour mobility from villages to cities, or rural areas being replaced by cities and towns (Xin, 2013). Many high-tech manufacturing and service industries have emerged in areas that are urbanised, enabling the creation of an open and competitive environment in which firms can interact with other innovation actors (e.g. governments, research institutions and companies). Such interactions facilitate knowledge spillover effects across innovation actors, and build up technological capabilities (Ning et al., 2016). Moreover, as the main FDI recipients, cities also proactively integrate into global supplier chains, and motivate local companies to strengthen their S&T collaborations and alliances with MNEs. Thanks to FDI spillovers, cities, especially those with emerging economies, can significantly accelerate their technological "catch-up" process, and avoid risky and costly in-house R&D activities. Hence, cities exhibit several competitive advantages such as intellectual resources and infrastructure superiority, and are now at the forefront of technological upgrading. For example, many large-scale cities, such as London and New York, have already become global innovation centres in terms of S&T (Pang, 2009).

Since the foundation of the People's Republic of China in 1949, and especially over the last three decades, China has experienced a rapid urbanisation process, which has been accompanied by industrial restructuring and increasing FDI expansion. Increasingly cities have emerged to replace underdeveloped rural areas in China, and accelerated the elimination of conventional inefficient and low-end economic development patterns. In order to accelerate its technological catch-up, China has made great efforts to build up indigenous innovative capabilities in the cities, with the aim of driving overall technological upgrading (Li, 2014). Therein, there are two critical determinant factors, namely foreign technology support and industrial restructuring, which are closely intertwined with such a complex process.

On the one hand, China hopes to develop knowledge-intensive manufacturing industries by means of industrial structure adjustments, and reduce the conventional labour-intensive sectoral proportions within the urban industrial system. Prioritising the development of high-end sectors can enhance inter-industry linkages in shared and complementary competences, and further promote comprehensive technological upgrading. On the other hand, as the largest developing economy worldwide, China has been constrained by its weak internal knowledge stocks, so it has been necessary to explore and exploit external technological sources overseas. China has therefore significantly increased the degree to which it has opened up to the rest of the world, and encouraged FDI expansion in the cities through a set of policy supports. Thanks to technology transfer and the dissemination of FDI to host cities, China is rapidly assimilating and exploiting advanced knowledge from developed countries, which is enabling it to accelerate its technological catch-up strategy (Ning, 2009).

Due to its aim of economic independence and its political desires, China has often insisted on a state-led technological upgrading mechanism in its S&T developments, which is quite different from that in most western countries. The government hold great power in terms of the planning and administration of S&T activities in the cities, rather than adopting entirely market-oriented innovation. Moreover, China is a relatively large country, and its provinces are even larger than some European countries. Regional disparity is therefore large across Chinese cities. This chapter systematically expatiates on the technological developments in Chinese cities over four specific periods: 1949-1957, 1958-1977, 1978-2000, and 2001-the present, with the aim of presenting the distinctive characteristics of the Chinese technological upgrading path. Hence, this provides the overall historical background of the PhD thesis.

2.1. Initiation Period of Technological Upgrading in Chinese Cities (1949-1957)

By the end of the 1900s, urbanisation had taken place in some advanced western countries (e.g. the UK and the USA). As a result of the industrial revolution, plenty of underdeveloped villages were urbanised for agglomerations of labour-intensive sectors, and small towns rapidly emerged as the primary form of large modern cities. In modern times, the urbanisation process has accelerated all over the world. Some international metropolises, e.g. London and New York, have already become global economic and innovative centres. In virtue of the third revolution of science and technology, which has taken place since the 1950s, these international metropolises have concentrated creative talents and superior intellectual resources, and made remarkable technological achievements (Pang, 2009, Wang and Chuanglin, 2011).

Since the foundation of the People's Republic of China in 1949, the China Communist Party has assumed the power to govern the whole country. Nevertheless, because of damage caused by wars e.g. the Liberation War during 1945-1948, the Chinese urbanisation rate was only 10.64%, and industrial facilities in most cities were mainly destroyed. Due to the shortage of intellectual resources, technological activities in Chinese cities started from almost nothing (Duan, 2012). The Chinese central government decided first, to start the recovery and reconstruction of the cities, and rebuild infrastructure facilities to lay down the foundations of urban technological development. In response to the call for "Building up Cities", many people moved from the rural to the urban areas, which caused the urban population to steadily increase over the initial period, from 1949-1957. By the end of 1957, the Chinese urbanisation rate had reached 15.39%, and most cities had resumed production.

Due to the havoc in universities and research institutions during the wars, the Chinese leadership decided to rebuild institutional systems for urban S&T development by means of domestic scientific talent cultivation. For this purpose, the central government established the Chinese Academy of Science (CAS) in 1949, and plenty of national level research institutions were subsequently founded in some developed cities (e.g. Shanghai and Nanjing). S&T activities in Chinese cities were thus slowly in recovery, and regional authorities proactively participated in local S&T development planning. Given the concerns about national security and its political desires, China established strict state-led technological upgrading systems in the cities, while the market approach to S&T development was not politically accepted. During this time, S&T development in China was strictly controlled by the government at all levels, and strived to serve the aim of socialist modernisation (Duan, 2012). For this purpose, China launched its first long-term S&T programme, “The 12-year Plan of Scientific and Technological Developments (1956-1967)” in 1956, in which it specified 57 centrally-planned and large-scale tasks for basic scientific research. By the end of 1957, the CAS had set up over 40 urban level affiliated research centres in large and developed cities. The total number of research institutions was over 840, and the number of S&T researchers had increased to about 400,000. This not only helped Chinese urban S&T development recover from the damage caused by the war, but also set up solid basis for future technological upgrading.

Because of blockades on techniques from western countries, technological sources in Chinese cities were relatively scarce during the period 1949-1957. Therein, urban industrialisation created the conditions for S&T development, and exerted a significant impact on the direction of technological upgrading (Ye, 2001). In the early 1950s, the Chinese domestic industrial basis was relatively weak, especially in manufacturing and heavy industries. Most Chinese cities lacked heavy machinery equipment and manufacturing factories. In 1952, the outbreak of the Korean War soon drew China into an intensive military conflict with the US, which resulted in great demand for military products in a short time. Suffering dual pressures from both domestic developments and supporting the war, the Chinese leadership decided to prioritise the development of national defence and heavy industries in the cities (Xue, 1997). This is because they believed that these industries were the cornerstone for industrialisation in the cities, and that such an industrialisation strategy could greatly accelerate industrialisation process (Ma, 2015). For this purpose, China issued “The First Five-Year Plan” in 1952, and emphatically developed labour- and resource-intensive heavy industries, such as coal and steel mining. By the end of 1957, China had implemented 694 large-scale industrial projects, and completed 455 of them. The proportion of secondary industrial value added dramatically increased from 20.88% in 1952 to 29.65% in 1957, and basically completed heavy industrial construction. Therefore, over this period, industrial R&D development was also concentrated in limited sectors such as physical chemistry, electronics, automations, and energy engineering, in order to support the military demands. However, technologically related interindustry linkages were still scarce, so sectors within the industrial system were relatively isolated and scattered during this period (Ma, 2015).

Constrained by relatively weak internal knowledge stocks, China also proactively explored external technological sources overseas. As indicated above, severe blockades on new techniques imposed by western developed countries such as the US and UK significantly impeded technological imports in Chinese cities. Hence, the Soviet Union's aid became the sole external assistance in regard to technological upgrading in Chinese cities. By the end of 1949, the USSR had decided to provide economic and technical support to China, and carefully selected over 40 cities in which to implement 156 assistance programmes (Yimin and Mingchang, 2007, Qi, 2003). These cities were mainly concentrated in northern, northeastern, and southwestern China, and most of them had a strong industrial base. During these 156 programmes, the USSR not only provided interest-free loans and construction proposals, but also sent technical specialists to guide Chinese urban industrial development from location choice to staff training. By the end of 1957, the accumulative capital from the USSR had reached over 11 billion RMB, accounting for 44.3% of the total Chinese industrial investments. The 156 USSR assistance programs were mainly concentrated on heavy industrial development, especially in the mining, heavy machinery, and power-generating industries.

During the USSR's assistance projects, cities were at the forefront of the foreign technological imports, and local authorities directly intervened in the resource distribution and R&D orientation of these projects. Under pressure to speed up the industrialisation in the cities, the objective of these projects was to satisfy the demands of macroeconomic development and national security. Integrated with "The First Five-Year Plan", the Chinese leadership hoped that domestic manufacturing would rapidly assimilate and exploit advanced technologies through the USSR's assistance projects, thus resulting in the establishment of indigenous industrial systems. Moreover, during this phase, the Chinese central government also intervened in the geographic distribution of industrial developments. In terms of national security, southeastern and coastal cities are more vulnerable to attack, so China decided to accelerate industrial relocations to inland regions. In order to build up the industrial system in under-developed regions, several southwestern and northwestern cities, such as Lanzhou and Chengdu, were selected as the destinations of some of the USSR's assistance projects. Thanks to these projects, foreign specialists provided insightful comments to local authorities in China, and helped them to set up industrial bases, especially heavy industries, in cities. They also cultivated plenty of native R&D talents during the urban industrialisation process in China. Hence, although foreign technology sources were relatively limited over 1949-1957, China still directly obtained plenty of cutting-edge technologies, which greatly contributed to basic scientific research. By the end of 1957, 56 civilian enterprises and 35 military enterprises were concentrated in central and western cities. The total amount of investment had reached 10.38 billion RBM, accounting for 52.9% of the total investment (Dong and Wu, 2000).

Over the period 1949-1957, Chinese urban technological upgrading occurred under state-led control (Xue, 1997). This is because the China Communist Party (CCP) highlighted political targets that could enable it to rapidly achieve socialism through a socialist transformation, and did not allow private investments, especially in technological activities. Central and local governments were the main investors in urban technological upgrading, and were responsible for allocating R&D resources. There were three main advantages for China of adopting such a technological mechanism. First, government-oriented S&T developments could efficiently allocate and distribute superior capital and intellectual resources to meet the urgent demand for national economic development and national defence, and obviously reduce repeated construction and resource waste. Second, such a state-led technological development pattern also accelerated the urban industrialisation process, enabling the setting up of a solid basis for technological upgrading in the future. Prioritising development in national defence and the heavy industries could rapidly meet the urgent demands of the macro-level economy. Moreover, thanks to governmental support, 156 USSR assistance projects were successfully implemented, and contributed to the building up of indigenous technological capabilities in Chinese cities. Third, state-led S&T developments helped to establish clear and specific quantitative targets, and thereby concentrated a large volume of resources in core cities. Different from the average technological developments in the cities, China adopted experimental and gradualist approaches in pilot cities, and disseminated the successful experiences to others. This minimised the nationwide systematic risks, and helped to effectively explore technological upgrading mechanisms suitable for the local conditions.

However, some problems with technological upgrading also emerged during this phase. First, the Chinese leadership overemphasised the importance of national security and the heavy industries, and sacrificed consumer and civilian industrial development. These sectors are capital-intensive and slow-returns , and created limited market value (Stalin, 1973). Second, during the centrally-planned industrial projects, local authorities in Chinese cities had limited rights to guide local industrial R&D developments, and were forced to implement polices resolutely to achieve quantitative targets. Due to their lack of autonomous rights, cities were not allowed to adopt suitable technological upgrading mechanisms based on the local conditions. Third, foreign technological imports and assistance were relatively limited over this period. The only overseas technological assistance was the 156 USSR assistance projects. Because of China's hostile diplomatic relations with advanced western countries such as the US and the UK, both the scale and scope of international technology disseminations and transfers were greatly confined.

2.2. Formation and Adjustment Period of Technological Upgrading in Chinese Cities (1958-1977)

The technological developmental path in Chinese cities cannot always run smoothly, and has experienced many twists and turns. Therein, the formation and adjustment of S&T frameworks were a significant characteristic of Chinese urban technological upgrading during the period 1958-1978. By the late 1950s, the Sino-Soviet relationship had become strained due to heated ideological disputes, and the USSR had decided to withdraw all of the technical specialists, and requested that the S&T assistance projects stopped within a compressed time. Meanwhile, the Chinese leadership was overconfident about the economic and social developments, and underestimated possible difficulties in future. China adopted deeper state-led S&T mechanisms for urban technological upgrading, and abandoned almost all of the foreign assistance. By the late 1950s, the Chinese leadership had launched two economic programmes: the “Great Leap Forward” and the “Giant People’s Cooperatives”, which aimed to enable to China to rapidly surpass the UK and USA in terms of agricultural and industrial outputs as well as S&T achievements.

Over the period 1958-1978, a set of S&T policies and regulations were launched by both the central and local governments, but most of them deviated from the actual urban conditions in China. In 1962, at the National Science Conference, the Chinese central government launched the “Plans of Scientific and Technological Developments in a decade (1962-1972)”, and proposed the concept of the “Big Science Institution”, aimed at the construction of a technological upgrading mechanism (Duan and Zhong, 2006). This mechanism highlighted that local authorities should concentrate resources on triggering technological breakthroughs through relying on large-scale collaborations among universities, research institutions, and industrial departments. Constrained by limited capital and intellectual resources, it was especially difficult for the private sector and firms to carry on such large-scale R&D projects. By contrast, the regional authorities further strengthened their administrative control of S&T activities in the cities, and quickly expanded research institutions, which were subordinated by industrial departments. In contrast to the period 1949-1957, the local authorities in Chinese cities were more focused on the importance of technological output commercialisation, and were thus encouraged to build up relationships among industries, companies, and research institutions. In other words, companies in cities were more inclined to collaborate with local universities and research institutions, and the commercialisation process of technological upgrading accelerated during this time. The cities engendered a more complex innovation networking environment, enabling isolated actors to become linked together.

However, the outbreak of some political events greatly hindered technological upgrading the in cities. Due to the “Down to the countryside movements” (shangshan xiaxiang), the Chinese leadership advocated that young people should go to the poor rural areas, and receive re-education. More than 16 million “Educated Youths”, nearly 1/10 of the urban population, were forced to leave the cities and go to the villages, where they worked in agricultural production over the period 1968-1977. Because of this, Chinese cities lost a large amount of creative talent, and many S&T activities were postponed. Meanwhile, due to the political dispute between Mao and Liu (who later replaced Mao as the chair of the PRC), Mao launched the “Great Proletarian Cultural Revolution” to counter Liu’s “capitalist development approach” to Chinese economic development, in 1966. The outbreak of the “Great Proletarian Cultural Revolution” thoroughly disrupted technological development in the cities. During the period 1966-1976, almost all technological plans were suspended, and most Chinese people were drawn into class struggles. These disruptions caused the cities to become severely afflicted areas. The students strike quickly spread across all of the large cities in China, and the college entrance examination system was suspended. Many intellectuals were denounced as the “stinking number nine”, and forced to leave the cities and go to the villages for educational reform. Moreover, plenty of research institutions were also disbanded. The class struggles and military conflicts heavily hampered S&T activities, and countless R&D devices and facilities were destroyed. By the end of 1976, the Chinese urbanisation rate had decreased to 17.86%, and the 106 state-led laboratories had reduced in number to 53 on a city level. The number of scientists and engineers also fell dramatically from 22,000 to 13,000 during this period.

Over the period 1958-1978, China's international environment worsened. As well as the collapse of its technological cooperation with the USSR, indicated above, China was also involved in military conflicts with other countries (Ning, 2009). During the late 1960s, China was simultaneously drawn into the frontier dispute with the USSR over Damansky Island (also known as Zhenbao Island) and the Vietnam War with the US. Moreover, political events, such as "The Great Proletarian Cultural Revolution", further created an unstable and turbulent business environment, greatly impeding foreign investments in Chinese cities. Overseas technological assistance and imports were thus seriously confined during this time. In order to cope with the military threats from both the USA and USSR, China further adjusted its strategy in terms of S&T geographic distribution. In order to be less vulnerable to military attack, the Chinese central government accelerated the relocation of existing research institutions from the southeastern and coastal cities to inland China. For example, cities including Chengdu, Kunming, Lanzhou, Xi'an and Changsha were selected as destinations to set up new factories in the fields of electronics, aircraft engineering and atomic energy. Furthermore, plenty of military factories and enterprises also moved from the coastal cities to inland China, thereby bringing R&D equipment and devices to underdeveloped regions (Cao, 1994, Wang, 1998).

The dramatic decrease of foreign technology transfers and supports caused serious consequences in Chinese technological upgrading. Due to the lack of communications with advanced countries (e.g. US and UK), it was difficult for China to directly get the access to latest S&T developmental directions. In some key industrial areas, e.g. steel and smelting industry, China adopted relatively inefficient way in its manufacturing as it cannot obtain advanced boilers from developed countries. This did not only result in huge wastes in natural resources, but also caused heavy pollutions in cities. Moreover, the withdrawal of the Soviet technical experts interrupted plenty of fundamental research projects in Chinese cities, and left a great mess. China was forced to increase indigenous R&D investments at the cost of lowering living standards of citizens. However, constrained by weak internal innovative capabilities, indigenous closed R&D activities became relatively risky and costly. Hence, technological upgrading process in Chinese cities greatly slowed down over such period.

Due to the lack of foreign technological imports, in part due to the interruption of the USSR assistance contracts, the Chinese leadership decided to adopt a “self-reliant and self-sufficient” industrial strategy to build up its indigenous technological capabilities. In order to prepare for potential wars in the future, Chinese industrial structure adjustments began to focus more on national defence and security (Naughton, 1988). Therein, military industrial enterprises rapidly emerged in the cities, and were especially focused on communications and electronics, and the nuclear and energy machinery industries. The manufacturing proportion dramatically increased, while the primary sectoral proportion reduced during this time. By the end of 1977, the proportion of added-value in secondary industries had increased from 36.96% in 1958 to 46.58%. The proportion of added-value in primary industries had reduced from 34.39% to 29.51% during the same period.

However, the Chinese industrialisation process also experienced a relatively difficult period from 1958, which revealed some lessons for future improvement. First, several economic reforms and political events, such as the "Great Leap Forward", the "Giant People's Cooperatives" and the "Great Proletarian Cultural Revolution", disrupted the industrialisation process in the cities. The central government greatly underestimated the potential difficulties in regard to urban industrial developments, and set plenty of unrealistic quantitative goals for industrial output (e.g. iron and steel outputs). To achieve these prospective goals, local authorities were forced to specialise in limited low-end and labour-intensive sectors through blind expansion. Many large-scale factories in the steelmaking and mining industries were disintegrated and replaced with small and inefficient workshops. Second, because of the severe "Leftism", extremely serious statistical exaggerations in regard to industrial production were made across almost Chinese cities. For the sake of obtaining political resources, local authorities often overstated the industrial outputs in cities to ingratiate themselves with the Chinese leadership, resulting in increasing financial constraints (Li, 1997). Third, China overemphasised its national defence sectoral developments, but neglected civilian industries. Compared with the period 1949-1957, the disequilibrium in Chinese industrial structures became even more serious. Hence, such industrial structures caused Chinese citizens' living standards to be greatly sacrificed, and created limited market value to satisfy public demand.

2.3. "Catching-up" Period of Technological Upgrading in Chinese Cities (1978-2000)

During "The Great Proletarian Cultural Revolution" from 1966 to 1976, plenty of scientists were persecuted, and S&T activities in the Chinese cities were disrupted. Nationwide industrial and student strikes caused enormous damage to urban technological upgrading. Such problems raised concerns from the Chinese leadership. By the late 1970s, the central government had become critical of the "leftist" policy, which was considered the main reason for the economic damage. China decided to revive the readjustment policies proposed in 1962-1965 (Ning, 2009). In the fields of science and technology, the Chinese leadership emphatically indicated the importance of S&T development for economic growth, and convened key conferences. During these conferences, a set of S&T policies and regulations were drawn up. For example, at the National Science Conference in March 1978, Deng proposed that "science and technology constitute a primary productive force", and advocated speeding up the establishment of indigenous technological capabilities. At this conference, the central government launched "The National Plans for the Development of Science and Technology (1978–1985)", and highlighted the prioritised position of basic technological research in Chinese cities. Before long, the National S&T Commission had resumed its operations in regard to the planning and administration of S&T activities in the Chinese cities, and rapidly implemented reforms in urban innovation systems.

In the early 1980s, the Chinese central government explicitly proposed that "economic development must rely on science and technology, and science and technology must be oriented toward economic developments". It also added S&T development plans into the "Sixth Five-Year-Plan (1981–1985)" as a national development strategy. In 1985, China launched the "Decisions on Reforms of the Science and Technology System", which aimed to boost the institutional reform of technological upgrading in Chinese cities. In the 1990s, China adopted deeper strategic planning and adjustments in regard to S&T reforms. In 1995, at the National Science and Technology Conference, the Chinese central government launched two critical policies, namely "Decisions on Accelerating the Progress of Science and Technology" and "Some Suggestions on Accelerating Science and Technology Popularizations". These macroscopic strategic blueprints not only provided S&T developmental directions in Chinese cities, but also explicitly determined the roles of government in S&T system construction.

During the early part of this period, the Chinese cities were rapidly revitalised after the damage caused by "The Great Proletarian Cultural Revolution", and became the frontline of S&T activities. More specifically, there were several important events that made a great impact on the S&T system reforms in Chinese cities. First, China decided to resume the university entrance examinations in 1977, and rebuild its tertiary education systems. After an interruption to higher education of over 10 years, over 100 million "educated youths" were able to return from the villages to the cities, and pursue S&T activities. By the end of 1977, over 273,000 educated youth had entered universities and colleges through the college entrance examinations, which became precious intellectual resources for S&T development in Chinese cities. Second, in contrast to the strict state-led technological upgrading mechanism that had existed previously, the central and local governments gradually handed over the administration to actual innovation participants. Technical experts resumed their leadership in innovation activities, and also proactively participated in formulating S&T development strategies. As a result, some market-oriented S&T projects obtained approval from the authorities. Therein, technical science and applied science were brought into priority construction projects, thus setting up the basis to create more market value in the future (Duan, 2012). Third, the local authorities in the cities obtained more autonomous rights in regard to technological upgrading based on the actual conditions, instead of being forced to complete rigid quantitative tasks at the request of high-level Chinese leadership. Therefore, officials in Chinese cities could select appropriate S&T strategies and adjust them accordingly.

During this time, "The National Plan for the Development of Science and Technology (1978–1985)" greatly accelerated Chinese innovative activities, and deepened reforms in S&T institutional construction. Conventional and inflexible state-led technological mechanisms were doubted, so it seemed necessary to reduce government intervention in S&T activities. For this purpose, China created a ''Technology Market'' to legitimise paid transactions for technology, and introduced competition mechanisms in S&T funding (Huang et al., 2004). Meanwhile, it also launched a set of S&T projects, such as the Spark Program (1985), the National High-tech R&D Program (863 Program, 1986), the Torch Program (1988), SSER (Pandeng Program, 1991) and the 973 Program (1997), and most of these were concentrated in the cities. The objectives of these projects were either to build up close connections among governments, industries, and research institutions, or to encourage a market orientation in technological mechanism reforms. For example, through the Torch Program (1988), China accelerated the construction of national high-tech zones and science parks in experimental cities such as Beijing (Heilmann et al., 2013). These high-tech zones, such as the Zhongguancun Science and Technology Park, helped to geographically co-locate high-tech firms, universities, and research institutions in a small knowledge-intensive area, thereby facilitating the industrialisation and commercialisation of research findings. Market-driven technological upgrading mechanisms emerged within such a high-tech zone (Tan, 2006). By contrast, the National High-tech R&D Program (863 Program) highlighted the importance of strategic high-tech industrial development (e.g. ICT, automation, and bio-technologies etc.), in order to build up core indigenous technological capabilities. This programme became the key engine to accelerate industrial structure adjustments in Chinese cities. Hence, a large amount of labour- and resource-intensive industries were replaced by other knowledge-intensive sectors, and the proportions of high-tech manufacturing and service industrial output to the total GDP dramatically increased in Chinese cities. By the end of 1999, China had implemented 539 national level S&T programmes, and made more than 100,000 key S&T achievements. Compared to the phases before 1978, the Chinese cities had significantly accelerated industrialisation and commercialisation processes in relation to S&T activities within both the domestic and global markets, and created over 153.4 billion RMB of market value.

Why did Chinese cities make so many remarkable S&T achievements over the period 1978-2000? The reasons can be mainly classified into two aspects. One is fast-growing technology transfers and dissemination overseas, while the other is Chinese indigenous industrial restructuring. By the late 1970s, the international environment had improved compared to the 1960s, as China had resumed diplomatic relations with the USA, Japan, and other advanced western economies. The military threat had thus greatly reduced, and economic globalisation was rapidly spreading all over the world. The remarkable and rapid S&T developments in newly industrialised Eastern Asian countries such as Singapore and South Korea significantly motivated the Chinese leadership to begin to look outwards, in order to explore and exploit technological sources overseas. Meanwhile, the technological gap between China and the advanced countries was still very large, especially in cutting-edge S&T fields. The Chinese indigenous market demand for high-tech products and services was increasingly large and urgent, thus creating a relatively huge market for MNEs to expand their business.

From 1978 onwards, “The Reform and Opening Policy” rapidly spread across the southern and coastal cities of China. This policy encouraged regional authorities to attract inward FDI activities in urban areas, and accelerate technological imports. Due to the huge domestic market, the Chinese leadership decided to adopt the “Exchange Market for Technology” strategy. Namely, China hoped to lower the foreign entry threshold for MNEs, and encourage them to bring in advanced technologies to disseminate to domestic actors. For this purpose, the Chinese central government established 18 “Special Economic Zones” in eastern and coastal cities during the 1980s (shown in Table 2.1). The local governments in these cities were entitled to issue a set of preferential policies such as fiscal subsidies and tax concessions to attract FDI, which enabled them to create an open business environment for S&T imports. R&D collaborations and alliances between domestic firms and MNEs were also encouraged in the “Special Economic Zones” (Jin, 2013). Through several FDI spillover channels e.g. labour mobility and demonstration effects, local companies could quickly assimilate and explore advanced technology and managerial patterns for their own production, and build up the technological capabilities of Chinese cities. During this time, the Chinese leadership showed a more open attitude to advanced technology and managerial experience overseas, which contrasted with its overemphasis of its S&T independence in the prior periods. In contrast to the 1950s, when the only S&T import was the 156 USSR assistance programmes, both the scope and scale of S&T imports were significantly enlarged. By the end of 2000, the total amount of FDI contracts had reached 22,347, and the total inward FDI value was 59.36 billion US dollars.

Meanwhile, the total amount of S&T import projects had reached 7,353, and the contract value amounted to 18.18 billion US dollars. Therein, S&T import costs were 7.2 billion US dollars, an increase of 26.15% compared to 1999 (He, 2001). FDI spillovers greatly contributed to Chinese technological upgrading in increasing ways, e.g. worker mobility, global supplier chains, and social networks. Thanks to great foreign technology transfers and disseminations, China did not only receive plenty of cutting-edge techniques, but also updated its industrial standardization system. This helped domestic firms became more internationalized and open to global markets, and better deal with overseas competitions. With increasing cooperation with MNEs, domestic firms also hired plenty of foreign specialists, and updated manufacturing and management modes. Therefore, during this period, foreign technology transfers became a key driver to technological upgrading in Chinese cities.

Table 2-1 Chinese Special Economic Zones

Special Economic Zones	***Provinces***	***Establishment Year***	***Administrative Level***	***Location***
Shenzhen	Guangdong	May 1980	Sub-provincial	S
Zhuhai	Guangdong	May 1980	Prefectural	S
Shantou	Guangdong	May 1980	Prefectural	S
Xiamen	Fujian	May 1980	Sub-provincial	E
Dalian	Liaoning	May 1984	Sub-provincial	NE
Qinhuangdao	Hebei	May 1984	Prefectural	N
Tianjin	Tianjin	May 1984	Municipality	N
Yantai	Shandong	May 1984	Prefectural	E
Qingdao	Shandong	May 1984	Sub-provincial	E
Lianyungang	Jiangsu	May 1984	Prefectural	E
Nantong	Jiangsu	May 1984	Prefectural	E
Shanghai	Shanghai	May 1984	Municipality	E
Ningbo	Zhejiang	May 1984	Sub-provincial	E
Wenzhou	Zhejiang	May 1984	Prefectural	E
Fuzhou	Fujian	May 1984	Prefectural	E
Guangzhou	Guangdong	May 1984	Sub-provincial	S
Zhanjiang	Guangdong	May 1984	Prefectural	S
Beihai	Guangxi	May 1984	Prefectural	S
Hainan	Hainan	April 1988	Province	S
Pudong New Area	Shanghai	April 1990	Sub-provincial	E

Note: location is classified by the geographic distribution of provinces in China: E: Eastern China (Shandong, Jiangsu, Shanghai, Zhejiang, Anhui, Fujian and Jiangxi); S: Southern China (Guangdong, Guangxi, Taiwan and Hainan); C: Central China (Hunan, Hubei and Henan); N: Northern China (Beijing, Tianjin, Hebei, Shanxi and Inner Mongolia); NW: Northwest China (Ningxia, Qinghai, Shaanxi, Gansu and Xinjiang); SW: Southwestern China (Sichuan, Guizhou, Yunnan, Chongqing and Tibet); NE: Northeastern China (Liaoning, Jilin and Heilongjiang)

Over the period 1978-2000, China began to proactively build up its technological capabilities via technological imports, and the increasing FDI activities significantly enhanced technology transfer and disseminations to local actors. Nevertheless, as a beginner in terms of international trade and markets, China was still short of experience, so some problems also emerged during this period.

First, owing to the lack of deep analysis and understanding of knowledge overseas, the local authorities excessively accelerated the introduction of the “newest” technologies in the cities, but often neglected the local conditions. Blind FDI expansion resulted in repeated constructions, and also dramatically increased the competition effects in local areas. Constrained by weak internal absorptive capacity and knowledge stocks, local actors faced great challenges and became crowded out of the domestic markets, rather than benefitting from technology transfer and the dissemination of FDI. Second, intellectual property rights (IPR) protection in Chinese cities was still at a relatively low level. Although the patent registration procedures and assessment criteria were increasingly refined during S&T imports, Chinese IPR protection was still quite weak compared with other developed countries. Due to such a backward IPR protection mechanism, MNEs were reluctant to license patents or commercialise their S&T achievements in Chinese urban markets, especially in cutting-edge fields, for fear of losing their competitive advantage (Liang and Xue, 2010). For example, software privacy problems were widespread in China, which greatly impeded sustainable development (Wang et al., 2005). Hence, both the scale and scope of technology transfer and the dissemination of FDI were greatly confined. Third, China adopted an experimental, gradualist and decentralised approach in regard to technological imports, so the FDI activities were mainly concentrated in developed coastal Chinese cities. Inter-regional connections were still too weak to interlink cities in spatial proximity to establish a more complex and greater “regional innovation system” across boundaries. Because of the overdependence on preferential policy support, some cities did not create a competitive and open business environment for MNEs’ FDI expansion, but accepted industrial transfers in low-end productions. Therefore, the FDI technological spillover effects exerted a limited impact on the building up of indigenous innovative capabilities in China.

As well as the exploration and exploitation of foreign technology, China also accelerated its indigenous industrial restructuring in the cities. This became another key engine of urban technological upgrading in China. Thanks to “The Reform and Opening Policy” in the late 1970s, domestic market demands rapidly increased, especially in civilian and consumer industries. Hence, disadvantages emerged in regard to the centrally-planned urban industrialisation process. Because the conventional national defence and heavy industry-oriented sectoral developments created technological outputs with less market-value, they could not fully satisfy the civilian demands of the general public. The Chinese leadership therefore decided to implement more radical industrial reforms to raise the living standards of the people, and place the consumer and civilian industries in a more important position (Wang, 2001). Soon afterwards, China introduced a set of policies in its industrial structure adjustments, which included the “Decisions on Some Issues to Accelerate Industrial Development” in 1978 and the “Decisions on the Reform of the Economic System” in 1984. These policies firstly proposed that cities should become the reform frontlines, and emphatically elaborated the importance of industrial restructuring in urban technological upgrading (Naughton, 1996, Zhao, 1995).

First, “The Reform and Opening Up Policy” highlighted the importance of transforming the centrally-planned economic system to a market-oriented one, thereby creating more economic value. Hence, China realised the importance of a market orientation in its industrial R&D activities, and enhanced the relationships between industries, universities, and research institutions. Therein, China accelerated institutional reforms in state-owned enterprises (SOEs), and encouraged the development of private industries and firms. Thanks to the deregulation of industrialisation, cities became the forefront of S&T activities, as competition mechanisms enabled industrial restructuring to become more efficient and market-driven. In other words, increasing competition effects forced the local authorities to strengthen the developments in high value-added industries, and also stimulated indigenous firms to explore and exploit advanced technology in productivity promotion. Moreover, the establishments of "Special Economic Zones" (SEZs) further intensified the role of markets both within the country and across the world. In these SEZs, industrial structure adjustments emphatically aimed to satisfy market demands, thereby significantly improving resource allocation and distribution efficiency. Therefore, although China still adopted a state-led industrial restructuring strategy in the cities, the market orientation began to play an increasingly significant role in adjustments to sectoral structures.

Second, due to the increasing demands from the consumer and civilian industries, the Chinese leadership decided to adjust its urban industrial structures, and hoped to accelerate the conversion of military production to civilian-driven manufacturing (Junzhuanmin). Before 1978, China had concentrated its capital and intellectual resources in the military and heavy industries, but neglected the civilian sectors. In order to obtain more profits to support the national defence industries, the Chinese leadership decided to combine civilian and military production, and encouraged the dissemination of advanced technology and managerial patterns from the military to the civilian sectors (Ning, 2009). Therefore, interindustry linkages rapidly increased, which made diversified industrial structures more technologically related. The focus of industrial development gradually shifted from the national defence and heavy industries to the labour-intensive manufacturing sectors

(Yan and Yudong, 2003), thus enabling the living standards of the general public in Chinese cities to improve. Over the period 1980-2000, the share of secondary industry added-value reached 45.92%, nearly half of the total value in China. The proportion of tertiary industry dramatically increased from 21.26% in 1980 to 39.02% in 2000. By contrast, the primary sectors' proportion significantly reduced from 30.17% to 15.06% over the same period.

Third, during the late 1970s, in the "Sixth Five-year Development Plan (1981–1985)", the Chinese leadership emphasized that national economic development should greatly rely on technological advantage, and that developments in knowledge-intensive industries should be accelerated. The "Seventh Five-year Development Plan (1986–1990)" further proposed a national strategy to promote S&T development in underdeveloped cities in western and central China through technology transfers from the coastal cities. Hence, industrial restructuring gradually spread across different cities in China. Manufacturing and labour-intensive industries began to relocate to the western and central regions, while the capital- and knowledge-intensive sectors were more concentrated in the eastern and coastal cities. Such industrial transfers not only facilitated advanced technology exchanges and dissemination within a larger region, but also optimised the geographic distributions of the different sectors in China.

To summarise, during the "Catch-up" period of 1978-2000, there were two main characteristics of technological upgrading in the Chinese cities. First, China accelerated its S&T reforms, and faced advanced technology overseas with a more open mind. Cities, as "Special Economic Zones", thus rapidly introduced advanced technology and managerial patterns through technology licensing or

FDI spillovers, and greatly reduced the costs of independent R&D activities. Not only was a set of S&T policies (e.g. tax concessions and fiscal subsidies) adopted to encourage MNEs' technology exports, but China also made great efforts to diversify its R&D collaborations and alliances with foreign investors, for example through joint ventures. Compared with the prior phases, foreign technology became the key external source to enhance Chinese urban technological upgrading. Second, China implemented industrial restructuring, and industrial enterprises began to play a key role as innovators in Chinese cities. China was no longer solely focused on the national defence and heavy industry sectors, but prioritised civilian and consumer industrial development in urban areas. Therefore, both the scale and scope of industrial R&D activities were expanded, thus creating increased market value compared to the prior periods. In other words, such industrial restructuring motivated domestic firms' innovation passion, and further built up indigenous technological capabilities.

2.4. Modernisation Period of Technological Upgrading in Chinese Cities (2001-Now)

Given that the practical analyses in the following empirical chapters mainly focus on technological upgrading in Chinese cities over the period 2001-2013, it is necessary to emphatically elaborate the history of urban S&T developments, and relevant key issues since China entered the WTO in 2001. Since the beginning of the 21st century, high-tech sectors, such as ICT, new materials and biotechnology, have quickly become key fields of S&T activity, and the key engine of sustainable economic development. Hence, some developed economies have taken the lead in building up knowledge-intensive cities, thereby enhancing their overall national strength. For example, Australia proposed the concept of the "Smart City: Sydney" in 2000 and has accelerated the technological upgrading in some high-tech industries such as information and communications. In 2002, the UK launched “Plans on London Innovation and Actions”, which aimed to make London an international innovation centre. Similarly, Tokyo, as the largest innovative industrial city in Japan, has made great efforts to focus on cutting-edge S&T research, and in particular has accelerated its construction of knowledge-based high-tech industrial clusters in core districts since the 2000s (Li, 2014).

Faced with increasing technology competition overseas, China has adjusted its S&T development strategies, and hopes to maintain sustainable technological upgrading in the cities. The Chinese leadership issued the “Eleventh National Five-year Plan (2006–2010)” and “Medium- to Long-Term Plan for the Development of Science and Technology (2006–2020)”. In 2016, it also issued the “Outlines of a National Innovation-driven Development Strategy”, and explicitly declared its “three-step” strategic targets in regard to S&T development. Namely, China aims to enter the ranks of the innovative countries by 2020, be at the forefront of the innovative countries by 2030, and become a world power in science and technology by 2050.

For such purposes, China has made great efforts through adopting four strategies since 2000, especially in regard to deeper reforms of its technological upgrading in the cities. First, the Chinese leadership decided to accelerate inter-regional R&D collaborations and alliances, as the cities are no longer isolated innovation entities in the national innovation system (NIS). In order to expand both the scope and scale of external sources of technology, the cities have become increasingly open and to proactively exploring and exploiting knowledge from other regions, and are now interlinked with each other. For example, Juan and Yun (2016) illustrated that synergy innovation plays an increasingly important role in urban technological upgrading, especially in facilitating cross-city R&D allocations and coordination within urban groups e.g. Beijing-Tianjin-Hebei. Significantly, this enables the building up of indigenous technological capabilities across a larger urban region. During recent years, China has officially launched various policies and regulations to highlight inter-city technological upgrading, in order to accelerate the technological upgrading in urban groups. It launched the "Outlines of Beijing-Tianjin-Hebei Cooperative Development Strategy" in 2015, and the "Development Plans of the Yangtze River Delta Urban Group" in 2016. The highlights of such a strand of policies are to build up cooperative and coordinated innovative networking systems, and accelerate advanced technology transfers and disseminations across cities.

Second, after "the "institutional reform and economic liberalisation" in the late 1990s, China hoped to establish a vigorous and open socialist market economy, thereby enabling companies to become the main players in R&D activities. This is because adopting a market orientation is regarded as a direct driving force for technological innovation, and creating greater market value (Yu and Yin, 2006). Hence, China has promoted marketisation reforms in R&D activities, and reduced governmental interventions to stimulate technological innovation (Zuo et al., 2016). In "the Thirteenth Five-Year Plan", China explicitly determined the dominant role of the market in resource allocations. Both central and local governments devoted themselves to accelerating institutional construction to support S&T activities in the cities, rather than the state having complete control over allocating and distributing R&D resources. For this purpose, China issued a set of key documents, including the "Implementation Program to Deepen the Reform of the S&T System" and the “Outline of a National Innovation-driven Development Strategy”. Therein, the Chinese leadership demonstrated its belief that a market orientation is critical for S&T development, and enhances competition mechanisms in technological innovation. Since 2000, China has begun to transform nearly all of the state-owned R&D research institutions into enterprises and non-profit organisations (Huang et al., 2004). The government aims to provide an appropriate institutional environment to coordinate innovation actors such as markets, companies, industries and research institutes etc. This strand of policies significantly promotes the autonomy of research institutions and the mobility of creative talent, enabling S&T activities to be increasingly efficient and motivating local actors to create market value.

Third, over the last few decades, Chinese technological upgrading has significantly accelerated (Fu, 2008, Ning, 2009). Because the technological gap between China and advanced western countries has reduced, it is increasingly difficult to introduce foreign technological assistance to support sustainable regional development. This is because less advanced countries hope to disseminate their core science and technology to China (Hu, 2002). Meanwhile, indiscriminative FDI expansions are also against maintaining a stable and competitive business environment in the Chinese cities. Hence, the Chinese leadership has realised that it is more imperative to build up indigenous technological capabilities and reduce its dependency on foreign technology assistance in strategic areas. They also encouraged more foreign technology imports to promoted native industrial standardization system, or update domestic firms’ management modes. Since 2000, the Chinese government has gradually imposed regulations to constrain both the scope and scale of FDI expansions in Chinese cities, and motivate domestic firms and research institutions to become the main innovators in terms of S&T

activities. Chinese cities thereby have started to change the role of conventional foreign technological import frontlines to domestic radical innovation incubators. Companies have been given more autonomous rights to implement S&T, in order to trigger technological breakthroughs. Under such circumstances, the speed of FDI expansion process has significantly slowed down. Over the period 2005-2011, the average growth rate of MNEs' number had decreased in Chinese cities. In 2005, the average growth rate reached 23.91%, while it hit -16.33% in 2011. More specifically, in 2011, only ten cities achieved a 25% growth rate in the number of MNEs in the local areas, while there was a decline in the number of MNEs in 94 cities. In some cities, such as Fuzhou, the number of MNEs decreased by over 40%. The FDI expansion slowdown has reduced China's reliance on technology assistance from overseas, and stimulated core R&D activities.

Fourth, since China joined the WTO in 2001, it has been necessary for Chinese industrial companies and manufacturers to integrate themselves into global supplier chains. Nevertheless, due to the lower level of Chinese industrial structures, these firms are often at the low-end of value chains, creating limited market value (Guo et al., 2013, Gao and Liu, 2012). China, as a country with large-scale manufacturing industries, has accelerated its industrial restructuring, and transformed its conventional labour- and resource-intensive industrial structure into a high capital- and knowledge-intensive one. The proportion of high-tech manufacturing and service sectors is continuously increasing, while the proportion of low-end primary industries is decreasing. Therefore, during this time, Chinese technological upgrading and industrial structure adjustments have been closely intertwined. China has issued plenty of key documents, such as the "Decisions on the Acceleration of Technological Innovation and High-tech Industrialization", "Made in China 2025" and

"Development Planning of National Strategic Emerging Industries". China has also explicitly declared its targets in regard to such industrial strategies. For example, the added-value of strategic emerging industries should occupy over 8% of the total GDP by 2020. Such industrial structure adjustments will help to promote the importance of S&T developments in the manufacturing industries, and further make the cities innovation highlands. Thanks to the development of high-tech industries, technology transfers and diffusions from universities to companies have been facilitated, thereby enabling the diversification of technological sources for in-house R&D in complementarities and commonalities (Hong, 2008, Hong and Su, 2013).

2.5. Concluding Remarks

To summarise, this chapter has systematically introduced and analysed the development path of Chinese technological upgrading in the cities over four specific periods, namely **1949-1957, 1958-1977, 1978-2000, and 2001-Now**. The analysis of each period has emphatically elaborated the key policies and regulations in regard to urban S&T development, and provided the historical background to enable an understanding of the technological mechanism changes in Chinese cities. Moreover, statistical data and examples have been given to illustrate the remarkable urban technological achievements, thus intuitively reflecting on the impacts of such policies and regulations on Chinese technological upgrading reforms. The findings of this chapter indicate that China has increasingly prioritised S&T development, especially since the "Reform and Opening-up Policy", and made great efforts to build up technological capabilities in the cities. The cities, as the frontlines of technological innovation, have gathered superior financial and intellectual resources to implement S&T activities, and accelerated commercialisation has satisfied the market demands from potential customers. More importantly, the cities are not isolated from each other, so it is necessary to investigate urban technological upgrading mechanisms from a spatial view. In order words, China has decided to continuously optimise the institutional constructions both within and across cities, enabling the setting up of “regional innovation systems” within a larger geographic area. Therefore, inter-regional technology transfers and disseminations have become a key source to facilitate technological upgrading in Chinese cities.

This chapter has analysed technological upgrading in Chinese cities in regard to foreign presence, the FDI expansion process, and industrial structures. Constrained by relatively weak internal knowledge stocks, China has proactively sought technological assistance and imports from overseas, and accelerated the “catch-up” process. With the establishment of “Special Economic Zones” in the coastal cities in 1980, a large number of MNEs rapidly entered China, and set up subsidiaries to expand their business in China. FDI, as a key external technological source, can facilitate the dissemination of advanced technology and managerial patterns to local actors, thus building up Chinese indigenous innovative capabilities (Fu and Gong, 2011, Fu et al., 2011). Because the cities have been the main FDI recipients, they have been at the frontline of the interactions between MNEs and domestic companies. Thanks to several FDI spillover channels, such as labour mobility, demonstration effects forward and backward linkages, China has rapidly promoted its urban technological upgrading, and avoided less risky and costly in-house S&T activities. Nevertheless, in order to reduce its reliance on foreign technology, China has issued regulatory constraints in some regions, such as Beijing-Tianjin-Hebei, during recent years, and protected its indigenous innovative activities. In such state-led regional clusters, both the scope and scale of FDI activities have been restricted in the cities, and therefore FDI technological spillovers are not evident.

China has also accelerated its industrial restructuring during the same period, which has been closely intertwined with the technological upgrading in cities. The findings indicate that China prioritised the national defence and heavy industries at the beginning of its urban industrialisation process. Before the late 1970s, the industrial structures in Chinese cities were relatively scattered and specialised, and technologically related interindustry linkages were limited. This type of industrial structure neither integrated different sectors in terms of complementarities, nor created high market value to satisfy civilian demands. Since the 1980s, the Chinese leadership has begun to facilitate industrial structure adjustments, and attach importance to interindustry collaborations and coordination. For example, the proportion of high-tech manufacturing and tertiary industries (e.g. Electronic and Telecommunications Equipment) has rapidly increased. Some large cities, such as Beijing and Shanghai, exhibit a high degree of industrial diversity and technologically related industrial structures.

Chapter 3 Literature Review

The core research purpose of this PhD thesis is to identify the externalities of foreign expansion time-based features and industrial structures in FDI spillovers, and find out how they affect technological upgrading both within and across Chinese cities. Previously, plenty of research has shown that FDI spillovers do not happen automatically, but are contingent upon a set of factors such as the host region's absorptive capability, industrial structures and degree of openness (Crespo and Fontoura, 2007, Ning et al., 2016). Cities are the main recipients of FDI activities, so they are also the loci of technological spillovers between foreign and local firms (Ning et al., 2016).

The rationale of literature review setting is as following. First, it introduces the knowledge spillover argument on city level, which is the heart of technological transfers and disseminations between foreign and local firms. Second, the section reviews current empirical findings of the relationship between inward FDI and host city technological upgrading, and discussed determinant factors in FDI spillovers. It also highlighted intercity FDI externalities from a spatial perspective. Third, in the next two sections, I emphatically discussed two determinants in FDI spillovers, namely foreign expansion time-based characteristics and industrial structures, which are normally neglected by most studies. This helps to build up the general theoretical grounding in this PhD thesis. Finally, in order to explore place-specific impacts on technological upgrading, I link cluster theory to FDI spillovers by considering both government and market orientations at an aggregated city level. Overall, this chapter aims to systematically review both theoretical and empirical findings regarding the role of inward FDI, the foreign expansion process and industrial structures in urban technological upgrading from previous studies, and provide a solid theoretical framework for the empirical analysis in Chapters 5, 6, and 7.

3.1. Knowledge Spillovers and Technological Upgrading in Cities

3.1.1. Rationales of Knowledge Spillovers in Cities

It has long been recognised that technological upgrading does not happen in isolation, but is largely contingent upon access to external knowledge sources (Enkel et al., 2009, Chesbrough, 2013, Tappeiner et al., 2008). As well as in-house R&D activities, technological upgrading also originates from the integration of external existing knowledge pieces or domains. Therefore, knowledge spillover effects (thereafter knowledge spillovers), also known as externalities, have long been regarded as a key factor in facilitating technological upgrading and innovation on a regional level (Tappeiner et al., 2008, Audretsch and Feldman, 1996). To be specific, knowledge spillovers are direct or indirect knowledge transfers and diffusions from one organisation to others through interactions (Ning et al., 2016, Gilbert et al., 2008). Namely, knowledge spillovers take place when newly created knowledge from an organisation or firm is not fully appropriated within strict organisational boundaries but disseminated to others. In more recent research, some scholars have shifted their focus on knowledge spillovers from the firm-level to the regional level from a systematic perspective (Cooke et al., 1997, Lundvall, 2010). Compared with individual firms, regions exhibit a more complex mechanism in regard to knowledge transfers and disseminations, enabling the establishment of a localised network of interlinked actors and institutions in regard to technological upgrading (Li, 2009, Iammarino, 2005). Therein, cities, as a specific regional level, are geographic concentrations of interlinked economic and organisational entities (e.g. institutions, companies, and industries etc.) in an area, leading to more frequent and effective knowledge spillovers.

Knowledge-based economies often emerge with intensive R&D interactions and communications, as communities are the driving force of technological upgrading (David and Foray, 2002). This is because knowledge spillovers do not take place instantly and automatically, but are greatly contingent upon the extent of both direct and indirect interactions with different external technological sources. Different from codified information, tacit and contextual knowledge transfers and disseminations often take place through unintended, direct and repeated interactions (Audretsch, 2003, Simmie, 2003), further contributing to knowledge sharing and learning across actors involved in city level technological upgrading.

Due to the tacit and contextual nature of ideas sharing and technological dissemination, knowledge spillovers are considered to be geographically bounded, and decay with increased spatial distance (Ning et al., 2016, Audretsch, 2003). This is because the interpretation and assimilation of tacit knowledge still require geographic proximity, as firms demonstrate better innovation performance when they are close to knowledge sources (Howells, 2002, Jaffe et al., 1993, Audretsch and Feldman, 1996). Face-to-face contact and interactions help to accelerate technology transfers and dissemination (Breschi and Lissoni, 2001). This impetus stimulates industries and firms to co-locate in cities to benefit from knowledge spillovers (Ó Huallacháin and Lee, 2011, Li, 2009).

Prior research has provided empirical evidence that knowledge spillovers are geographically bounded, and that some are concentrated in urban areas. For example, based on data from 86 European regions, Bottazzi and Peri (2003) found that localised knowledge spillovers only exist within a distance of 300 km, and that even doubling R&D still cannot significantly increase technological innovation. Similarly, using a dataset from 175 European regions over 1978-2001, Moreno et al. (2005a) also demonstrated that knowledge spillovers are confined by national boundaries within 250 km, and that technological activities are strictly geographically bounded within a small region. Based on data from European regions, Maurseth and Verspagen (2002) indicated that knowledge spillovers are intensive between regions in the same country, and make patents more often be in citations. Compared to individual firms or industries, cities are a localised and complex network of various interlinked firms, organisations, and institutions in terms of technological upgrading, enabling knowledge transfers and dissemination to take place both within and across their boundaries (Shearmur, 2012). Distinctive place-specific resources and factors exert an impact on both the scale and scope of regional knowledge spillovers (Porter, 2000, Iammarino, 2005). Previous literature has identified several determinant factors in regard to city level mechanisms, which either enhance or diminish knowledge spillovers. For example, Breschi and Lissoni (2001) argued that face-to-face contact and labour mobility are two critical factors in regional knowledge transmissions. This is because knowledge is regarded as local public goods, and retained in co-located economic actors. Based on data from the Values Study in European regions, Hauser et al. (2007) found that local social capital is a key tacit technological sharing channel, but that not all of the dimensions have the same influence in terms of knowledge spillovers. Therein, the dimension of 'Associational Activity' is the most effective in regard to technological innovation.

3.1.2. Intra- and Intercity Externalities

Cities, as the major loci of industrial agglomerations, have long been recognised as the frontlines of technological innovation and upgrading (Ning et al., 2016). Plenty of intellectual resources (e.g. creative talents, universities and research institutions) are concentrated in cities, and have become the key engine of technological breakthroughs (Acs, 2002, Florida, 2002). Cities also agglomerate industries and firms in spatial proximity, thereby enabling the facilitation of technology transfers and dissemination. In this case, cities and technological upgrading are closely intertwined, and has also shown that innovation outputs are more numerous in cities than in non-urban areas such as villages. For example, based on a dataset from the USA for the period 1980-2001, Bettencourt et al. (2007) demonstrated that larger metropolitan areas produce more patents than smaller ones. Similarly, Duranton and Puga (2001) argued that technological outputs such as new products are more likely to be developed in diversified cities, as they provide a variety of local knowledge sources.

In line with regional technological upgrading mechanisms, cities are diversified localised networks consisting of various interlinked actors and institutions, enabling the facilitation of technology transfers and dissemination. Duranton and Puga (2004) distinguished three main micro-foundations of urban agglomeration economies: sharing, matching, and learning, which explain the rationales of knowledge sharing and technological learning. This research explores several important mechanisms of knowledge spillovers within cities. First, cities, especially large ones, provide firms and industries with geographic proximity and co-locate enterprises into diversified business. This facilitates interactions across firms and industries in terms of supplier sharing, common labour pools, and technological learning (Combes et al., 2012, Storper and Venables, 2004). Based on a division of labour, productive and technological connections are closely matched across different firms in cities, enlarging both the scale and scope of the interactions within and between industries (Duranton and Puga, 2004). Second, cities present sharing frameworks e.g. infrastructure facilities indivisible public goods, and marketplaces, enabling the distribution of fixed costs among actors, and lower transaction costs during interactive activities (Duranton and Puga, 2004). Hence, larger and denser cities facilitate more efficient knowledge spillovers across actors, as they reap the benefits of cost advantages, further helping companies to accelerate their technological upgrading and market commercialisation in cities (Ciccone and Hall, 1996, Helsley and Strange, 2004). Third, larger markets in mega-cities often attract creative workers and productive firms, leading to tough competition in local areas. These competition effects can be felt by innovation actors in cities, thus forcing them to build up indigneous technological capabilities. Cities also foster opportunities in terms of matching different companies, industries, and other organisations (e.g. universities, research institutions and R&D laboratories), greatly facilitating knowledge exchanges and diffusion for technological upgrading (Audretsch and Feldman, 1996, Rosenthal and Strange, 2004).

However, studies on insular cities that state that regional technological upgrading is entirely based upon their own resources might be problematic, as a strand of the research has pointed out that cities are not isolated from each other (Shearmur, 2012). Thanks to inter-regional “pipelines” such as social networking systems, labour mobility, forward and backward linkages etc., cities are interlinked within the whole domestic economy, and urban technological upgrading is dependent on both in-house R&D activities and external sources from adjacent cities. Therefore, knowledge spillovers might not be strictly bounded within an insular city, but transferred and disseminated to neighbouring areas (Simmie, 2003). Moreover, labour divisions and industrial specialisations also interlink a set of cities in spatial proximity in terms of both complementarities and commonalities (Ning, 1991). This not only minimises transaction costs and intensifies knowledge sharing and ideas exchanges across specialists, but also helps knowledge spillovers spread from a city to neighbouring areas, accompanied by inter-regional interactions (Ellison et al., 2010). Hence, urban technological sources are not confined within an isolated city, but come from localised knowledge stocks both within and between cities (Usai, 2011). Nevertheless, as indicated above, the tacit and contextual nature of technological sharing constrains both the geographic scale and scope of intercity knowledge spillovers. The intensity of knowledge spillovers decays with longer spatial distance as the strength of the interactions attenuates.

3.2. FDI Spillovers and Technological Upgrading in Host Cities

3.2.1. FDI Spillovers and City Level Technological Diffusion Channels

Technological upgrading has long been regarded as a key driver of regional economic growth and social development, but also a long-term, costly, and risky process. Most technological innovation activities have thus been largely concentrated in a limited number of advanced countries (Fu and Gong, 2011). It is widely recognised that technological upgrading does not take place in isolation, but is dependent on the accessibility of both internal and external sources (Enkel et al., 2009, Chesbrough, 2013). In most developing economies, it seems that their internal knowledge stocks are too weak to embark on indigenous R&D activities and technological advancements (Athreye and Cantwell, 2007, Fu, 2008, Xu and Sheng, 2012). To build up city level technological capabilities in these countries, it is necessary for local firms to explore and exploit external sources of new knowledge.

Inward FDI (thereafter FDI) has been long recognised as a key external source of newly created and advanced knowledge, allowing international technology transfers to take place from developed countries to host regions. Thanks to advanced technological knowledge embedded FDI activities, plenty of local firms in emerging economies proactively interact with foreign investors to benefit from ideas exchanges and knowledge dissemination (Crespo and Fontoura, 2007, Fu et al., 2011, Fu and Gong, 2011). Hence, emerging economies such as China have rapidly built up their indigenous technological capabilities through learning from MNEs, which has allowed them to catch up with other developed countries through a "springboard effect" (Ning, 2009, Crespo and Fontoura, 2007, Fu et al., 2011). Cities are the main recipients of FDI activities, and they are ideal research settings to understand FDI spillovers in terms of host region technological upgrading (Ning et al., 2016).

In line with the knowledge spillover rationales indicated above, FDI spillovers are also geographically bounded when local firms co-locate and closely interact with MNEs within a specific region. Prior literature has shown that FDI spillovers contribute to local technological upgrading through several knowledge spillover channels (Crespo and Fontoura, 2007, Meyer, 2004, Görg and Greenaway, 2004). These channels mainly derive from interactions between domestic firms and MNEs, and I argue that FDI spillovers can take place through five main channels on the city level, as follows: imitation and demonstration effects, worker mobility, competition, exports, forward and backward linkages.

Demonstration and imitation effects are one of the most evident FDI spillover channels, stemming from direct interactions between MNEs and domestic firms operating at different technological levels (Meyer, 2004). With foreign expansion in cities, foreign investors often exploit and demonstrate advanced technology in their subsidiaries. In contrast to costly and risky in-house R&D activities, imitation is a more direct way for domestic firms to "steal" novel knowledge, and helps them to catch up with their foreign counterparts in cutting-edge technological fields (Crespo and Fontoura, 2007). Due to the high intensity of foreign presence on the city level, indigenous innovation actors such as firms and research institutions have more opportunities to interact with MNEs, and proactively recognise and exploit technology and managerial experience that have been used successfully in previous production. In other words, MNEs can directly transfer and disseminate information and ideas regarding technological innovation to domestic companies in host region cities, allowing them to reduce the uncertainty and complexity of new technology exploitation. Barrios and Strobl (2002) have argued that both product and process similarity could enhance demonstration and imitation effects. As well as technologies, other types of knowledge (e.g. marketing strategy and management patterns) can also be transferred and diffused between domestic firms and MNEs via this FDI spillover channel. Cities often foster more interaction opportunities in various industries, leading to a larger scope and scale of FDI technological spillovers (Ning et al., 2016). Nevertheless, demonstration and imitation effects between MNEs and domestic firms are not always free riding. Glass and Saggi (2002) have demonstrated that intellectual property rights (IPR) protections that is too strong diminishes FDI spillovers through such a channel. Local firms suffer from higher imitation costs and cannot efficiently assimilate and exploit knowledge from MNEs.

The second FDI spillover channel is labour (or worker) mobility between foreign and local firms in cities. Human resources such as intelligence and relationships have long been regarded as a key resource for firms to implement value-creating strategies (Barney, 1991). Namely, creative and skilled talent, especially talent that has strong mobility across industries and companies, is an important knowledge carrier for technological upgrading (Breschi and Lissoni, 2001). In order to maintain their international competitive advantage, MNEs usually make great efforts in terms of staff education and training (Fosfuri et al., 2001). Torre (2008) identified that skilled workers are much more mobile in cities, whatever their geographic size. Namely, if indigenous firms recruit workers who have previously worked for an MNE, information and ideas exchange will take place. These well-trained and skilled workers disseminate all or part of their competitive advantages (e.g. advanced technology, managerial experience, marketing strategies etc.) to host region cities when they join local firms (Poole, 2013, Hale and Long, 2006). Nevertheless, worker mobility is not an automatic process, and the empirical evidence regarding worker mobility effects in FDI spillovers still remains mixed and inconclusive (Saggi, 2002). For example, a possible negative impact emerges when MNEs offer higher wages to skilled workers to prevent human intelligence outflows; they may even attract the best workers from local firms to join their businesses (Sinani and Meyer, 2004). This situation is even more serious if cities are underdeveloped, as local firms cannot compete with foreign investors in terms of productivity efficiency and managerial experience.

Competition induced by MNEs is the third FDI spillover channel in cities. MNEs, especially from developed countries, are usually equipped with more newly created and advanced knowledge, which is often novel to local innovators (Wang and Blomström, 1992, Markusen and Venables, 1999). FDI expansion by MNEs can break down urban monopolies and stimulate competition with domestic firms. In order to compete with these foreign investors, local firms are forced to promote their own production efficiency and managerial efforts (Wei and Liu, 2006, Liu et al., 2009b). Intensified competition effects due to foreign presence also accelerate new technology and management pattern adoption, and result in the "crowding out" of the least efficient local firms (Fu et al., 2011). However, this FDI spillover channel also exhibits a negative impact in cities, as fierce competition results in a loss of market power for domestic firms. Moreover, due to the competition caused by foreign investors, host region firms are likely to struggle to operate their business with increased costs (Aitken and Harrison, 1999, Harrison, 1994, Crespo and Fontoura, 2007).

Exports are the fourth channel of FDI spillover in terms of benefitting domestic firms in cities. FDI expansions contribute to the export capabilities of domestic firms in host countries (Aitken et al., 1997, Kokko et al., 2001). Exporting firms are more productive than non-exporting ones. This is because export-oriented firms are often confronted with more challenges overseas than in their local markets, as host region customers' tastes and markets are quite different from those in their home country. If a positive relationship between foreign presence and local firms' exporting performance is identified, indirect FDI spillovers therefore emerge in cities. Based on manufacturing firm-level data from the UK, Kneller and Pisu (2007) showed that FDI spillovers through exports are diverse and affect exporters and non-exporters in different ways. This is because exporting is an uncertain and complex process involving issues such as overseas trade experience, social networks and infrastructure facilities (Greenaway et al., 2004). Export-oriented MNEs are often more innovative, productive and efficient in overseas markets (Greenaway and Kneller, 2004). Therefore, with increasing FDI activities in cities, it is helpful for domestic firms to recognise and assimilate international trade experience from foreign investors, with the aim of building up their own export capabilities. By means of imitation or R&D collaboration, domestic firms can imitate experience and managerial patterns that have been successfully exploited by MNEs, allowing them to reduce their entry costs into foreign markets (Crespo and Fontoura, 2007).

Forward and backward linkages are one pecuniary FDI spillover channel, focusing on interindustry knowledge spillovers between domestic firms and MNEs in cities (Meyer, 2004, Ning et al., 2016). MNEs must set up robust relationships with local customers, suppliers and distributors, and also need to become embedded in the host region's supplier chains. Foreign presence can therefore benefit domestic firms in both upstream and downstream sectors through productivity and technological diffusion (Girma and Gong, 2008, Liu et al., 2009a). Ning et al. (2016) have argued that cities matter in FDI spillovers as indigneous firms benefit from FDI spillovers that are enhanced by urban industrial agglomerations.

To be specific, foreign investors, as the customers, establish close relationships with domestic suppliers to purchase goods and services (backward linkages) in order to support their own manufacturing process (Javorcik, 2004b). Due to the increasing demand for high-quality supplies, MNEs may provide technical support (e.g. staff training) to domestic suppliers in downstream industries, so technology transfers occur during these interaction activities (Lall, 1980). Focusing on forward linkages, domestic firms as the receivers of high-quality products and services from MNEs also benefit from FDI spillovers. If MNEs adopt new technologies and more efficient processes in their own production, local customers can directly receive high-quality inputs (Miozzo and Grimshaw, 2008, Markusen and Venables, 1999). Thanks to such interindustry linkages between domestic and foreign firms, R&D interactions and collaboration are enhanced, leading to effective knowledge flows in cities (Glaeser et al., 1992).

3.2.2. Determinant Factors in City Level FDI Spillovers

It has long been accepted that FDI spillovers are not an automatic process but are contingent upon a set of determinant factors in terms of host regional effects, MNEs' characteristics and domestic firms' features (Crespo and Fontoura, 2007). This section aims to summarise several determinant factors, identified from the prior literature, that can affect city level FDI spillovers. These determinant factors can either be fundamental pre-conditions or exhibit a moderating effect on the existence or the extent of FDI spillovers in host countries.

Host Region Characteristics: Owing to the tacit and contextual nature of knowledge spillovers, previous literature as argued that knowledge spillovers are geographically bounded, and decay with increased spatial distance as interactions reduce (Ning et al., 2016, Audretsch, 2003). This is because new knowledge is created and transferred more efficiently in spatial proximity, and knowledge-intensive activities prefer to agglomerate within a geographic region (Audretsch and Feldman, 1996, Audretsch, 1998). Cities, as spatially-bounded entities, also agglomerate both local and foreign firms within a small region, therefore facilitating ideas exchange and knowledge flows (Torre, 2008, Helsley and Strange, 2004). Hence, FDI spillovers in cities possess a circumscribed geographical dimension in regard to facilitating technological upgrading. Abdel-Rahman and Anas (2004) have also argued that urban interindustry linkages are geographically confined, as high costs impede inter-regional transactions. Cities can exhibit several localised advantages e.g. the sharing of social networks, and infrastructure and institutions facilitating interactions across different industries within a specific region (Boschma, 2005). Based on the rationales of agglomeration economies, knowledge related labour market pooling and local inputs cannot spread to other regions in larger geographical distance. Firms in spatial proximity foster opportunities for information and technology transfers, creating local pools of new knowledge and ideas (Jordaan, 2005).

Previously, there has been plenty of research focusing on urban dimensions of FDI spillovers, and exploring specific determinant influences. Therein, some of this research has investigated the contingency of FDI spillovers based on sub-regional (e.g. county- or provincial level) datasets, which also helps us to understand how urban characteristics affect FDI spillovers. For example, using a county level dataset from Portugal, Crespo et al. (2009) confirmed that geographical proximity exhibits a significant impact on both horizontal and vertical FDI spillovers. Small spatial distances have a negative effect on horizontal externalities, while they have a positive impact on vertical international technology transfers in cities. Focusing on empirical evidence in developing economies such as China, some literature has also explored regional effects in FDI spillovers. Using Chinese provincial data from 1995 to 2000, Cheung and Ping (2004) found that FDI spillovers are stronger for minor innovations in the form of external design patents. Constrained by geographic interactions, the empirical results highlight the ‘‘demonstration effect’’ in FDI spillovers. Based on an urban level dataset in China, Ning et al. (2016) have shown that interindustry linkages across different sectors are geographically confined, because increasing intercity transaction costs impede trade across cities.

FDI Characteristics: The existence and magnitude of city level FDI spillovers depends not only on host regional effects, but also on FDI characteristics. One topic that has generated heated debate is whether FDI from different countries generates the same spillover effects on domestic firms. Prior literature has argued that FDI spillovers are dependent upon a set of factors such as technology level, institutional systems, and information transfer modes (Crespo and Fontoura, 2007). Cities are considered the main recipients of FDI activities, so foreign investment internal characteristic impacts are more evident in FDI spillovers in cities than in non-urban areas. For example, some countries such as Japan place more emphasis on a less capital-intensive domestic base because of their culture and institutional structure, while other countries (e.g. the US) prefer to develop capital-intensive and technologically sophisticated sectors (Banga, 2001). Cities that receive technology-intensive foreign investments are more likely to gain benefits from knowledge spillovers.

Ownership advantages also play a crucial role in FDI spillovers, because MNEs from different regions might possess different technology levels. More specifically, small HMT (Hong Kong, Macau and Taiwan) firms do not own strategic assets, while foreign investors from advanced countries such as the US and EU exhibit technological advantages (Buckley et al., 2007a, Kay, 1993). FDI from the latter group are more likely to accelerate larger and denser technology transfers and dissemination in cities. Moreover, rather than a static approach in host regions, prior studies also point out that FDI activities are a dynamic and path-dependent process (Wang et al., 2012a, Vermeulen and Barkema, 2002). The strength of FDI spillover channels is not only dependent on the level of foreign presence, but is also moderated by the process of MNEs' building up subsidiaries over time (Wang et al., 2012a). Namely, cities are likely to encounter time compression diseconomies if FDI expansions are too rapid or irregular. This is because foreign entry within a compressed period of time often constrains international technology transfers from MNEs.

The consideration of various FDI characteristics has led to mixed and inconclusive empirical results regarding FDI spillovers. Nevertheless, specific urban empirical analysis is relatively scarce, as most of the prior literature has focused on firm- or industrial-level research in host regions. This therefore indirectly reflects foreign investment characteristic impacts on FDI spillovers. For instance, using US-based firm-level data from the pharmaceutical industry, Kotabe et al. (2007) demonstrated that international knowledge transfers at the low-moderate technological level are more likely to benefit domestic firms' innovation performance. By contrast, high-level international knowledge content diminishes the benefits from such knowledge spillovers in cities. Based on a data sample from both the US and Japan, Banga (2001) showed that the presence of Japanese equity exhibits positive spillovers, but an increase in the Japanese market share diminishes the productivity growth of Indian firms. The US's FDI exhibits no significant impacts. Using industry-level data from China, Buckley et al. (2007a) demonstrated that there is a curvilinear relationship between productivity spillovers and FDI from HMT, while such empirical results do not exist in FDI spillovers from other western countries. Similarly, using a dataset from large and medium sized

Chinese firms, Hu and Jefferson (2002) found that the FDI concentrations of OECD countries exhibit a more negative competitive impact on Chinese indigenous firms than that from HMT. From a process-dependence perspective, Wang et al. (2017) have argued that the pace and rhythm of foreign expansions significantly moderate FDI spillovers in Chinse cities. Because of time compression diseconomies, a foreign expansion process that is too irregular will greatly impede technology transfers and dissemination to domestic firms, constraining their productivity.

Domestic Firm Characteristics: There is another strand of the literature that focuses on the influence of domestic firms' characteristics in FDI spillovers. Cities are geographic concentrations of a set of interlinked organisational and economic entities (e.g. firms and institutions) within a particular region in terms of both commonalities and complementarities. More productive firms and workers prefer to agglomerate in larger and denser cities, thereby enlarging both the scale and scope of their interactions to facilitate knowledge flows and ideas exchanges (Combes et al., 2012, Rosenthal and Strange, 2004, Melo et al., 2009). Hence, local companies' characteristic impacts in inter-firm knowledge spillovers also affect overall FDI spillovers in cities. Therein, absorptive capacity is a key ability that domestic firms need in order to recognise, assimilate and exploit advanced technology from MNEs. The intensity of FDI spillovers is therefore greatly contingent upon domestic firms' absorptive capacity (Imbriani et al., 2014, Ferragina and Mazzotta, 2014, Zhang et al., 2010). Greater human resource capital and R&D activities boost domestic firms' absorptive capacity, allowing them to reap the benefits of FDI spillovers (Romijn and Albaladejo, 2002, Sánchez-Sellero et al., 2014).

Moreover, domestic firms' export capacity is another determinant factor in FDI spillovers, as export-oriented host region firms faced with competitive pressure in overseas markets are more internationally experienced than non-exporting ones (Blomström and Sjöholm, 1999). Technology transfers and disseminations of FDI are more evident to non-exporting firms in cities. By contrast, export-oriented domestic firms can also exhibit competition towards MNEs in local markets, helping to minimise the negative impact of FDI spillovers through the competition channel (Barrios and Strobl, 2002, Schoors and Van Der Tol, 2002). Other firm characteristics, such as firm size and ownership structures (e.g. state-owned or private), should also be taken into consideration when exploring the existence and magnitude of FDI spillovers in host countries. More specifically, larger firms are more capable of recognising, absorbing and learning advanced technology and managerial patterns from MNEs than small firms in host countries. Large domestic companies can also spread costs and benefit from economies of scale (Bronzini, 2007, Aitken and Harrison, 1999). Focusing on the ownership structures of domestic firms, private and state-owned enterprises may benefit from FDI spillovers in other ways apart from competition and demonstration effects (Li et al., 2001, Sinani and Meyer, 2004). These firm characteristics either enhance or diminish city level FDI spillovers within host countries.

Previous literature has explored the influence of domestic firms' characteristics in FDI spillovers on the basis of evidence from both developed and developing countries. Blomström and Sjöholm (1999) found that FDI spillovers are restricted to non-exporting domestic firms in host regions, as they are faced with overseas competitive pressure and are less sensitive to MNEs' competition effects. Similarly, based on panel data from Russia, Ponomareva (2000) demonstrated that FDI spillovers to domestic firms in export-oriented sectors are more evident than in non-exporting sectors. While investigating ownership structure impacts, using a dataset from 29 manufacturing industries in Shenzhen, China, Liu (2002) showed that FDI spillovers greatly contribute to both the growth rate and level of productivity, and that state and joint-owned sectors are more responsive to such benefits than other sectors. Also using a dataset from the Chinese industrial census in 1995, Li et al. (2001) differentiated FDI spillovers in domestic firms with different ownership types. Therein, collective- and private enterprises benefit from FDI spillovers through demonstration effects, while state-owned enterprises enhance their productivity by means of FDI competition.

3.2.3. FDI Intercity Externalities

Previous literature has explored FDI spillovers from various angles in terms of research methods (panel versus cross-sectional), research levels (firm, regional and industrial levels), and research objectives (developed versus developing countries) (Sinani and Meyer, 2004, Fu, 2008, Görg and Greenaway, 2004, Crespo and Fontoura, 2007, Meyer, 2004). As well as the aforementioned FDI spillover channels and determinant factors stated above, a key issue that is often neglected by studies is whether FDI exerts inter-regional (intercity) externalities. Namely, as yet, little is known about technology transfers and diffusions of FDI across cities, and there is even less empirical evidence from emerging economies. Similar to the rationales regarding regional technology transfers and dissemination, FDI technological spillovers can spread from the FDI recipient metropolis to adjacent cities through inter-regional interactions. Based on the intercity externalities indicated above, a set of cities in spatial proximity are interlinked through several “pipelines” such as labour mobility, supplier chains and transport systems, and form a localised innovation network (Simmie, 2003, Ning et al., 2016). Foreign investors that are integrated to these intercity linkages are able to transfer and disseminate new and advanced technology to domestic firms across cities, thereby enabling the building up of indigenous technological capabilities within a larger geographic region. Nevertheless, FDI spillovers are also geographically confined, as the intensity of the interactions between MNEs and local firms decays with increased spatial distance. In other words, higher trading costs significantly impede inter-city transactions, and local advantages e.g. sharing institutions and social networks facilitate localised transactions within cities rather than across them (Abdel-Rahman and Anas, 2004). In the same vein, MNEs also prioritise collaborations and alliances with local domestic firms, and FDI spillovers to remote regions are constrained by the increased transaction costs.

Previously, little research has explored the intercity externalities of FDI, and the empirical evidence is mixed. In terms of early studies, Aitken and Harrison (1999) investigated the existence of inter-regional FDI spillovers in the case of Venezuela, and argued that FDI spillovers are locally bounded. Similarly, using a firm-level panel dataset regarding UK manufacturing industries, Girma and Wakelin (2002) demonstrated that domestic firms benefit from technology transfers and dissemination both in the same region and sector, but that such positive FDI spillovers fade away across regions. Based on different models and a panel dataset on Hungarian firms, Halpern and Muraközy (2007) showed that although regional boundaries are not significant in international technological transfers, FDI horizontal spillovers still decrease with spatial distance. Using the Chinese firm-level census dataset from 2000 to 2003, Hamida (2013) found that FDI exhibits inter-regional externalities, as knowledge spillovers through forward linkages could spread from FDI recipient provinces to other regions. Wang et al. (2017) also demonstrated that FDI spillovers can spread from the FDI receiving city to neighbouring ones, and greatly promote city level technological upgrading.

3.2.4. FDI spillovers and Technological Upgrading in Host Cities

Plenty of the previous literature has investigated the mechanisms whereby cities in host countries can benefit from inward FDI based on evidence from both developed and developing countries (Hamida, 2013, Ferragina and Mazzotta, 2014, Liu and Zou, 2008, Tian, 2007). Over the last three decades, theoretical frameworks regarding the impacts of FDI spillovers have become more completed. Generally, research on the influence of foreign presence on host regions can be classified into several groups including technological innovation and upgrading (Cheung and Ping, 2004, Ning et al., 2016, Kokko et al., 1996, Wang et al., 2014), economic growth (Temiz and Gökmen, 2014, Madariaga and Poncet, 2007, Yao and Wei, 2007), as well as exporting performance (Greenaway et al., 2004, Zhang and Song, 2002). This PhD thesis emphatically discusses FDI spillovers in regard to host region technological upgrading based on both intra- and inter-regional evidence from Chinese cities.

FDI spillovers, as indicated above, take place when indigenous firms geographically co-locate and interact with MNEs in cities. However, the empirical results on FDI spillovers still remain inconclusive and mixed, and whether or not FDI spillovers exhibit a positive influence in terms of urban technological upgrading is still the subject of a heated debate. The majority of the prior literature has argued that inward FDI significantly contributes to technological upgrading in cities, as technology transfers and dissemination through interactions between MNEs and domestic firms are a key external technological source. However, specific city level studies are still scarce, and some firm- or industrial level empirical evidence also indirectly reflects the relationship between inward FDI and technological upgrading in cities. For example, in some highly-urbanised European countries, FDI spillovers often take place in cities, as they are the main recipients of foreign investments. Using a firm-level dataset on the Swiss manufacturing services and construction sectors, Hamida (2013) showed that FDI demonstration-related spillovers emerge in firms with a strong absorptive capacity, enabling them to promote their productivity. Similarly, focusing on eight transition countries, Damijan et al. (2003) demonstrated that inward FDI exerts significant positive impacts on host regions, as direct linkages to MNEs are a key source of domestic firms' productivity growth. Driffield (2006) argued that inward FDI exerts strong knowledge spillovers in UK manufacturing sectors, but FDI spillovers are more localised within a geographical region. Hanel (2000) also found that international knowledge spillovers via FDI have positively affected Canada's TFP, although the effects have been weaker than both local interindustry spillovers and R&D.

Nevertheless, some scholars hold the opposite view, that inward FDI has no effect or even a negative impact on technological upgrading in cities. To be specific, in order to maximise the positive FDI spillover in technological upgrading, it is necessary for domestic firms to be able to fully recognise, assimilate and exploit the advanced technologies from MNEs. Otherwise, they can scarcely benefit from FDI technological spillovers (Fu, 2008, Imbriani et al., 2014, Zhang et al., 2010). Cities foster opportunities in market realisation, and facilitate the sharing of indivisibilities (Helsley and Strange, 2004), so FDI expansions are more likely to present "crowding-out effects" in city level marketplaces. Indigenous companies often face fierce competition from MNEs with more efficient productivity and better innovation performance. FDI competition effects also result in raising intermediate the input and production costs in cities. Because of pressures from MNEs, domestic firms might lose their power and control in local markets (Tian, 2007, Aitken and Harrison, 1999, Martinez-Noya et al., 2013).

This PhD thesis aims to discuss both the intra- and inter-regional externalities of FDI based on evidence from Chinese cities. It is thus necessary to review previous studies in the Chinese context. It can be seen from China's experience over the last three decades that FDI inflows have indeed brought plenty of advanced technology and promoted local economic development (Ning, 2009, Tian, 2007). In the late 1970s, China proposed "The Reform and Opening-up Policy", which marked the beginning of a new era for foreign capital utilisation. Subsequently, China has proactively pursued a set of policies to encourage FDI inflows, in the hope of facilitating imitation and learning from foreign investors and building up its indigenous technological capabilities. FDI, especially from advanced economies, usually brings advanced technologies and managerial patterns in host regions, fostering opportunities for domestic firms to accelerate their own R&D activities (Meyer and Sinani, 2009). Therefore, one of the primary goals of Chinese FDI policies is to facilitate international technology transfers and dissemination.

Plenty of scholars have focused on FDI spillovers in technological upgrading based on the Chinese context. For example, using a panel dataset from 1980 to 2005, Hong and Sun (2011) demonstrated that there are significantly positive effects of inward FDI on TFP both within and across Chinese provinces. Similarly, the studies of Wang et al. (2014) and Ning et al. (2016) have shown that inward FDI contributes to regional patents within both Chinese provinces and cities. As the largest emerging country with weak internal knowledge stocks, China's regional innovation performance is closely correlated with its inward FDI in terms of benefitting from advanced technology transfers. Based on a unique industry-province level dataset, Ito et al. (2012) showed that FDI presents substantial intra-industry spillovers to facilitate invention patent applications through MNEs' R&D activities, and it promotes TFP from production activities in China. Using provincial data from 1995 to 2000, Cheung and Lin (2004) also demonstrated that inward FDI exerts a significantly positive impact on the number of Chinese domestic patents, and highlight in particular the ‘‘demonstration effects’’ of foreign presence. Based on a city level dataset, Wang et al. (2017) have demonstrated that foreign presence contributes to technological upgrading both within and across Chinese cities. However, the opposite empirical results also emerge in the Chinese context, as FDI spillovers may have no, or even a negative, impact on local technological upgrading. For instance, using a Chinese firm-level panel dataset from 2001-2005, Fu and Gong (2011) showed that foreign-invested R&D activities may negatively affect Chinese technological upgrading. Similarly, Hu and Jefferson (2002) also found that inward FDI results in "market-stealing", a significant negative spillover effect on domestic firms' TFP. Using an industry-level dataset from China, Buckley et al. (2007a) determined a curvilinear relationship between productivity and FDI spillovers, and argued that FDI could hinder technological upgrading because of competition effects.

3.3. The Foreign Expansion Process and FDI Spillovers in Host Cities

3.3.1. City Level Foreign Expansion Process over Time

“Time” has long been considered a key issue in international business, as it affects a wide range of both MNEs' and domestic firms’ activities such as FDI location choice, financial performance and technological spillovers (Erramilli, 1991, Chang, 1995, Vermeulen and Barkema, 2002, Wang et al., 2012a, Eden, 2009). MNEs’ international expansion can foster opportunities for interactions between foreign and local companies, and benefit urban technological upgrading and innovation through knowledge transfers and dissemination (Ning et al., 2016). However, international expansions are not always a static and continuous process; they may present great risks, complexity and uncertainty (Malnight, 1996, Malnight, 1995, Hedlund, 1994). Due to the problem of 'foreignness', foreign expansion processes are often carried out within a compressed period, as MNEs need to make great efforts to learn about the new markets, institutions, and culture in the host countries, and establish connections with local customers, suppliers and competitors in the cities (Vermeulen and Barkema, 2002). This is because cities, especially large metropolises, are interdependent entities and are also interlinked through information diffusion channels, to form a larger and more complex system (Simmie, 2003, Bathelt et al., 2004).

Hence, it is necessary for these foreign investors to successfully adapt their operational and managerial patterns from their home countries to the overseas urban marketplaces in the host countries. Even if MNEs hope to rapidly reap substantial benefits from international markets, a sequential, balanced and stable FDI expansion process is still preferable for them to minimise the potential uncertainty and risk. However, in the rapidly changing international business environment of today, it is necessary for MNEs to make quick actions in overseas markets; this is regarded as a key source of time-based competitive advantage (Riolli-Saltzman and Luthans, 2001, Stalk Jr, 1988, Cohen et al., 1996). In order to capture competitive advantage, such as engagement in price skimming, establishing unique markets and access to scarce resources, MNEs have an incentive to adopt a first-mover strategy in their international expansions and rapidly gain returns (Li et al., 2003).

Prior literature has suggested that there are several incentives for MNEs to expand their business in cities at various speeds and in different ways, and the empirical evidence about their impacts is still mixed and inconclusive. For example, using a firm-level data sample from the semiconductor industry, Salomon and Martin (2008) argued that a shorter time-to-build contributes significantly to firms' performance. Similarly, based on a worldwide dataset from both oil and gas facilities over the period 1996-2005, Pacheco-de-Almeida et al. (2008) showed that increasing firms' speed capabilities can accelerate their expansion, leading to positive market value. Larger and denser cities often provide a wider variety of production inputs and resources, and also reduce the transaction costs for firms to achieve market realisation (Ciccone and Hall, 1996, Helsley and Strange, 2004). Hence, MNEs might prefer to accelerate their FDI expansions in such metropolises, to obtain first-mover advantages.

Other scholars hold the opposite viewpoint. Based on a firm-level panel dataset from the Amsterdam Stock Exchange, Vermeulen and Barkema (2002) demonstrated that time compression diseconomies emerge during the setting up of subsidiaries, as neither rapid nor irregular international expansions contribute to MNEs' financial performance. As a matter of fact, these different speeds and patterns of foreign expansion not only influence MNEs' economic and market performance, but also exert a crucial impact on their interactions with domestic firms, resulting in variations in technology transfers to, and exchanges with, host regions (Wang et al., 2012a, Zhang et al., 2013, Vermeulen and Barkema, 2002).

3.3.2. FDI Expansion Process and Technological Spillovers in Host Cities

Prior literature has explored a set of determinant factors in FDI spillovers such as domestic firms' characteristics and urban conditions, but most of the literature has neglected the externalities of the FDI expansion process (Buckley et al., 2007a, Ning et al., 2016, Fu, 2008). Wang et al. (2012a) argued that the extent of FDI spillovers is dependent not only upon the degree of foreign presence, but also on the building up of MNEs' subsidiaries over time. Based on technological diffusion channels of FDI spillovers in cities, domestic firms can benefit from technology transfers and exchanges of FDI to promote their productivity (Crespo and Fontoura, 2007, Hamida and Gugler, 2009). Therein, effective interactions between local and foreign firms are the central element in city level FDI spillovers (Wang et al., 2017).

To be specific, interactions with MNEs help domestic firms to fully recognise and assimilate advanced technology and managerial patterns, but this process is also constrained by the level of absorptive capacity of local firms (Hamida and Gugler, 2009). In this case, stable and continuous international expansions are more appropriate to foster opportunities for interactions with foreign investors, or to make it easier for domestic firms to imitate the successful organisational routines and managerial practices of MNEs. Entry modes (e.g. direct entry versus acquisition) also affect technology transfers of FDI in host regions. Mattoo et al. (2004) argued that the high costs of international technology transfers in developing countries mean that domestic firms attract more direct entry than acquisitions, while indigenous firms in developed countries prefer acquisitions due to their high level of technological capability. In this PhD thesis, I mainly concentrate on the time-based characteristics, namely pace and rhythm, of FDI expansions, in order to investigate both the intra- and inter-regional externalities in FDI spillovers based on evidence from Chinese cities.

3.3.3. Pace and FDI Spillovers in Host Cities

Previous research has argued that the magnitude of FDI spillovers depends not only on the degree of foreign presence in the host country, but also on FDI intrinsic characteristics such as international expansion entry process (Wang et al., 2012a). Therein, the pace of foreign entry is considered a key time-based characteristic in the FDI expansion process; it is a measure of how fast MNEs set up their subsidiaries in host countries at a particular point in time. The current literature mainly focuses on foreign expansion pace at an individual or industrial level (Vermeulen and Barkema, 2002, Wang et al., 2012a, Zhang et al., 2013). On the individual firm level, there are various definitions of pace. For example, some of the literature has used time-to-build to measure how rapidly large firms develop projects; this is defined as the time that elapses from the decision to build a plant to completion of the construction (Brooks, 2000, Pacheco-de-Almeida and Zemsky, 2003). Vermeulen and Barkema (2002) defined the pace of foreign entry as how many foreign expansions, measured by the average number of subsidiaries, an individual MNE undertook per year. The larger the number of MNE subsidiaries, the more rapid the international expansion process. Similarly, Chang and Rhee (2011) also defined the foreign expansion pace as the average number of subsidiaries in new host countries each year since the individual MNE's first international expansion. Moreover, some prior studies have also defined the pace of foreign expansion on an industrial level. For instance, Wang et al. (2012a) defined the pace of foreign entry as the process of building up foreign presence in an industry within a given period, measured by the change in the number of MNEs within a specific industry and province each year.

However, the pace of foreign expansion at the aggregate city level is different from an individual MNEs' expansion process; it refers to the composition of all of the FDI activities in a specific city. In other words, how fast do FDI expansions in host cities not only affect the performance of MNEs, but also exert an impact on interactions with local actors (Wang et al., 2017). This is because time is needed for foreign and local firms to establish mutual trust and to allow FDI technological spillovers to take place (Andersson et al., 2002, Wang et al., 2012a). Local firms also need enough time to fully recognise and assimilate advanced technology from MNEs (Wang et al., 2012a). Hence, there are several reasons to believe that foreign expansion pace can significantly affect FDI spillovers in host cities.

First and foremost, MNEs are more likely to suffer from time compression diseconomies when they adopt a rapid international expansion strategy in overseas markets (Vermeulen and Barkema, 2002). Financial returns from subsidiaries to parent companies are not instantaneous, but emerge over time. Slowing down the foreign expansion process implies larger profitable benefits for foreign investors, as it is easier for MNEs to be familiar with the host markets, and adapt to the complexity in the new business environment within a less compressed period (Vermeulen and Barkema, 2002). The reason for this is that MNEs are often confined to their internal cognitive scope and rationality, so the process of decision-making and implementation take a long time. To expand international markets, MNEs also need to spend sufficient time to overcome the issue of foreignness through competitiveness or ownership strengths (Dunning, 1988, Hymer, 1976). Hence, MNEs should slow down their international expansion pace, with the aim of fully realising the potential benefits of overseas expansions (Chang and Xu, 2008, Vermeulen and Barkema, 2002). Foreign investors who undertake rapid foreign expansion often demonstrate poor financial performance, thereby constraining both the scale and scope of technology transfers and dissemination to domestic firms in the host countries (Wang et al., 2012a, Vermeulen and Barkema, 2002).

Second, local firms are constrained by bounded rationality and absorptive capacity, so it is difficult for them to adopt managerial adjustments and organisational restructuring over a compressed time, in order to respond rapidly to fast foreign entry in local areas (Simon, 1959, Wang et al., 2012a). A higher foreign entry pace may overwhelm the absorptive capacity of domestic firms, thereby impeding their ability to recognise, assimilate and exploit the potential value of MNEs' advanced technology. More specifically, international expansion at a fast pace does not give sufficient time for domestic firms to promote their own productivity or narrow the technological gaps with foreign investors. Because of large technological gaps in relation to foreign investors, the new and advanced technology of MNEs will be too sophisticated and local firms will be unable to imitate it or implement reverse engineering over a compressed time (Wang et al., 2012a). Moreover, if the foreign expansion process is too rapid, the demands for inputs and supplies will dramatically increase, and more efficient and specialised inputs and services will be required across industries. In other words, a higher pace of FDI expansion gives local suppliers and customers limited time to react and adjust to these changes (Lin and Saggi, 2005, Navaretti et al., 2004). Time is also needed for domestic firms and MNEs to build up a strong and trusting relationship, in order to maintain long-term and stable collaborations and cooperation (Andersson et al., 2002). These social networks are particularly important in order for domestic companies to interact with MNEs and reap knowledge spillover benefits, as they can access target resources, improve their internal skills and reduce their transaction costs (Wang et al., 2012a). Under the condition of a higher foreign entry pace, domestic firms suffer from great pressure to build up social linkages with MNEs, thereby diminishing FDI productivity spillovers in host cities.

Third, there is no doubt that rapid international expansion exhibits greater competition effects in host cities. Previous literature has argued that competition from MNEs, as a key FDI spillover channel, contributes to technological upgrading in the host region (Wang and Blomström, 1992, Markusen and Venables, 1999). Because of pressures caused by MNEs' more efficient productivity and advanced managerial patterns, domestic firms are forced to learn from these foreign competitors and build up indigenous technological capabilities (Wei and Liu, 2006, Liu et al., 2009b, Blomström and Sjöholm, 1999). A rapid foreign expansion process can enlarge the technological gaps between MNEs and domestic firms, and intensify "crowding-out" effects in host cities. In other words, with a faster pace of foreign expansion, fierce competition effects reduce the market shares of domestic firms, diminishing the positive technological spillover effects on them. They do not have sufficient time to increase their productivity, but struggle in operating their business with increased costs and less efficient economies of scale.

Based on the empirical evidence from both developed and developing countries, previous literature has explored the impacts of foreign expansion pace on FDI spillovers at different levels. For example, using a dataset from the UK manufacturing sectors over the period 1983-1989, Perez (1997) argued that a large technological gap between local and foreign firms prevents domestic firms from reaping the benefits of technology transfers and exchanges via FDI, and more rapid foreign expansion further impairs their financial performance. Nevertheless, such negative impacts can attenuate when domestic firms are technologically developed, because they can easily offset the competitive pressures from MNEs. Using a panel dataset from Chinese manufacturing industries over the period 1998-2006, Wang et al. (2012a) demonstrated that the pace of foreign entry negatively moderates the relationship between foreign presence and local firms' total factor productivity. Moreover, such negative effects are more evident for domestic firms operating in low-tech sectors, as FDI spillovers to host region industries are also accompanied by crowding-out effects (Spencer, 2003). MNEs that employ state-of-the-art technology disseminate great pressures to local firms in emerging economies, and these quickly spread over a compressed time. On the contrary, using a panel dataset on Chinese cities from 2004-2011, Wang et al. (2017) demonstrated that rapid foreign expansions exert a positive moderating effect on intercity FDI spillovers, further contributing to technological upgrading in neighbouring cities.

3.3.4. Rhythm and FDI Spillovers in Host Cities

Rhythm is another time-based feature, illustrating the degree of regularity of the FDI expansion process in host cities over a certain period. In line with the mechanism of pace, the rhythm of MNEs' foreign expansion also affects technology transfers and disseminations. The central argument is that time compression diseconomies are likely to emerge when the foreign entry process is unpredictable and discontinuous. In other words, domestic firms can learn more from foreign firms and assimilate advanced technology through a stable, constant and rhythmic process (Wang et al., 2012a). Vermeulen and Barkema (2002) first used Figure 1 to explain foreign expansion rhythm intuitively. Considering the foreign expansion paths of Firm 1and Firm 2, they recognise that pace and rhythm are two independent dimensions of the foreign expansion process. For example, Firm 1 and Firm 2 have the same expansion same, but their rhythms are entirely different. Assuming the time span in Figure 1 is one year, the annual increased number of Firm 1's subsidiaries is constant. It is considered that Firm 1 will establish its subsidiaries in a rhythmic and regular pattern, and its total number of subsidiaries will increase sequentially. On the contrary, Firm 2 only sets up subsidiaries in two separate years, and the number of expansions on the first occasion is larger than on the second. Therefore, although the total number of subsidiaries for both firms is the same, the foreign expansions of Firm 2 are much more irregular and unpredictable.

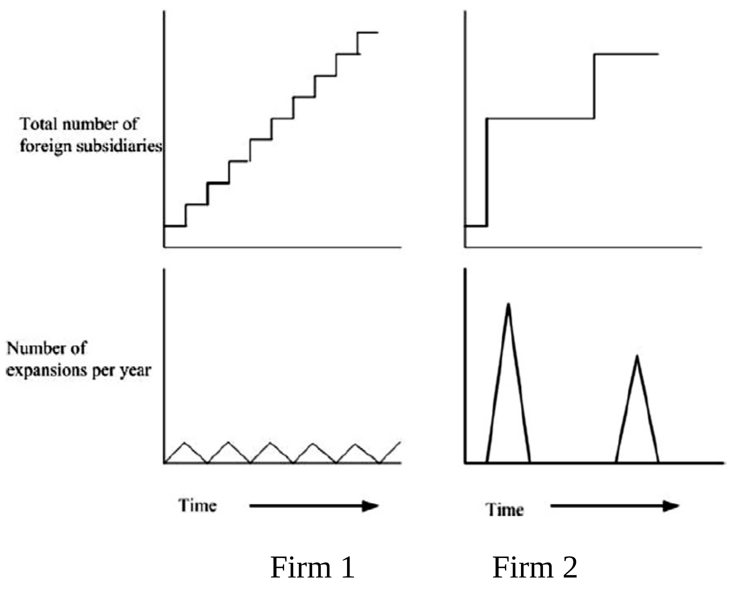

Figure 2 Comparison between rhythmic and irregular foreign expansion patterns (Vermeulen and Barkema, 2002)

Previously, the majority of the literature has defined foreign entry rhythm at both the industrial and individual firm level. For example,Vermeulen and Barkema (2002) denoted that the rhythm describes the changing number of subsidiaries in one individual MNE over a time period, measured by the kurtosis of the first derivative of the number of subsidiaries. Other studies have also adopted this measurement. Using a longitudinal dataset from 772 Taiwanese firms for the period 2000-2008, Lin (2012) also used the kurtosis of the first derivative of a firm's foreign venture number over a certain period to measure internationalisation rhythm. Similarly, based on a data sample from Chinese manufacturing industries over the period 1998-2007, Zhang et al. (2013) adopted the same measurement to denote the rhythm of foreign firms' entry pattern.

On an industrial level, Wang et al. (2012a) used the standard deviation of foreign entry pace to measure MNEs' internationalisation rhythm, which is different from most prior studies. The fundamental mechanism of the international expansion rhythm is that MNEs, at the individual firm level, often have different capabilities and strategies in regard to expanding into overseas markets, so their international expansion process is not constant and stable from their initial entry to the point where they have a certain degree of foreign presence. MNEs' foreign expansions often exhibit sudden sharp peaks or long periods of inactivity, which exert different influences on domestic collaborators in regard to making predictions and taking appropriate action (Vermeulen and Barkema, 2002, Lin, 2012). There is no doubt that the rhythm of foreign expansions affects the interactions between domestic firms and MNEs, and also exerts an impact on technological spillovers.

The rationales of the influence of rhythm on FDI spillovers are similar to those regarding pace, as time compression diseconomies constrain the absorptive capacity of both sides, the local and foreign firms. In this PhD thesis, I emphatically investigate the externalities of foreign expansion rhythm in FDI spillovers at an aggregate city level. The city level foreign expansion rhythm can better reflect the overall FDI expansion irregularity of all of the MNEs within a specific geographic region. There are several good reasons to believe that irregular and unstable foreign expansion processes greatly diminish FDI spillovers in host cities.

First, MNEs that adopt rhythmic, stable and continuous international expansion often exhibit better financial performance than others, and thereby enlarge both their product and geographical scopes in the host countries (Vermeulen and Barkema, 2002, Wang et al., 2012a). This is because foreign investors are often confined with limited absorptive capacity, and they have to follow the previous trajectory, and learn from prior experience to better adapt to new markets (Vermeulen and Barkema, 2001). If the internationalisation process is irregular and unstable, it is difficult for foreign investors to successfully replicate their operational patterns or experience in host cities. More specifically, irregular foreign expansions can take the form of either large peaks or long-term inactivity, which can constrain MNEs' financial performance. On the one hand, large peaks in foreign expansions result in an overload in organisational learning during a short period. MNEs have to bear higher uncertainty and risk if they break with the normal routine and adopt a totally new expansion pattern (Simon, 1959, Huber, 1991). On the other hand, long-term inactivity in the foreign expansion process can reduce the level of MNEs' absorptive capacity (Cohen and Levinthal, 1990, Eisenhardt and Martin, 2000). This is because internationalisation inactivity results in lock-in effects in regard to the existing production models, structures, and systems. In addition, it also provides less opportunities for MNEs to follow a prior trajectory, so they may forget this valuable experience (Darr et al., 1995, Argote et al., 1990). Hence, the poor performance of MNEs can lead to market expansion with limited product and geographical scope, thereby reducing opportunities for interactions with domestic firms in host cities.

Second, abrupt and unpredictable foreign expansion in a specific city is often accompanied by a sudden change in competition effects in the local area, which creates a relatively unstable business environment. If there are sudden changes in the number of MNEs' subsidiaries, the dramatically increased competition is more likely to overwhelm the absorptive capacity of domestic firms, preventing them from fully recognising, assimilating and exploiting the advanced technology and managerial patterns of foreign investors (Wang et al., 2012a). For MNEs themselves, prolonged periods of inactivity will limit their absorptive capacity to deal with unpredictable and abrupt issues in the future. In other words, local firms are less likely to prepare well and respond to sudden foreign expansions if they have not dealt with FDI activities for a long time (Wang et al., 2012a). Hence, more stable, predictable, and constant foreign expansions strengthen the positive effects of competition, which is a key FDI spillover channel, to domestic companies, and stimulate them to build up indigenous technological capabilities.

Third, irregular and unstable foreign expansions are accompanied by sudden changes in demand in the host region's upstream and downstream industries. In an unpredictable business environment, it is difficult for local suppliers and customers to predict the demands of MNEs, or adopt appropriate strategies in their production. Because MNEs are often integrated in local buyer-supplier networks, interindustry interactions with domestic suppliers and customers can generate positive technology transfers and disseminations (Girma and Gong, 2008, Liu et al., 2009a). In this case, demand fluctuations dramatically increase the uncertainty, risks, and complexity in the relationship between MNEs and domestic firms in host cities. Moreover, mutual trust is regarded as a cornerstone of R&D alliances and joint ventures between MNEs and domestic firms, and it is especially necessary to retain long-term social connections to reduce transaction costs (Fryxell et al., 2002, Tan and Meyer, 2011, Chen, 2012). Trust-based social networks help both sides to access scarce resources and target information more easily, and facilitate interactions (Wang et al., 2012a). Rhythmic and stable foreign expansions thereby enable learning-by-doing for domestic firms, and enhance FDI spillovers in host cities.

There are studies that focus on the role of rhythm in technology transfer and dissemination. For example, based on an industrial panel dataset for Chinese manufacturing industries over the period 1998-2006, Wang et al. (2012a) showed that a higher level of irregularity in foreign expansions significantly constrains FDI spillovers, further impeding total factor productivity on an industrial level. The effects of rhythm are similar to those of pace, i.e. that time compression diseconomies emerge if advanced knowledge inflows overwhelm the absorptive capacity of domestic firms. Similarly, using a firm-level panel dataset for Chinese manufacturing industries over the period 1998–2007, Zhang et al. (2013) demonstrated that MNEs' entry tenure in an industry exerts a positive relationship with the productivity of domestic enterprises in the same industry. This relationship is much stronger when MNEs' international expansion process is more rhythmic and stable. Based on a panel dataset of 90 countries over the period 1970-2000, Desmet et al. (2008) showed that gradual and rhythmic foreign expansions enhance FDI spillovers in host regions. In line with empirical evidence in developing countries such as China, more stable and regular foreign capital inflows provide enough time to transfer and disseminate new technology to domestic firms, and thus contribute to their productivity. By contrast, Wang et al. (2017) showed that irregular FDI expansion negatively moderates knowledge spillovers in Chinese cities, but enhances technological upgrading in adjacent regions.

3.4. Host City Industrial Structures and FDI Spillovers

It has been widely recognised that industrial agglomeration affects technological upgrading in cities (Paci and Usai, 1999, Henderson, 1997). Companies and industries often prefer to co-locate in spatial proximity and benefit from agglomeration economies such as intra- and inter-industry technological spillovers (Melo et al., 2009, Fujita et al., 1999, Fujita and Thisse, 2002). Based on evidence from both developed and developing countries, some scholars have shown that firms within specific industrial clusters e.g. Silicon Valley and Beijing Zhongguancun (ZGC) Science Park are more likely to build up indigenous innovation capabilities, further promoting overall city level technological upgrading (Tan, 2006, Florida, 1994). Moreover, technological innovation in an organisation cannot take place in isolation, but depends on access to external knowledge sources across industries. Since the early research of Glaeser et al. (1992), there has been a heated debate about what type of industrial agglomeration exerts a positive impact on technological upgrading and innovation. Therein, two externalities of industrial agglomeration are identified in cities, namely localisation (intra-industry clustering or specialisation) and urbanisation economies (inter-industry clustering or diversity) (Beaudry and Schiffauerova, 2009, Feldman and Audretsch, 1999).

More literature has demonstrated that interindustry knowledge spillovers (urbanisation economies) are the cornerstone of regional innovation. This is because the agglomeration of different sectors facilitates various complementary competences and knowledge transfers and exchanges, and is more likely to trigger radical innovation (Quatraro, 2010, Jacobs, 1969). Nevertheless, industrial diversification (urbanisation economies), as a diversified industrial structure consisting of different sectors in a given city, may influence the rate and direction of technological upgrading differently. Namely, industrial variety (or diversification) per se is not a necessary condition for knowledge spillover effects, as prior literature has often neglected the cognitive distance between sectors (Castaldi et al., 2015, Nooteboom, 2000). Little is known about whether a diversified industrial structure with a small interindustry cognitive distance better facilitates city level knowledge spillovers than other types of diversified structures.

3.4.1. Related and Unrelated Variety: Two Dimensions of Host City Industrial Diversification

Although Jacobs (1969) argued that industrial diversity is the basis of knowledge spillovers, there is still some doubt about whether all types of industrial diversity can contribute to technological upgrading. One of the key reasons for this is that knowledge transfers and disseminations can only take place effectively across different sectors if they have both complementary and shared competences (Frenken et al., 2007). It is widely accepted that if knowledge is shared across technologically related sectors it is more likely to be recombined and disseminated in cities. By contrast, if the urban industrial structure consists of a set of different sectors with a large cognitive distance and limited complementarities, it will be difficult for local firms to fully recognise, assimilate and exploit advanced technologies from other sectors that are unrelated to their internal knowledge stocks (Castaldi et al., 2015, Nooteboom, 2000).

In order to further differentiate the inherent technologically relatedness within industrial variety, prior literature has come up with the concepts of "*industrial related variety and unrelated variety*" (*related and unrelated variety* thereafter) (Essletzbichler, 2005, Frenken et al., 2007, Boschma and Iammarino, 2009). Based on the mechanism of this classification, some degree of cognitive distance is necessary to facilitate effective interactions and communications across different sectors, enabling technology transfers and disseminations to effectively take place (Nooteboom, 2000). Namely, a cognitive distance that is too small or too large will not be able to stimulate technological upgrading through knowledge spillovers. Therefore, the concepts of related and unrelated variety move beyond the conventional notion of industrial diversification, further dividing it into two specific dimensions.

Frenken et al. (2007) and Porter (2003) were the first to emphasise the important role of industrial relatedness in interindustry knowledge sharing and learning. Related variety, as an industrial structure consisting of a set of sectors in cognitive proximity, facilitates effective knowledge spillovers (Nooteboom, 2000, Boschma, 2005, Nooteboom et al., 2007). The related variety argument splits industrial diversity into more specific sectors on the city level, indicating that different forms of industrial variety exert different effects on technological upgrading (Boschma et al., 2012, Boschma and Iammarino, 2009, Bishop and Gripaios, 2010). Previously, a strand of the literature has adopted a set of indicators to measure related variety. For instance, for metropolitan clusters in the US over the period 1990-2000, Porter (2003) attempted to define related industries based on the geographic distributions of economic activities. Different employment locational correlations across traded industries clearly indicate the industrial cluster boundaries. Hidalgo et al. (2007) used the "proximity" between two products to indicate the industrial relatedness. This indicator is based on the ability of an individual country to develop comparative advantage between different products. In more recent studies, scholars have chosen an entropy measurement at the three-digit industrial level to define related variety in cities (Frenken et al., 2007).

By contrast, it is necessary to distinguish another form of industrial variety, that is, unrelated variety on the city level. Unrelated variety refers to a set of sectors within a geographical region that share relatively limited complementary competences and knowledge (Boschma and Iammarino, 2009). In essence, the argument regarding unrelated variety places more emphasis on portfolio-effects and discusses how to reduce vulnerability in regard to regional economic and technological developments (Essletzbichler, 2005, Eriksson, 2011, Boschma et al., 2012). In contrast to effective knowledge spillovers in related variety, unrelated variety exhibits risk-spreading strategies to avoid specific-sector shocks, and triggers technological breakthroughs (Castaldi et al., 2015, Essletzbichler, 2005).

3.4.2. Related Variety and Technological Upgrading in Cities

Prior research has argued that sectoral diversity per se cannot guarantee effective interactions across firms, because a cognitive distance that is too large can impede interindustry knowledge spillovers in cities. (Nooteboom, 2000, Boschma and Iammarino, 2009, Nooteboom et al., 2007). Prior studies argue that cities matter in technological upgrading because urban industrial agglomerations can promote knowledge spillovers for firms' needs (Ning et al., 2016). Namely, effective knowledge flows and idea exchanges are the basis of technological upgrading in cities. Hence, there are several reasons to believe that related variety facilitates local technological upgrading through knowledge spillovers on the city level. First, related variety fosters opportunities for interindustry labour mobility, leading to diffuse newly created and advanced technology across firms whose internal knowledge bases are technologically related. Worker mobility, as one of important technological diffusion channels, enables firms to hire skilled talent from others and benefit from productivity spillovers via such labour turnover (Stoyanov and Zubanov, 2012). City level worker mobility is more frequent through related variety, because sectors in cognitive proximity can foster more opportunities for workers to exploit and utilise previously successful technical capabilities and experience in their new business. For example, technicians and managers in a telecommunications equipment manufacturing firm prefer to seek jobs in E-commerce or computer science firms, but are less likely to work in the textile or clothing industries.

Second, related variety facilitates the building up of interindustry linkages in cities, and contributes to technological upgrading within a larger product scope. Urban supplier chains can disseminate new knowledge from technology producing industries to technology using ones (Hauknes and Knell, 2009). In the early studies, some scholars argued that technological innovation is often driven by frequent interactive activities across industries (Kline, 1986, Robertson and Langlois, 1995). Knowledge spillovers, as the heart of urban technological upgrading, are geographically bounded, as the intensity of interactions attenuates with increased spatial distance (Ning et al., 2016, Boschma, 2005). Therefore, the complementary and shared competences of related variety facilitate interactive activities between firms in different industries, and intensify technology transfers and diffusions. Technologically related sectors are more likely to set up stable sectoral linkages such as joint R&D activities and supply-demand relationships, and promote firms' technological capabilities in cities.

Third, related variety contributes to urban technological upgrading in a gradual and incremental pattern. In contrast to radical technological breakthroughs, recombinant innovation often creates "short-cuts" in technological innovation and reduces transaction costs to avoid "lock-in" effects (Frenken et al., 2012). Related variety is likely to generate incremental and recombinant innovation, as knowledge spillovers across a set of technologically related sectors often come from the recombination and recreation of pre-existing technology in newly created ways (Frenken and Boschma, 2007). This is because cities with a high degree of interindustry cognitive proximity (related variety) help to create a stable business environment and stimulate productivity and recombinant innovation in a more evolutionary and less risky way. Prior literature has also argued that decision-makers in companies are often constrained by limited cognitive capability, so external knowledge that is unrelated to their internal knowledge basis impedes the identification of sources for technological upgrading (Nightingale, 1998, Nooteboom, 2000).

Previously, plenty of literature has explored the role of related variety based on evidence at different regional levels. The majority of studies have identified a positive effect of related variety on knowledge spillovers. These findings could also reflect the impacts of related variety in cities, as they are at a specific regional level. For example, using a Dutch dataset at the NUTS 3 level over the period 1996-2002, Frenken et al. (2007) showed that related variety significantly stimulates employment creation and growth in cities, as a result of knowledge transfers and diffusions between sectors. Essletzbichler (2015) used an industrial level dataset from 360 US metropolitan areas over the period 1977 -1997 in order to explore the role of related variety in industrial branching. The empirical results confirm that technological relatedness significantly contributes to the emergence of new industries, while it impedes industry exits in local areas. Similarly, based on a dataset for Italian provinces (NUTS 3) and industries (three-digit) over the period 1995-2003, Boschma and Iammarino (2009) demonstrated that regions that are endowed with related variety exhibit a better economic performance, and therefore technologically related industries dramatically enhance regional growth. Using a Spanish dataset at the NUTS 3 level over the period 1995–2007, Boschma et al. (2012) found that related variety contributes to inter-regional value added growth. Moreover, based on two new measurements of inter-industry relatedness (Porter's cluster classification and proximity index), regions with a high degree of related variety have rapid economic growth rates. Using both a patent and associated citation dataset for US states over the period 1977-1999, Castaldi et al. (2015) confirmed that related variety enhances technological innovation, as it fosters opportunities to recombine knowledge in a new manner.

3.4.3. Unrelated Variety and Technological Upgrading in Cities

As well as knowledge spillovers across technologically related industries (related variety), it is necessary to distinguish another type of industrial diversity, namely unrelated variety. Unrelated variety refers to industries that do not share complementary competences and knowledge. It has no substantial input-output linkages to establish a complete supply chain, and each sector in unrelated variety is technologically isolated from the others in the city (Boschma and Iammarino, 2009).

Different from the fundamental mechanism of knowledge spillovers in related variety, unrelated variety mainly focuses on the portfolio effects of urban development (Frenken et al., 2007, Brachert et al., 2011). The portfolio theory highlights that it is important to maintain product diversification to reduce potential risks and uncertainty, as a stable business environment can minimise fluctuations in demand and supply (Montgomery, 1994). Cities in high degree of unrelated variety adopt risk-spreading strategies to avoid specific-sector shocks, and are more likely to trigger radical innovation (Castaldi et al., 2015, Essletzbichler, 2005).

For example, take a city that has an industrial structure consisting of 20 different sectors that are technologically unrelated. If sector-specific shocks occur (e.g. oil price fluctuations or a trade war), they are unlikely to hit all 20 sectors at the same time. In other words, unrelated variety spreads the risks across a set of unrelated sectors, enabling the creation of a relatively stable business environment. Based on empirical evidence from developed economies, unrelated variety often dampens unemployment growth because due to the portfolio strategy (Frenken et al., 2007). Less fluctuations in the employment marketplace are likely to facilitate long-term R&D collaborations and alliances, thereby contributing to overall urban technological upgrading in cities.

Hence, unrelated variety seems to impede technology transfers and diffusions across industries, but contributes to technological upgrading from another point of view. This is because unrelated variety builds up blocks of unrelated knowledge, and creates the cornerstone for technological breakthroughs (Castaldi et al., 2015). More specifically, the recombination and recreation of unrelated knowledge can lead to wholly new functionalities and applications, further expanding new technological trajectories in the future (Dosi, 1982). In other words, unrelated variety is likely to trigger breakthrough technological innovation in cities. Due to the large interindustry cognitive distance, unrelated variety can help technological developments by reducing the risk of uncertainty in cities. For instance, using a dataset from the Netherlands for the period 1996-2002, Frenken et al. (2007) explored the role of unrelated variety in avoiding sector-specific shocks in cities. They confirmed the argument about regional shock-resistance, and stated that unrelated variety creates a stable business environment. Similarly, using a data sample of US state-level patents and associated citations from 1977-1999, Castaldi et al. (2015) demonstrated that radical innovation is more likely to stem from unrelated variety, as technologically unrelated knowledge can be recombined and used to create totally new functionalities (e.g. technological breakthroughs). This also reflects the fact that cities with a high level of unrelated variety intensity can trigger technological breakthroughs. Based on a sub-regional data sample (including densely populated urban areas) from the UK at the two-digit level for 23 industries, Bishop and Gripaios (2010) showed that industrial unrelated diversification significantly enhances environmental stability, thereby facilitating regional growth across sectors.

However, some scholars are of the opposite opinion and argue that unrelated variety exerts no impact or even a negative impact on technological upgrading at different regional levels. This somewhat confuses the understanding of the mechanisms of unrelated variety in cities. Using an export and import statistical dataset from Italian provinces, Boschma and Iammarino (2009) also found that the portfolio-protecting effects of unrelated variety are not evident. In other words, it is difficult for cities with a high level of unrelated variety to avoid sector-specific shocks in technological upgrading. Using the new industrial relatedness indexes proposed by the studies of Porter (2003) and Hidalgo et al. (2007), their empirical results show that unrelated variety does not exert effects on regional value-added growth. Based on a patent-level dataset of 366 US cities from 1981-2010, Boschma et al. (2014) found that high level of relatedness greatly increases the probability of the entry of new technology, and that unrelated variety impedes technological upgrading in urban areas.

3.5. Clusters and Technological Upgrading in Cities

Technological upgrading is widely recognised as a key driver of the industrialisation process and economic growth in cities, but many innovation activities are concentrated in relatively few developed countries. If advanced technologies and managerial patterns are costless in terms of transferring and disseminating them all over the world, and their effectiveness is the same within developed and developing countries' cities, there is surely no need to facilitate indigenous technological upgrading (Fu and Gong, 2011). From the economic geography perspective, increasing economic globalisation involves a paradox, that is, whether regionalisation is still necessary in technological upgrading and innovation. This is because with the rapid development of both communications and transportation, global business networks can help firms obtain easier access to information, capital, and resources, and greatly reduce the transaction costs of international trade. It is therefore not necessary for firms to be located near to their customer markets overseas, and some conventional region-specific roles have diminished (Porter, 1990a, Porter, 2000).

However, although some conventional reasons for the importance of regionalisation have gradually diminished due to increasing globalisation, another strand of the burgeoning literature has pointed out the crucial role of place-specific resources, factors and environments in technological spillovers (Florida, 1994, Glaeser et al., 1992, Barro and Sala-I-Martin, 1995). Cities are the frontlines of technological upgrading, and most innovative firms are concentrated in a few key metropolitan regions. They can combine localised knowledge stocks within a specific geographic region, and become international nodes of technological spillovers (Simmie, 2003). Cities also matter in FDI spillovers because local industrial agglomerations can promote the strength of the interactions between local and foreign firms (Ning et al., 2016). Bell and Albu (1999) adopted a systemic perspective to investigate the longer-term competitiveness in industrial clusters. Pike and Tomaney (1999) also argued that "localisation", as opposed to "globalisation", is still at least part of the solution to understanding industrial dynamics and is helpful to solve regional economic development dilemmas in newly emerging conditions. Prior literature has therefore focused on the role of localisation in global competitive advantage, or technological innovation (Florida, 1994, Prescott, 1998, Asheim and Isaksen, 2002). Hence, cities are ideal research settings in which to understand place-specific factors and resource influence in technological upgrading, as they are the most knowledge-intensive and innovative regions within regional clusters.

3.5.1. What are City Level Clusters?

From the geographic perspective, regional clusters (thereafter clusters) are defined as geographic agglomerations of a set of interlinked economic and organisational entities (e.g. institutions, firms, and industries etc.) in a particular geographic area in term of both commonalities and complementarities (Porter, 2000, Porter, 1998a). The geographic scope of a cluster is relevant to the distance over which a set of issues occur, including information sharing, transactions and incentives. The boundaries of clusters scarcely conform to standard industrial classification systems, but are contingent upon connections across different industries. Namely, due to expansions or shrinkages of industries, the boundaries of clusters will continually evolve (Suarez-Villa and Walrod, 1997, Porter, 2000). On specific city levels, boundaries of clusters expand to a larger geographic region if new metropolises participate, and facilitate technological learning and knowledge spillovers both within and across cities. Notably, knowledge transfers and sharing exist in both developed and developing economies, but the clusters in developing countries are often more underdeveloped and less systematic (Porter, 1998b, Bell and Albu, 1999). This therefore provides some unique evidence regarding city level technological mechanisms.

More than insular industries and firms in cities, clusters consist of an array of interlinked sectors, enterprises and institutions, as well as other economic entities. The key participants within clusters are closely interlinked suppliers, distributors and customers in both upstream and downstream industries, as well as providers of specialised infrastructure. Firms that co-locate within clusters can benefit from marketing complementarities, information accessibility, and sectoral specialisations through trade associations and labour divisions (Marshall, 1920, Porter, 1998b, Adams and Jaffe, 1996, Maskell, 2001). Many clusters also include governments and other institutions, which provide public services to all of the entities. In particular in metropolitan areas, governments often participate in almost all of the economic and technological issues in terms of R&D activities and policy making. Florida (1994) argued that the institutional and economic environment exerts a significant impact on the collective learning process, collaboration, and innovation within a developed cluster e.g. Silicon Valley. Metropolises like San Francisco and Berkeley are the key nodes of information exchange and knowledge sharing, leading to improved overall technological capabilities within the cluster. Moreover, clusters include not only a set of innovation actors (e.g. governments, research institutions and firms), but also trade associations, which transfer and disseminate technology (Porter, 2000). These technological diffusion channels expand linkages to both upstream and downstream industries in cities based on complementary competences and cognitive proximity. With increasing economic globalisation, MNEs also become an important part of clusters, as interactions with domestic firms facilitate technology transfer and diffusion (De Propris and Driffield, 2006, Thompson, 2002).

Within the clusters, connections across firms and sectors are fundamental mechanisms of productivity, competitiveness and technological development (Porter, 2000). Therein, horizontal and vertical linkages have long been recognised as facilitating technology transfer and dissemination, enabling clusters to increase their competitiveness and production efficiency (Schmitz and Nadvi, 1999, Porter, 2000). The research of UNCTAD (2001) defines horizontal linkages as those involving competitive interactions across firms in the same industry. Vertical linkages are interindustry connections to upstream and downstream industries that facilitate technological spillovers. Cluster participants are closely interlinked in regard to both commonalities and complementarities, and set up a constructive and efficient platform for interactions among firms, industries, governments and other institutions. They enjoy lower transaction costs and a clearer understanding of customers' needs, and discern trends faster than their isolated competitors (Porter, 2000). Thanks to such ongoing relationships and interactions, idea exchanges and knowledge spillovers continually take place, and are integral to the greater and more complex geographic "regional innovation system" across cities. Moreover, place-specific resources and factors in typical clusters can either enhance or diminish knowledge sharing and dissemination, further affecting the overall technological performance of the cluster (Porter, 1998b, Asheim and Isaksen, 2002).

From the spatial perspective, clusters do not exist entirely in isolation; externally linked trades and market information make clusters open to outside knowledge stocks, allowing both intra- and inter-cluster knowledge transfers and spillovers to take place (Bell and Albu, 1999, Lawson et al., 1997). This is because although internal structures and organisations are important to clusters, knowledge sources outside of clusters are regarded as the key driver of their technical change and dynamics in order to maintain long-term competitiveness (Bell and Albu, 1999). Externally linked technical advice, information services, trade and marketing facilitate knowledge transfer and dissemination across different clusters (Nadvi, 1996, Visser, 1996, Sandee, 1995).

Moreover, national cumulative forward and backward linkages can be decomposed to explore the influence of intra- and inter-cluster knowledge spillovers on economic activity (Oosterhaven et al., 2001). Tewari (1996) speculated that sustainable innovation within clusters cannot depend entirely on endogenous incremental changes, and it is necessary to obtain knowledge inflows from the external environment to facilitate knowledge-circulation and accumulation. Indeed, the spatial dimensions of clusters also change radically with their evolution and intercity associations, so such spatial restructuring helps knowledge spillover within a larger region. In line with intercity externalities, cities can be interlinked through several “pipelines” e.g. worker mobility, supplier chains or social networks, either within the cluster or beyond its boundaries (Ning et al., 2016). Hence, focusing on a specific cluster consisting of cities (e.g. urban groups) can provide us with a deeper understanding of knowledge sharing and transfer from a spatial perspective.

3.5.2. Governments and Markets within City Level Clusters

3.5.2.1. Government Orientations within City Level Clusters

A key reason for focusing on clusters rather than traditional groups of industries and firms is that governments are playing an important role in both technological and economic development in cities. This is because under-investment often emerges when R&D activities are left entirely to the private sectors and firms. These firms and sectors are often profit-driven, and less willing to develop slow-return R&D activities. Namely, the cluster upgrading process requires the continuous removal of constraints and obstacles that are impeding innovation activities, but some of these cannot be automatically addressed by market or private initiatives. In particular in cities, as knowledge-intensive geographic areas, most state-led funding is concentrated on R&D activities, as well as the public and private sectors (Simmie, 2003). Hence, there is no doubt that governments exert a significant impact on local technological development (Yigitcanlar et al., 2008).

First, in contrast to totally interest-driven and market-oriented incentives, governments often make great efforts to entrust non-profit universities and research institutions with undertaking long-term, risky and strategic R&D projects, with the aim of facilitating breakthrough innovation and maintaining competitive advantage (Etzkowitz and Leydesdorff, 2000, Anselin et al., 1997). Furthermore, cities can concentrate plenty of creative talent in local universities and research institutions, and become the incubators of advanced technology (Florida, 2002, Acs et al., 2002). Governmental influence is therefore most evident in cities, especially in large metropolitan regions. Based on the Triple Helix relationship between universities, industries and governments, Etzkowitz and Leydesdorff (2000) argued that governments are in a crucial position in terms of the retention mechanism to develop innovation systems, and that public universities are a laboratory locus to facilitate knowledge-intensive network transitions. Second, governments often draw up appropriate policies and regulations (e.g. such as financial subsidies and grants) to encourage R&D activities in private firms, with the aim of increasing the competitiveness of individual firms (Hsu and Chiang, 2001, Porter, 2000). Government investments are often aimed at improving the business environment in cities, and benefitting industries and firms by means of limiting competition. Some of the literature has shown that incubators are designed to stimulate small start-ups and support these firms over a short period (often 3-5 years) (Caiazza, 2014, Bergek and Norrman, 2008). Hence, some public universities and political groups with social objectives set up "innovation incubators" both within and across cities, to allow clusters to expand by encouraging low-tech firms to undertake R&D activities. Thanks to preferential policies such as tax concessions and financial subsidies, SMEs are encouraged to embark on their own R&D activities and new business (Hsu and Chiang, 2001). Third, firms in larger and denser cities often reap the benefit of cost advantages in regard to technological upgrading and innovation. This is because governments can provide and enhance specialised and efficient individualities e.g. transportation, communication, and other infrastructure facilities (Ciccone and Hall, 1996, Helsley and Strange, 2004, Porter, 2000). Governments within clusters can increase state-led institutional and financial investments to improve public services and goods, with the aim of reducing the transaction costs of technology transfers and exchanges.

However, some of the literature has also argued that governments do not always exert a positive impact on cluster upgrading. For instance, policymakers often prefer to formulate regulations and policies that focus on scarce resource allocations, rather than making great efforts to build up inter-industry linkages to achieve synergic developments (Feser and Bergman, 2000). They ignore both intra- and inter-regional linkages between technology transfers and disseminations, and rely more on simplistic measurements (e.g. industrial size) to upgrade clusters, leading to complex and expensive resource allocations (Gordon and McCann, 2000). Some cluster governments also pay more attention to descriptive information gathering, rather than facilitating emerging business developments or understanding industrial cluster complexity (Davies, 2001). In this case, governments often underperform in terms of building up long-term competitiveness in urban technological upgrading, and constrain knowledge spillovers both within and across clusters.

Previously, some of the literature has explored the role of governments in cluster technological upgrading based on evidence from cities. Using the example of a leading ICT service cluster in Beijing Zhongguancun, Zhou and Xin (2003) emphasise the importance of governmental administration in high-tech cluster developments. Strong public R&D investment and national market admittance rapidly promoted innovation during the early stage of the cluster (Wang and Zhou, 2001). In such a knowledge-intensive region in a metropolis, an experimental approach, namely Guo-You-Min-Ying (state-owned and privately-operated), has encouraged innovative activities within the cluster, and central state-control has significantly improved the cluster infrastructures. Governments can also compensate for under-investment in R&D activities by means of financial subsidies, and by supporting technological developments in cities. However, using a unique Japanese dataset of 229 small firms in the early 2000s, Nishimura and Okamuro (2011) argued that governments fail to achieve the optimal level of R&D efficiency, because of information asymmetry.

3.5.2.2. Market Orientations within City Level Clusters

Some of the previous literature has argued that market orientations are a key engine of firms' technological innovation (Zhang and Duan, 2010, Jaw et al., 2010, Atuahene-Gima, 1996). Market and technologcial developments facilitate the emergence of new industries, building up linkages, and modifying the markets served within clusters (Porter, 2000). Larger and denser cities often allow the sharing of marketplaces and infrastructure facilities, enabling the commercialisation of new technology (Ciccone and Hall, 1996, Helsley and Strange, 2004). Hence, cities are ideal research settings in which to investigate market orientations in regard to knowledge sharing and dissemination, in order to contribute to the understanding of technological upgrading within clusters.

Market orientations are often defined as an key element that enables firms to behave effectively and efficiently, so that they can meet both current and future customers' demands and maximise their business performance (Narver and Slater, 1990, Kohli and Jaworski, 1990). In other words, driven by both customers' demands and pressure from competitors, they aim to maximise their returns and make a success of their innovations. To be specific, market orientations do not only affect business performance within a competitive environment, but also relevant to job satisfactions and product quality in a specific firm (Zhou et al., 2008, Sin et al., 2003). Hence, moving beyond this view to the city level within clusters, markets exert several important impacts on technological upgrading.

First, firms within marketplaces often adopt customer-oriented strategies, and hope to satisfy customers' demands and reduce the potential risks during the technological upgrading process (Atuahene-Gima, 1996). In other words, market-oriented strategies focus on the maximisation of R&D efficiency, emphasising the importance of customers as sources of new product ideas both within and across cities. Differnent from the social objectives or macro-level economic targets of public R&D projects, market-oriented R&D activities are focused less on technological breakthroughs, and more on enabling incremental innovation to take place within clusters.

Second, a key characteristic of mature and open markets is appropriate competition, which can lead to the frequent entry and exit of technologcial upgrading actors (Porter, 1998a, Porter, 1990b). The entry barriers within a cluster are lower than they are elsewhere, so local entrepreneurs are more likely to be new entrants to clusters (Porter, 2000). Larger metropolitses where more productive firms and industries agglomerate further increase the competition effects within clusters (Combes et al., 2012). Such effects are conducive to technology transfers, facilitating the new entry of specialised firms and regional technologcial upgrading (Jacobs, 1969, Feldman and Audretsch, 1999, Porter, 1990b). In Chinese contexts, Li et al. (2006) demonstrated that market competitive pressures greatly improved SOEs organizational and technological performance, although they are under strict control of governments. In other words, too many governmental interferences impede domestic firms' innovative activities, further slow down local technological upgrading process.

Third, clusters also present obvious competitive advantages in terms of market complementarities, providing competitive cost advantages for local actors e.g. for firms and research institutions to access technological sources (Porter, 2000). In terms of market orientations, specialised labour divisions make innovation entities interlinked in terms of cognitive and organisational proximity, and facilitate knowledge sharing and technological learning through interactions. In other words, complementary coordination facilitates effective teamwork oriented towards shared goals. This teamwork exhibits greater integration and recombination of new knowledge, especially across marketing and R&D (Atuahene-Gima, 1996, Narver and Slater, 1990).

Nevertheless, it has been widely recognised that markets cannot always be effective, and some of the prior literature has highlighted market failure in technological upgrading and innovation (Martin and Scott, 2000, Joseph and Johnston, 1985, Dodgson et al., 2011). Market failure, often shown as resource misallocations and information asymmetry, can impede knowledge spillovers, and even eliminate innovation (Dodgson et al., 2011). For example, in a perfect market environment, it is quite difficult for small and medium sized enterprises to undertake large-scale technological projects, because they are often faced with shortages of financial support from urban authorities. Due to severe market competition, state-led and public support are therefore especially important to SMEs' technological upgrading. Based on cases of Taiwanese industrial upgrading, Hsu and Chiang (2001) demonstrated that governments need to build up incubator centres to promote the technological upgrading of SMEs, enabling the offset of market failure in R&D activities.

3.5.3. Clusters and Technological Upgrading in Cities

Cluster technological upgrading and innovation has long been the subject of heated debate, and the previous literature has focused on specific regional dimensions based on evidence from both developed and developing countries. For example, based on a case study of three typical regional clusters in Norway, Asheim and Isaksen (2002) argued that place-specific contextual knowledge greatly affects firms' innovation activity within clusters. More specifically, in Jaeren and Sunnmore, local organisations play a key role in promoting shared and local specific competences in regard to both tacit and codified knowledge, with the aim of facilitating technology collaboration and transfers. Similarly, Asheim and Coenen (2005) adopted five case studies in a Nordic comparative SME project, and emphasised the strong sectoral connotation within clusters. Using a novel panel dataset from the Longitudinal Business Database (LBD) and US Cluster Mapping Project, Delgado et al. (2010) also demonstrated that clusters have a significant impact on regional entrepreneurship when local-based complementarities are successfully realised. Strong clusters (i.e. a large presence of sectors that are technologically related) contribute to higher new business formation growth, as well as more firm start-ups and their increased survival.

However, some literature has not found evidence of cluster impacts on technological upgrading and innovation in cities. For example, groupthink may resist the adoption of newly created knowledge, and insist on traditional behaviors (Glasmeier, 1991). To avoid potential risks, clusters might also prevent radical innovation in urban areas, resulting in greater barriers to the triggering of technological breakthroughs (Porter, 2000). For example, in specific Dutch spatial contexts, Wever and Stam (1999) showed that regional clusters associated with strong innovation linkages with other firms and knowledge centres scarcely exist in such a small and homogeneous developed country, as high-tech SMEs are likely to have nationwide connections.

With increasing economic globalisation, a relatively closed and scattered knowledge system cannot support continuous and sustainable long-term competitiveness within clusters. Prior research has noted that sources outside clusters are also a key contributor to technical change and dynamism (Nadvi, 1996, Visser, 1996, Sandee, 1995). Inward FDI, as a major external knowledge source, seems to play a crucial role in technology transfer and dissemination within clusters. Therein, cities, as the main recipients of MNE expansions, can better reflect the spatial effects of FDI spillovers within clusters (Ning et al., 2016). For example, based on two datasets from the UK, De Propris and Driffield (2006) showed that domestic firms within clusters benefit more from technological spillovers of FDI than firms not in clusters. Similarly, using a data source from a survey of Hong Kong garment enterprises, Thompson (2002) demonstrated that agglomerations of FDI within industrial clusters facilitate more technology transfers and dissemination to domestic companies than dispersed FDI. Geographically clustered FDI attracts more suppliers and facilitates close cooperation between domestic firms and MNEs both within and across cities.

This PhD thesis aims to emphatically discuss Chinese cluster technological developments, and explore specific technological upgrading mechanisms on the city level. It is therefore necessary to review prior studies about cluster technological developments and evidence from emerging economies, especially in the Chinese context. For instance, based on one specific Chinese ICT industrial cluster, the Beijing Zhongguancun (ZGC) Science Park, Wang and Zhou (2001) showed that this industrial cluster has successfully combined indigenous state-led polices and technological spillovers from MNEs, and created a favourable business environment to facilitate urban technological upgrading. Similarly, also within the Beijing ZGC Science Park, Zhou and Xin (2003) demonstrated the hierarchical relationship between MNEs and domestic firms from a spatial perspective. Collaborations with foreign firms can significantly enhance the technological training of local firms and build up innovative capabilities in home markets. Using a case study of the Dalian Software Park in China, Zhao et al. (2009) showed that there are competitive advantages for industrial technological developments within a cluster, as substantial resources rooted in local institutional systems (e.g. governments, institutions, and academic aspects) facilitate innovative new product development in the city.

3.6. Concluding Remarks

The literature review in Chapter 3 presents systematic theoretical frameworks of FDI spillovers, cluster theory, the foreign expansion process, and industrial structures in cities. Plenty of literature has investigated FDI spillovers in regard to host city technological upgrading, but the results of the empirical studies on FDI knowledge sharing and transfers are still mixed and inconclusive. One key reason for that is that prior studies have adopted varied methods (panel and cross sectional), levels of study (regional, industrial and firm), research objectives (developed and developing economies) and periods for their FDI spillover research. Moreover, FDI spillovers are not an automatic process but are contingent upon a set of determinant factors related to the characteristics of host regions, indigenous firms and MNEs (Crespo and Fontoura, 2007, Meyer, 2004). Nevertheless, the majority of studies have neglected the externalities of the foreign expansion process and industrial structures in FDI spillovers. From a spatial perspective, cities are interlinked through several channels e.g. labour mobility and supplier chains, and it is therefore necessary to consider intercity FDI spillovers.

Hence, Chinese cities are ideal research settings in which to investigate the relationship between FDI and technological upgrading.

In summary, Chapter 3 provides a systematic and solid theoretical foundation for the research for this PhD thesis.

Chapter 4 Data and Methodology

In the last chapter, I systematically reviewed the theoretical frameworks regarding FDI spillovers, cluster theory, the foreign expansion process, and industrial structures, and indicated the research gaps in the previous literature. To carry out an empirical analysis, it is necessary to select appropriate data sources and a methodology. This chapter aims to describe the data sources used in this PhD thesis, and introduce the dataset compilation for the practical analysis in detail. Generally, the prior literature on FDI spillovers has adopted various methodologies, including comparative analysis, evolutionary analysis, explanatory analysis, descriptive analysis and case studies as well as questionnaire survey analysis. Therein, based on evidence from Chinese cities, this PhD thesis adopts both descriptive and econometric analysis in each empirical chapter. Section 4.2-4.4 discusses the choice of a suitable methodology and research strategy for the quantitative analysis in Chapters 5, 6, and 7 in order to provide a deeper understanding of the methodological framework for this PhD research.

The remainder of this chapter is organised as follows. Section 4.1 elaborates the two key database sources adopted in this PhD thesis, namely *The Chinese Urban Statistical Yearbooks* and *The Annual Industrial Survey Database*. Section 4.2-4.4 emphatically expatiates on the data collection, the variable definitions, and the econometric configurations used in Chapters 5, 6, and 7, respectively.

4.1. Data Source Selection and Collection

In order to answer the core research question of this PhD thesis, *"How do foreign expansion time-based characteristics and industrial structures moderate both intra- and inter-city relationships between inward FDI and technological upgrading in Chinese cities?"*, it was necessary to collect city level data based on the Chinese context. China is a large country with a hierarchical administrative system, which mainly includes four specific layers: provinces (municipalities, autonomous administrative regions, and special administrative regions), prefectural cities (sub-provincial cities), county-level cities (counties) and villages.

The affiliations between the regional layers jointly constitute the integral administrative system in China. Hence, it is necessary to introduce each regional layer in detail, with the aim of explaining the research objectives of this PhD thesis. There are 34 provincial administrative regions in China, including four municipalities, twenty-three provinces, five autonomous regions and two special administrative regions, all of which are under the direct jurisdiction of the central government. The provincial administrative regions are the highest-level authorities in terms of implementing economic, social, and technological activities, and they are the main bridge connecting the central and local governments. Apart from municipalities (Beijing, Shanghai, Tianjin, and Chongqing) and special administrative regions (Hong Kong and Macau), each province or autonomous region consists of a set of cities. However, the total number of Chinese prefectural cities is not always constant, because the central government makes timely adjustments to the administrative divisions to meet economic and social demands. For example, in 1997, Chongqing was upgraded from a sub-provincial city to a municipality, the same level as Beijing, under the direct jurisdiction of the

Chinese central government, and the number of municipalities thereby increased to four. In addition, Chaohu, which was previously a prefectural city in Anhui Province, was revoked by the central government in 2011. Nowadays, it is a county-level city under the jurisdiction of Hefei City Government. In 2012, for the purpose of both administrative jurisdiction and national defence in the South China Sea, Sansha was established as a prefectural city in Hainan Province. *The Chinese Urban Statistical Yearbooks* list these cities and their geographic locations in China. Moreover, county-level cities and counties are the smallest urban areas, and the former are often under the administration of prefectural cities or sub-provincial-level cities. As of 2013, there were 368 county-level cities, and over 1400 counties in China. Finally, villages are the smallest unit in the Chinese administrative system; they are the rural areas. Generally, the municipalities and the sub-provincial-level and prefectural cities are the research focus of this PhD thesis. Taking the time span into consideration, I eliminated all of the cities that were either officially revoked or newly established over the period 2000-2014, in order to avoid data deficiency. This PhD thesis also excludes Hong Kong, Macau and cities in Taiwan province. Hence, I identified 286 Chinese cities as the research objectives in this research, including 267 prefectural cities, 15 sub-provincial-level cities, and 4 municipalities.

Previously, research on a variety of topics in terms of Chinese FDI and technological issues has mainly used datasets on the industrial-, provincial- or firm-level, but has scarcely discussed empirical evidence from cities. For example, Cheung and Lin (2004), using Chinese provincial data over the period 1995 to 2000, demonstrated that FDI significantly increased the number of patent applications. Fu (2008) revealed similar results, namely that inward FDI was positively correlated with regional innovation efficiency for 31 Chinese provinces and municipality cities over 1998-2004. Using a dataset from 191 sub-sectors from the Third National Industrial Census of the People's Republic of China, Liu and Wang (2003) showed that foreign presence enhances sectoral total factor productivity. Using a panel firm-level dataset over 2001-2005, Fu and Gong (2011) showed that R&D activities from foreign investors significantly impede technological changes in domestic firms in China. Also, based on standardised questionnaire datasets on Pearl River Delta firms in electronic sectors, Fu et al. (2013) demonstrated that firms that adopt intensive interactive learning can significantly promote their incremental product innovation.

However, the literature above might have neglected several important issues due to data source deficiency. Although provincial level research has provided some indications the role of regional FDI spillovers in technological upgrading, it has not explored urban heterogeneity and interregional externalities across cities (Ning et al., 2016). This is because China is a relatively large country that includes 31 provincial-level administrative regions, and some provinces are quite large, surpassing even some European economies (Ning et al., 2016, Cheung and Lin, 2004, Fu, 2008). Moreover, there are more than 200 cities distributed across the whole country from the coastal to the inland regions, and each of them has an independent administrative system to implement economic and technological activities. Due to the urban heterogeneity in terms of the geographical conditions, infrastructure facilities and public services etc., local authorities from two cities but within the same province might even adopt completely different innovation strategies in regard to regional technological upgrading. In terms of firm level studies, although they can provide more detailed empirical evidence on technological performance, the firm-level data sample scope coverage is relatively limited. In other words, firm-level studies often neglect the regional effects, or simplify them as dummy variables. Hence, in order to deal with these problems, it is increasingly necessary to adopt city level analysis based on the Chinese context, to help contribute to the existing theoretical and empirical frameworks.

4.1.1. The Chinese Urban Statistical Yearbooks

Chinese Urban Statistical Yearbooks are the main data sources used in this PhD thesis. *Chinese Urban Statistical Yearbooks* are the authoritative statistical publications produced by The Department of Urban Survey in the Chinese National Bureau of Statistics (CNBS). Every year in December, The Department of Urban Survey publishes a *Chinese Urban Statistical Yearbook* on the last year, which includes statistical data about the economic and social development of over 600 cities (all of the cities above prefectural level and county-level). More specifically, the yearbooks include four sections. The first section indicates the administrative division and geographic distribution of the cities at different levels. The second section lists statistical data in terms of economic, social, and technological developments of all of the cities above prefectural level. The third section lists statistics regarding the economic, social, and technological development of all of the county-level cities. The fourth section is the appendix and gives the main indicator descriptions. Because in China, cities above prefectural level and county-level cities employ different statistical systems, the indicators for these two administrative regions are not completely consistent.

4.1.2. The Annual Industrial Survey Database

In order to investigate the roles of industrial agglomerations in FDI spillovers, it was necessary to integrate the industrial level data sample and the regional level dataset. The *Chinese Urban Statistical Yearbooks* do not provide firm- or industrial level statistics, so I employed *The Annual Industrial Survey Database* as another data source for this PhD thesis. *The Annual Industrial Survey Database* is currently the only data source to provide detailed basic and financial information on Chinese manufacturing firms. In terms of its scope, *The Annual Industrial Survey Database* includes all large- and medium-sized firms with annual sales above the "Designed Size" (500 million RMB), and the time span that it covers is 1998 to 2009.

More specifically, this database provides comprehensive information on these large- and medium-sized firms, such as their industrial output value, their employment composition and their financial index etc. It also indicates the ownership structure of each firm listed, namely whether it is state-owned, collectively-owned, individually-owned, foreign-owned, corporate-owned or HMT-owned. More importantly, each firm in the database has a four-digit Standard Industrial Classifications (SIC) code, indicating the specific sector to which it belongs. The four-digit SIC code reveals both the specific industrial branch and the main industry in which each firm operates. Therein, the first two digits represent the main industry. If two industrial branch SIC codes have the same first two digits, these two industrial branches are in the same main industry. Appendix 4 shows the industrial classification in this database. For example, there are three industrial branches of the main industry Coal Mining and Washing, because the SIC codes of these three industrial branches all have the same first two digits (06). In other words, the three industrial branches are the more detailed classifications in the main Coal Mining and Washing industry: Soft coal and anthracite mining and washing (0610), Lignite mining and washing (0620), and Other coal mining and washing (0690). There are 39 main industries in *The Annual Industrial Survey Database*, and each main industry contains one or more industrial branches. Nevertheless, the number of industrial branches is quite different across the main industries. For example, there are 51 industrial branches that belong to the Special Equipment Manufacturing Industry (36), while there are only 2 industrial branches that belong to the Waste and Scrap Recycling Industry (43). This is because some main industries cover a wide range of manufacturing fields, but others only focus on relatively narrow ones.

4.2. Externalities of the Foreign Expansion Process in Host City FDI Spillovers

4.2.1. Dataset Collection and Processing

In total, the original panel dataset of Chinese cities indicated above includes 286 cities, namely 267 prefectural cities, 15 sub-provincial-level cities, and 4 municipalities. This study adopted a data sample taken from the *Chinese Urban Statistical Yearbooks* over the period 2004-2013. This is because the *Chinese Urban Statistical Yearbook* include statistics regarding the number of MNEs from HMT (Hong Kong, Macau and Taiwan) and foreign countries in 2004, which is an indicator that can be used to measure time-based characteristics, namely the pace and rhythm, of foreign expansions. Lhasa in Tibet has been excluded from this thesis, as its statistical data are incomplete. I also eliminated 42 prefectural cities where key indicators were missing, such as inward FDI volume and annual GDP growth etc. In order to eliminate endogeneity, a one-year lag is implemented for all of the independent variables in the panel regressions, so the time span of the independent variable dataset is period 2003-2011, corresponding to the dependent variables from

2004 to 2012. Hence, the final data sample contains 244 cities over 8 years, and the number of city/year observations is 1952.

4.2.2. Variable Definitions

Dependent Variable:

Total Factor Productivity (TFP): In order to investigate both the intra- and inter-regional externalities of FDI on host region technological upgrading, I adopt total factor productivity (TFP) at the city level as the dependent variable of the production function. TFP is used to measure the technological change effects in outputs not caused by capital and labour investments, thereby reflecting technological progression and productive evolution (Comin, 2006, Javorcik, 2004a). Previously, several alternative indicators have been used to measure TFP, such as the Solow Residual Method (Solow, 1957), instrumental variables estimation and semi-parametric analysis etc. (Liu et al., 2009a). In this chapter, I employ the Levinsohn and Petrin (L-P) method to measure TFP on the Chinese city level, as this method has several strengths (Liu et al., 2009a). First, intermediate input is a valid proxy in the formula to replace investments. The production function is data-driven under the condition of non-zero investments (Levinsohn and Petrin, 2003). Second, investment is the partial variable in traditional growth-accounting formulae, and certain productivity stocks cannot fully respond to investments. This method adds intermediate input to deal with such a problem as they are less likely to change over time, and can represent entire productivity better than investments. Third, intermediate inputs are not state variables, so it bridges estimation strategy and economic theory in a simple form.

The TFP measurement by L-P estimation is in the Cobb-Douglas Production Function (Levinsohn and Petrin, 2003):

$$Y = F(K, L; t) \tag{1}$$

Where *Y* represents the outputs, and *K* and *L* indicate the capital and labour inputs in physical capital, respectively. Meanwhile, *t* is the time in the function, allowing for technical changes (Solow, 1957). The function above can be converted into the Cobb-Douglas function below:

$$Y = A(t)\, f(K, L) \tag{2}$$

Where $A(t)$ is the TFP, indicating the cumulated technical changes over time. Converting the function above into logarithm form gives:

$$y_t = c_0 + c_1 l_t + c_2 k_t + \epsilon_t \tag{3}$$

Levinsohn and Petrin (2003) modify the formula above in the following form:

$$y_t = c_0 + c_1 l_t + c_2 k_t + c_3 m_t + \omega_t + \mu_t \tag{4}$$

Where y_t is the logarithm of value added, k_t, l_t and m_t are the logarithms of capital, labour and intermediate input, respectively. ϵ_t is assumed to be additively separable in two forms: μ_t is the i.d.d component of the disturbance term, and ω_t is a transmitted component. It is assumed that the intermediate inputs are a function of the capital and state-dependent productivity term. In this way, the intermediate inputs are denoted as the following function:

$$m_t = m_t\,(k_t, \omega_t) \tag{5}$$

$$\omega_t = \omega_t\,(k_t, m_t) \tag{6}$$

Rewrite the function:

$$y_t = c_1 l_t + \emptyset_t\,(m_t, k_t) + \mu_t \tag{7}$$

$$\emptyset_t\,(m_t, k_t) = c_0 + c_2 k_t + \omega_t\,(k_t, m_t) \tag{8}$$

The unobserved productivity term can be inverted to the observed variable, if the demand function is monotonically increasing in ω_t. Following the first-order Markov process, ω_t takes the form below:

$$\omega_t = E(\omega_t|\omega_{t-1}) + \vartheta_t \tag{9}$$

Where ϑ_t refers to productivity that is uncorrelated with capital k_t. In this way, we can estimate the parameters of the production function. After that, using the parameter estimation in the production function above, we can calculate TFP on the city level. In this empirical chapter, $TFP_{i,t}$ indicates the logarithm of the degree of total factor productivity of city *i* in year *t*.

Explanatory Variables

***Inward FDI (IFDI)*:** In my PhD thesis, $IFDI_{i,t}$ represents the annual flow of inward foreign direct investment per capita in city *i* in year *t* to proxy the density and presence of inward FDI in China. The FDI inflows are the actual utilised amount of foreign investments in millions of US dollars. Based on prior literature, I use this measure because new technology and managerial patterns are often embedded in foreign investments, further benefiting local productivity and innovation (Cheung and Lin, 2004, Driffield and Love, 2007).

Pace: To measure the rate of MNE expansion in cities, we construct the pace variable based on the prior study of Wang et al. (2012a) as follows:

$$Pace_{i,t} = \frac{MNEs\ Number_{i,t} - MNEs\ Number_{i,t-1}}{MNEs\ Number_{i,t-1}} \times 100\% \tag{10}$$

Where *MNEs Number*$_{i,t}$ denotes the number of foreign enterprises, including firms from both HMT and foreign countries in city *i* in year *t*. Different values for adjacent years indicate an increasing or decreasing number of foreign firms in a given city. Hence, the increasing/decreasing rate of foreign enterprises in one city reflects the inward FDI speed; a large value of $Pace_{i,t}$ indicates a more rapid foreign expansion process.

Rhythm**:** This thesis employs the kurtosis of foreign expansion to indicate the regularity of inward FDI based on previous literature (Vermeulen and Barkema, 2002). In describing the shape of a statistical distribution, kurtosis refers to the degree of peaks or flatness. Therefore, it indicates the changing rate of a set of statistics over a specific period.

$$Rhythm_{i,t} = \left\{\frac{n(n+1)}{(n-1)(n-2)(n-3)} \sum \left(\frac{x_i - \bar{x}}{s}\right)^4\right\} - \frac{3(n-1)^2}{(n-2)(n-3)} \quad (11)$$

Where *n* is the number of observations and *s* is the standard deviation of the MNE expansion in city *i* in year *t*. x_i is the number of foreign enterprises in year t, and $\bar{x}$ is the average number of foreign enterprises. The value of $Rhythm_{i,t}$ describes the regularity of the foreign expansion process. More stable and regular foreign expansions lead to a relatively flat distribution (Vermeulen and Barkema, 2002). A high value of $Rhythm_{i,t}$ indicates irregular and unstable FDI expansions, which is shown as either long-term inactivity or large peaks over a period.

Control Variables

***Scale*:** Gross Domestic Product (GDP) is a measurement that is used to describe the growth potential and economic size of urban areas. GDP growth is used as a proxy to control the stage of development across different regions. Therefore, I employ annual GDP growth rate as the economic scale of cities' development level.

***Output*:** Industrial outputs are used as the control variable to reflect the economic structure. Therefore, I employ the value of industrial output over the total gross domestic product of city *i* in year t as $Output_{i,t}$, to indicate the industrial composition of the local economy. It controls for the structural effects affecting city level technological upgrading.

***Transport*:** $Transport_{i,t}$ is measured by the number of total travel journal per capita as the transportation density. The transportation density is used to control for the degree of interactions among cities.

***Population*:** Population density is the control variable calculated as the total number of individuals in 10,000 per square kilometer in the city. In certain industrial sectors, a labour-intensive pattern is still playing a leading role in productivity. Therefore, $Population_{i,t}$ reflects the urban economy in relation to the city size (Sterlacchini, 2008, Usai, 2011).

***Education*:** $Education_{i,t}$ is calculated as the number of people in tertiary education out of the total population. Skilled labour, especially with a tertiary degree, is quite important to urban innovation promotion. It is regarded as having the capability to capture and absorb external knowledge (Fu, 2008).

Table 4-1 Variable Definitions of Chapter 5

Variables	***Definitions***
$TFP_{i,t}$	Natural log of the Total Factor Productivity of city *i* in year *t*
$IFDI_{i,t}$	Natural log of the annual flow inward foreign direct investment per capita in US dollar of city *i* in year *t*
$Pace_{i,t}$	The increasing rate of MNEs expansion of city *i* in year *t*
$Rhythm_{i,t}$	The kurtosis of MNEs expansion of city *i* in year *t*
$Scale_{i,t}$	Natural log of the GDP growth rate of city *i* in year *t*
$Output_{i,t}$	Natural log of the value of industrial output over total gross domestic products of city *i* in year *t*
$Transport_{i,t}$	Natural log of the passenger capacity in times per capita of city *i* in year *t*
$Population_{i,t}$	Natural log of the population in 10,000 people per square kilometer of city *i* in year *t*
$Education_{i,t}$	Natural log of the number of people in tertiary education over total population of city *i* in year *t*

Sources: Chinese Urban Statistical Yearbooks (2004-2013)

4.2.3. Estimation Methods

Chapter 5 adopts pooled Ordinary Least Square (OLS) and ML spatial regressions to investigate the relationship between foreign presence and technological upgrading both within and across Chinese cities. Therein, the pooled OLS regression is the baseline for the econometric analysis. I first regard TFP as a function of FDI, foreign expansion time-based characteristics and the regional effects of cities. It is expressed in a non-spatial form as follows:

$$TFP_{i,t} = \alpha + \beta_1 IFDI_{i,t-1} + \beta_2 Pace_{i,t-1} + \beta_3 Rhythm_{i,t-1} + \beta_4 \left(IFDI_{i,t-1} * Pace_{i,t-1}\right) + \beta_5 \left(IFDI_{i,t-1} * Rhythm_{i,t-1}\right) + \beta_6 Scale_{i,t-1} + \beta_7 Output_{i,t-1} + \beta_8 Transport_{i,t-1} + \beta_9 Population_{i,t-1} + \beta_{10} Education_{i,t-1} + \varepsilon_{i,t} \quad (12)$$

Where $TFP_{i,t}$ is the dependent variable, $\varepsilon_{i,t}$ is the random disturbance term and α denotes the individual effect. As indicated before, a one-year lag is implemented for all of the independent variables to mitigate possible endogeneity across different variables in the production function (Fu, 2008, Usai, 2011).

In order to explore both the intra- and inter-regional externalities of the foreign pace and rhythm in FDI spillovers based on evidence from Chinese cities, I employ the spatial econometric model (LeSage and Pace, 2009). Based on the study of Elhorst (2014), it is necessary to first identify the existence of spatial autocorrelations to differentiate the error or lag form of spatial dependence, and determine the final model. As indicated above, this is based on the use of robust versions of Lagrange multiplier tests.

Spatial Error Model (SEM)

We start with the Spatial Error Model (SEM), which assumes that $\varepsilon_{i,t}$ takes the following form:

$$\varepsilon_{i,t} = \rho \sum_{h=1}^{n} W_{i,h}\varepsilon_{i,t} + v_{i,t} \tag{13}$$

where ρ is the estimated autocorrelation coefficient, and $v_{i,t}$ is a disturbance term. Therein, $\boldsymbol{W}$ is a row standardised spatial weight matrix of the $n \times n$ dimension describing the spatial configuration and arrangement of the units in the data sample (Elhorst, 2014). $\boldsymbol{W}$ is constructed by $\sum_{h=1}^{n} W_{ih}$, which depends on the geographical distance, and n is the total number of cities. The geographic distance is the inverse squared, in order to reflect the inter-city gravity relationship (Ning et al., 2016). $\sum_{h=1}^{n} W_{ih}$ denotes i, the h^{th} element of the row standardised spatial weight matrix of the $n \times n$ dimension.

Spatial Lag Model (SAR)

The SAR requires the inclusion of a spatially lagged dependent variable at the right hand of the equation as follows:

$$TFP_{i,t} = \alpha + \beta \sum_{h=1}^{n} W_{i,h}\, TFP_{h,t} + \delta X_{i,t} + \varepsilon_{i,t} \tag{14}$$

where β is the estimated coefficient of the spatially lagged dependent variable. $X_{i,t}$ denotes all the independent variables. δ is the corresponding estimated parameters of $X_{i,t}$.

Spatial Durbin Model (SDM)

Next, we adopt a general approach to determine a Spatial Durbin Model (SDM) as follows, to examine whether it can be simplified to either a lag or error form.

$$TFP_{i,t} = \alpha + \beta \sum_{h=1}^{n} W_{i,h}\, TFP_{h,t} + \delta X_{i,t} + \theta \sum_{h=1}^{n} W_{i,h}\, X_{i,t} + \varepsilon_{i,t} \tag{15}$$

θ denotes the corresponding estimated parameters of $\sum_{h=1}^{n} W_{i,h}\, X_{i,t}$. In order to control for the simultaneity that arises due to spatially weighted dependent variables, I adopt the maximum likelihood method in Elhorst (2014) to examine all of the spatial models above. If one of the SAR and SEM tests is suitable to describe the data, we proceed with that estimation model accordingly. On the contrary, if those tests are inconsistent, then we adopt the general SDM model. Finally, we employ spatial Hausman tests following LeSage and Pace (2010) to examine whether the random effect can be used to replace the fixed effect in our estimations. In the case of fixed effects, we further test whether either spatial or time-period fixed effects ("two way" fixed effects) should be included or jointly included in the estimation models based on likelihood ratio (LR) tests.

4.2.4. Univariate Analysis

Table 4-2 Summary Statistics of Variables in 2004 (Chapter 5)

Variable	*Observations*	*Mean*	*Std. Dev.*	*Minimum*	*Maximum*	*Skewness*	*Kurtosis*
$\boldsymbol{TFP_{i,t}}$	244	4.995	0.947	1.765	7.579	0.117	3.274
$\boldsymbol{IFDI_{i,t}}$	244	-0.521	2.366	-6.756	5.220	-0.327	3.001
$\boldsymbol{Pace_{i,t}}$	244	12.689	30.448	-100.000	166.667	0.142	9.800
$\boldsymbol{Rhythm_{i,t}}$	244	2.139	2.795	-2.179	9.000	0.987	3.348
$\boldsymbol{Scale_{i,t}}$	244	2.652	0.212	1.974	3.629	0.325	5.235
$\boldsymbol{Output_{i,t}}$	244	-0.211	0.532	-1.844	1.022	-0.393	2.911
$\boldsymbol{Transport_{i,t}}$	244	2.559	0.682	0.913	5.325	0.462	3.968
$\boldsymbol{Population_{i,t}}$	244	-3.406	0.843	-7.648	-1.545	-1.295	6.013
$\boldsymbol{Education_{i,t}}$	244	4.036	1.155	1.321	6.736	0.224	2.675

Table 4-3 Summary Statistics of Variables in 2005 (Chapter 5)

Variable	*Observations*	*Mean*	*Std. Dev.*	*Minimum*	*Maximum*	*Skewness*	*Kurtosis*
$\boldsymbol{TFP_{i,t}}$	244	5.273	0.926	1.940	8.000	0.080	3.401
$\boldsymbol{IFDI_{i,t}}$	244	-0.440	2.311	-7.217	5.025	-0.246	2.900
$\boldsymbol{Pace_{i,t}}$	244	23.910	36.948	-36.364	200.000	1.899	8.583
$\boldsymbol{Rhythm_{i,t}}$	244	2.139	2.795	-2.179	9.000	0.987	3.348
$\boldsymbol{Scale_{i,t}}$	244	2.624	0.249	0.993	3.371	-0.802	10.698
$\boldsymbol{Output_{i,t}}$	244	-0.080	0.497	-1.856	0.926	-0.543	3.418
$\boldsymbol{Transport_{i,t}}$	244	2.641	0.633	1.041	4.618	0.416	3.345
$\boldsymbol{Population_{i,t}}$	244	-3.395	0.855	-7.658	-1.324	-1.218	5.937
$\boldsymbol{Education_{i,t}}$	244	4.206	1.140	1.464	6.848	0.279	2.573

Table 4-4 Summary Statistics of Variables in 2006 (Chapter 5)

Variable	***Observations***	***Mean***	***Std. Dev.***	***Minimum***	***Maximum***	***Skewness***	***Kurtosis***
$\boldsymbol{TFP_{i,t}}$	244	5.570	0.908	2.049	8.192	-0.122	3.744
$\boldsymbol{IFDI_{i,t}}$	244	-0.143	2.168	-5.998	5.120	-0.116	2.763
$\boldsymbol{Pace_{i,t}}$	244	15.854	25.764	-42.857	233.333	3.395	25.241
$\boldsymbol{Rhythm_{i,t}}$	244	2.139	2.795	-2.179	9.000	0.987	3.348
$\boldsymbol{Scale_{i,t}}$	244	2.643	0.186	1.808	3.399	-0.311	6.163
$\boldsymbol{Output_{i,t}}$	244	0.023	0.470	-1.787	1.220	-0.496	3.570
$\boldsymbol{Transport_{i,t}}$	244	2.693	0.680	1.071	5.655	0.877	4.883
$\boldsymbol{Population_{i,t}}$	244	-3.388	0.848	-7.663	-1.534	-1.294	6.035
$\boldsymbol{Education_{i,t}}$	244	4.314	1.115	1.319	6.951	0.257	2.643

Table 4-5 Summary Statistics of Variables in 2007 (Chapter 5)

Variable	***Observations***	***Mean***	***Std. Dev.***	***Minimum***	***Maximum***	***Skewness***	***Kurtosis***
$\boldsymbol{TFP_{i,t}}$	244	5.862	0.868	2.873	8.301	-0.141	3.478
$\boldsymbol{IFDI_{i,t}}$	244	0.172	2.075	-6.365	5.234	-0.136	2.900
$\boldsymbol{Pace_{i,t}}$	244	14.206	18.734	-50.000	100.000	1.280	7.841
$\boldsymbol{Rhythm_{i,t}}$	244	2.139	2.795	-2.179	9.000	0.987	3.348
$\boldsymbol{Scale_{i,t}}$	244	2.705	0.178	1.281	3.493	-1.687	20.367
$\boldsymbol{Output_{i,t}}$	244	0.112	0.466	-1.916	1.185	-0.882	5.015
$\boldsymbol{Transport_{i,t}}$	244	2.747	0.654	1.034	5.380	0.666	4.034
$\boldsymbol{Population_{i,t}}$	244	-3.382	0.849	-7.637	-1.526	-1.276	5.960
$\boldsymbol{Education_{i,t}}$	244	4.427	1.080	2.046	7.005	0.362	2.517

Table 4-6 Summary Statistics of Variables in 2008 (Chapter 5)

Variable	*Observations*	*Mean*	*Std. Dev.*	*Minimum*	*Maximum*	*Skewness*	*Kurtosis*
$TFP_{i,t}$	244	6.025	0.832	3.065	8.202	-0.201	3.564
$IFDI_{i,t}$	244	0.438	2.001	-5.747	5.330	-0.119	2.984
$Pace_{i,t}$	244	8.572	15.997	-50.000	75.000	0.759	7.031
$Rhythm_{i,t}$	244	2.139	2.795	-2.179	9.000	0.987	3.348
$Scale_{i,t}$	244	2.568	0.280	0.000	3.243	-3.665	32.409
$Output_{i,t}$	244	0.182	0.448	-1.749	1.262	-0.856	4.550
$Transport_{i,t}$	244	2.817	0.679	1.041	5.770	0.768	4.305
$Population_{i,t}$	244	-3.373	0.851	-7.613	-1.517	-1.267	5.911
$Education_{i,t}$	244	4.510	1.055	2.104	7.057	0.372	2.541

Table 4-7 Summary Statistics of Variables in 2009 (Chapter 5)

Variable	*Observations*	*Mean*	*Std. Dev.*	*Minimum*	*Maximum*	*Skewness*	*Kurtosis*
$TFP_{i,t}$	244	6.333	0.785	3.576	8.451	-0.279	3.710
$IFDI_{i,t}$	244	0.480	2.025	-6.744	5.342	-0.141	2.963
$Pace_{i,t}$	244	4.509	16.653	-54.839	100.000	1.559	11.863
$Rhythm_{i,t}$	244	2.139	2.795	-2.179	9.000	0.987	3.348
$Scale_{i,t}$	244	2.533	0.261	0.833	3.258	-2.359	15.349
$Output_{i,t}$	244	0.206	0.438	-1.705	1.136	-0.892	4.771
$Transport_{i,t}$	244	2.953	0.718	1.015	6.388	1.179	6.063
$Population_{i,t}$	244	-3.366	0.855	-7.607	-1.510	-1.280	5.958
$Education_{i,t}$	244	4.596	1.046	2.183	7.113	0.371	2.561

Table 4-8 Summary Statistics of Variables in 2010 (Chapter 5)

Variable	*Observations*	*Mean*	*Std. Dev.*	*Minimum*	*Maximum*	*Skewness*	*Kurtosis*
$TFP_{i,t}$	244	6.506	0.748	3.687	8.482	-0.421	4.030
$IFDI_{i,t}$	244	0.669	1.961	-4.869	5.374	-0.077	2.792
$Pace_{i,t}$	244	3.192	15.820	-23.077	150.000	4.416	35.453
$Rhythm_{i,t}$	244	2.139	2.795	-2.179	9.000	0.987	3.348
$Scale_{i,t}$	244	2.661	0.136	2.332	3.223	0.381	3.855
$Output_{i,t}$	244	0.310	0.416	-1.752	1.230	-0.994	5.493
$Transport_{i,t}$	244	3.032	0.723	1.053	6.400	1.205	5.913
$Population_{i,t}$	244	-3.357	0.856	-7.591	-1.502	-1.269	5.928
$Education_{i,t}$	244	4.644	1.034	2.340	7.135	0.352	2.612

Table 4-9 Summary Statistics of Variables in 2011 (Chapter 5)

Variable	*Observations*	*Mean*	*Std. Dev.*	*Minimum*	*Maximum*	*Skewness*	*Kurtosis*
$TFP_{i,t}$	244	6.597	0.747	3.831	8.596	-0.365	3.979
$IFDI_{i,t}$	244	0.877	1.917	-5.991	5.442	-0.165	3.052
$Pace_{i,t}$	244	-16.331	16.045	-100.000	46.154	0.187	7.433
$Rhythm_{i,t}$	244	2.139	2.795	-2.179	9.000	0.987	3.348
$Scale_{i,t}$	244	2.562	0.178	1.409	2.996	-2.006	12.070
$Output_{i,t}$	244	0.346	0.407	-1.795	1.293	-1.103	6.229
$Transport_{i,t}$	244	3.099	0.718	1.195	6.444	1.256	6.043
$Population_{i,t}$	244	-3.353	0.857	-7.579	-1.497	-1.261	5.904
$Education_{i,t}$	244	3.428	1.770	-0.480	7.014	-0.110	2.182

Tables 4.2-4.9 illustrate the summary statistics of the indicators adopted in the regressions each year, with the variation tendency in both the dependent and independent variables over the 8 years. Focusing on the dependent variable, namely total factor productivity, the mean value increased steadily from 4.995 to 6.597 over the period 2005-2012, indicating that China continuously promoted the level of urban technological upgrading. By contrast, the annual dispersion degree of the TFP value across different cities significantly reduced, as the Std. Dev. Value decreased year by year. This is because the Chinese authorities made great efforts to build up technological capabilities in the cities, and were also devoted to achieving harmonious developments across the whole nation (Fan, 2006).

Correspondingly, the mean value of $IFDI_{i,t}$ also increased from 2004 to 2011, demonstrating that the level of foreign capital utilisation maintained steady growth. In other words, this visually reflects that foreign presence evidently contributed to technological upgrading in the Chinese cities. Focusing on both pace and rhythm, the mean value of $Pace_{i,t}$ reached a peak of 23.91% in 2005, and then remained continuous, decreasing over the next 6 years. Finally, it hit the bottom, at -16.33% in 2011. In regard to rhythm, as the measurement used to indicate the irregularity of foreign expansions over the period 2004-2011, the summary statistics remain consistent every year.

In terms of the control variables, the $Scale_{i,t}$ mean value remained relatively stable over the period 2004-2011, indicating that the economic scale in Chinese cities increased steadily. By contrast, $Output_{i,t}$ exhibited a more evidently increasing mean value during the same period, from -0.211 to 0.346. The growth rate of $Output_{i,t}$ is much more significant than that of $Scale_{i,t}$, as the proportion of total industrial output over GDP increased annually. Meanwhile, the Std. Dev. Value of $Output_{i,t}$ is larger than that of $Scale_{i,t}$ each year. This reflects that the annual dispersion degree of $Output_{i,t}$ was higher than $Scale_{i,t}$ across the cities. Focusing on $Transport_{i,t}$, the mean value increased steadily during the 8 years, from 2.559 to 3.099. This is because both the central and local authorities made great efforts to accelerate the interregional construction of the transport system, thereby increasing transportation capabilities across cities. The passenger capacity in times per capita significantly increased in China. Despite being the largest emerging economy, the mean value of $Population_{i,t}$ remained stable at a relatively high level. The $Education_{i,t}$ mean value maintained steady growth, reaching a peak of 4.644 in 2010, and then dramatically decreased to 3.428. The Std. Dev. Value also increased from 1.034 to 1.770 in the same year.

4.3. Externalities of Foreign Expansion Process in Host City FDI Spillovers.

4.3.1. Dataset Collections and Compiling

Chapter 6 uses data sources from both the *Chinese Urban Statistical Yearbooks* and *The Annual Industrial Survey Database*. First, I collected and compiled a firm-level dataset from *The Annual Industrial Survey Database*. In order to ensure the reliability of the empirical analysis, I dropped all observations that were obviously incorrect. For example, firms with a negative value of total industrial output value or staff number were eliminated from the dataset. Based on the calculation method of related and unrelated variety (see contexts below), I also excluded firms with missing data for the industrial SIC code or total employment amount. Finally, in order to make it identical to the regional dataset of Chinese cities, I selected the period 2001-2009 from the database, and dropped all observations without a city identification code. Following the data collection and compilation above, the final firm-level panel dataset included 2,418,627 firm/year observations over the period 2001-2009.

Once the firm-level panel dataset had been compiled, it was necessary to aggregate it to the regional dataset of Chinese cities. In order to match the two datasets on both the firm- and city levels, I used the city identification code and year as clues to link each firm observation to a specific city. Similar to Chapter 5, the original city level panel dataset comes from the *Chinese Urban Statistical Yearbooks*. Due to the considerable amount of missing data for Chinese cities before 2000, I selected the period 2001-2009 from regional dataset to match with the firm-level dataset. More specifically, Lhasa in Tibet is also excluded in this chapter, as its statistical data were almost all missing. I also eliminated 47 prefectural cities due to missing key indicators, such as inward FDI volume and annual GDP growth etc. In order to eliminate endogeneity, a one-year lag is implemented for all of the independent variables in the panel regressions, so the time span of the independent variable dataset is the period 2001-2009, corresponding to dependent variables from 2002 to 2010. Hence, the final data sample contains 239 cities over 9 years, and the number of city/year observations is 2151. Hence, I had finally obtained an integrated dataset consisting of both firm- and city level statistics.

4.3.2. Variable Definitions

Dependent Variable

Total Factor Productivity (TFP): Similar to Chapter 5, this chapter also employs total factor productivity as the dependent variable. It employs the Levinsohn and Petrin (L-P) method to measure TFP at the city level. TFP is a key driver of production output, and is determined by both the efficiency and intensity of inputs during the production process. Hence, TFP has been widely used to reflect technological upgrading and productivity efficiency (Comin, 2006, Fu and Gong, 2011). This L-P method provides several evident advantages such as the data-driven production function under the condition of non-zero investments, and a simpler form built by the intermediate input (Liu et al., 2009a, Levinsohn and Petrin, 2003). The variable definitions in section 4.2.2 introduce the calculation methods in detail, so those will not be repeated here. In this empirical chapter, $TFP_{i,t}$ indicates the logarithm of the degree of total factor productivity of city *i* in year *t*.

Explanatory Variables

Inward FDI (IFDI): In this chapter, $IFDI_{i,t}$ employs the logarithm of the annual flow of inward foreign direct investment per capita in city *i* in year *t* to proxy foreign presence in Chinese cities. FDI inflow is the actual amount of foreign investment that is used in millions of US dollars. Based on empirical evidence from the prior literature, it is assumed that technology transfers and disseminations of FDI greatly contribute to host region technological upgrading (Cheung and Lin, 2004, Driffield and Love, 2007).

Related and Unrelated Variety:

Related and unrelated variety are the measurements of industrial structures in Chinese cities. As indicated above, the integrated dataset I put together consists of both firm- and city level statistics, and the city identification code and year are the clues to link each firm observation to a specific city. In *the Annual Industrial Survey Database*, each firm has a four-digit SIC code to indicate which specific industrial branch it operates in. In the line with the study of Frenken et al. (2007), I adopt an "entropy measurement" to indicate related and unrelated variety on the Chinese city level. More specifically, I use the entropy measurement at the two-digit level (main industries) to calculate the degree of unrelated variety, while the degree of related variety is calculated by the weighted sum of the entropy at the four-digit level (industrial branches) within the main industry. In other words, two different industrial branches sharing the same two-digit sector (same main industry) are in cognitive proximity, and share complementary competences (Boschma and Iammarino, 2009, Frenken et al., 2007).

The formal calculation of related and unrelated variety is as follows. First, based on the inclusive relationship between the main industries and their industrial branches, the employment in a main industry is the sum of the employment in all of its industrial branches. Namely,

$$E_a = E_{a1} + E_{a2} + \dots E_{ab} \tag{16}$$

Therein, E_a is the employment number in the a^{th} main industry, calculated as the sum of the employment in all of the firms belonging to the a^{th} main industry. b is the number of industrial branches in the a^{th} main industry and E_{ab} is the employment number in the b^{th} industrial branch within the a^{th} main industry.

$$p_{i,b} = \frac{\text{Number of employment in } b^{th} \text{ industrial branch in city } i}{\text{Total number of employment in all industries in city } i} \tag{17}$$

$$P_{i,a} = \sum_{b=1}^{b} p_{i,b} = \frac{Number\ of\ employment\ in\ a^{th}\ main\ industryin\ city\ i}{Total\ number\ of\ employment\ in\ all\ sectors\ in\ city\ i} \tag{18}$$

Where $P_{i,a}$ is the share of employment in the a^{th} main industry over the total employment in the city i. $p_{i,b}$ is the share of employment in the b^{th} industrial branch over the total employment in city i. b is the number of industrial branches in the a^{th} main industry.

Unrelated variety (***UR$_{i,t}$***) is defined as a two-digit main industry entropy distribution (Frenken et al., 2007), and the degree of unrelated variety in city i in year t is:

$$UV_{i,t} = \sum_{a=1}^{G} P_{i,a} \log_2(1/P_{i,a}) \tag{19}$$

Therein, G is the total number of main industries in city i in year t.

Related variety is defined as the weighted sum of the four-digit industrial branches within each two-digit main industry. Let all four-digit sectors b fall exclusively under a two-digit sector S_a, where a=1, 2, …G.

$$H_a = \sum_{b \in S_a} \frac{p_{i,b}}{P_{i,a}} \log_2\left(\frac{1}{p_{i,b}/P_{i,a}}\right) \tag{20}$$

So, the related variety (***RV$_{i.t}$***) in city i in year t is:

$$RV_{i,t} = \sum_{a=1}^{G} P_a H_a \tag{21}$$

Control Variables

***$Scale_{i,t}$*:** Gross Domestic Product (GDP) is a measurement used to describe the growth potential and economic size of urban areas. This chapter adopts the logarithm of the annual GDP growth rate of city *i* in year *t* to control for the economic size and stage of development of urban areas in China.

***$Industry_{i,t}$*:** Industrial outputs are used as the control variable to reflect the economic structure. This chapter uses the logarithm of value of industrial outputs per capita in city *i* in year *t*. This indicator represents the industrial composition in the local economy, and controls for the structural impacts that affect technological upgrading in Chinese cities.

***$Transport_{i,t}$*:** *$Transport_{i,t}$* is measured by the logarithm of the average travel time per capita in city *i* in year *t*. This variable is used to control the degree of interactions among the cities. A higher value of *$Transport_{i,t}$* indicates more frequent interactions between different regions.

***$Education_{i,t}$*:** *$Education_{i,t}$* is the logarithm of the proportion of the number of people in tertiary education out of the total population of city *i* in year *t*. *$Education_{i,t}$* is used to reflect the education level of the citizens. In fact, skilled labour with a higher level of education is a key source for technological upgrading in Chinese cities (Fu, 2008).

***$Investment_{i,t}$*:** *$Investment_{i,t}$* is measured by the logarithm of the fixed-asset investments per capita in city *i* in year *t*, and controls for the degree of inrastucture construction and production facilities. In order to provide better public services, governemnents increase their fixed-asset investments, enabling the accleration of inrastucture construction in Chinese cities.

Table 4-10 Variable Definitions of Chapter 6

Variables	***Definitions***
$\boldsymbol{TFP_{i,t}}$	Natural log of the Total Factor Productivity of city *i* in year *t*
$\boldsymbol{IFDI_{i,t}}$	Natural log of annual flow inward foreign direct investment per capita of city *i* in year *t*
$\boldsymbol{RV_{i,t}}$	Natural log of related variety of city *i* in year *t*
$\boldsymbol{UR_{i,t}}$	Natural log of unrelated variety of city *i* in year *t*
$\boldsymbol{Scale_{i,t}}$	Natural log of the GDP growth rate of city *i* in year *t*
$\boldsymbol{Industry_{i,t}}$	Natural log of the value of industrial output per capita of city *i* in year *t*
$\boldsymbol{Transport_{i,t}}$	Natural log of the passenger capacity in times per capita of city *i* in year *t*
$\boldsymbol{Education_{i,t}}$	Natural log of number of people in tertiary education over total population of city *i* in year *t*
$\boldsymbol{Investment_{i,t}}$	Natural log of fixed asset investments over total population of city *i* in year *t*

Source: Chinese Urban Statistical Yearbook (2003-2011)

4.3.3. Estimation Methods

Similar to Chapter 5, this chapter also adopts pooled Ordinary Least Square (OLS) and ML spatial regressions to investigate the relationship between foreign presence and technological upgrading both within and across Chinese cities. Therein, the pooled OLS regression is the baseline for the econometric analysis. I first regard TFP as a function of FDI, industrial structures and regional effects of cities. It is expressed in a non-spatial form as follows:

$$TFP_{i,t} = \alpha + \beta_1 IFDI_{i,t-1} + \beta_2 RV_{i,t-1} + \beta_3 UR_{i,t-1} + \beta_4 \left(IFDI_{i,t-1} * RV_{i,t-1}\right) + \beta_5 \left(IFDI_{i,t-1} * UR_{i,t-1}\right) + \beta_6 Scale_{i,t-1} + \beta_7 Industry_{i,t-1} + \beta_8 Transport_{i,t-1} + \beta_9 Education_{i,t-1} + \beta_{10} Investment_{i,t-1} + \varepsilon_{i,t} \quad (22)$$

Where $TFP_{i,t}$ is the dependent variable, $\varepsilon_{i,t}$ is the random disturbance term and α denotes the individual effect. As indicated before, a one-year lag is implemented for all of the independent variables to mitigate possible endogeneity across different variables in the production function (Fu, 2008, Usai, 2011).

In order to explore both the intra- and inter-regional externalities of the foreign pace and rhythm in FDI spillovers based on evidence from Chinese cities, I employ the spatial econometric model (LeSage and Pace, 2009). Based on the study of Elhorst (2014), it is necessary to first identify the existence of spatial autocorrelations to differentiate the error or lag form of spatial dependence, and determine our final model. As indicated above, this is based on the use of robust versions of

Lagrange multiplier tests and their robust versions. The determining process is introduced in the econometric configurations of Chapter 5 in detail, so that will not be repeated here.

Finally, I adopt a general approach to determine a Spatial Durbin Model (SDM) as follows, to examine whether it can be simplified to either a lag or error form.

$$TFP_{i,t} = \alpha + \beta \sum_{h=1}^{n} W_{i,h}\, TFP_{h,t} + \delta X_{i,t} + \theta \sum_{h=1}^{n} W_{i,h}\, X_{i,t} + \varepsilon_{i,t} \quad (23)$$

θ denotes the corresponding estimated parameters of $\sum_{h=1}^{n} W_{i,h}\, X_{i,t}$. In order to control for the simultaneity that emerges due to spatially weighted dependent variables, we adopt Elhorst (2014) maximum likelihood method to examine all of the spatial models above. If one of the SAR and SEM tests is suitable to describe the data, we proceed with that estimation model accordingly. On the contrary, if those tests are inconsistent, then we adopt the general SDM model. Finally, we employ spatial Hausman tests following LeSage and Pace (2010) to examine whether the random effect can be used to replace the fixed effect in our estimations. In the case of fixed effects, we further test whether either spatial or time-period fixed effects ("two way" fixed effects) should be included or jointly included in the estimation models based on likelihood ratio (LR) tests.

4.3.4. Univariate Analysis

Table 4-11 Summary Statistics of Variables in 2001 (Chapter 6)

Variable	*Observations*	*Mean*	*Std. Dev.*	*Minimum*	*Maximum*	*Skewness*	*Kurtosis*
$TFP_{i,t}$	239	13.130	0.923	10.640	15.595	0.321	3.027
$IFDI_{i,t}$	239	2.404	1.746	-2.003	7.582	0.192	3.097
$RV_{i,t}$	239	5.310	2.074	0.135	11.172	0.257	3.212
$UR_{i,t}$	239	4.253	1.061	1.592	7.615	0.354	3.356
$Scale_{i,t}$	239	2.121	0.675	-3.507	2.902	-3.841	25.122
$Industry_{i,t}$	239	8.510	1.042	6.229	12.360	0.425	3.236
$Transport_{i,t}$	239	2.476	0.653	0.851	5.313	0.583	4.491
$Education_{i,t}$	239	12.584	1.214	8.859	15.430	-0.043	3.154
$Investment_{i,t}$	239	7.481	0.803	5.786	10.799	0.819	4.439

Table 4-12 Summary Statistics of Variables in 2002 (Chapter 6)

Variable	*Observations*	*Mean*	*Std. Dev.*	*Minimum*	*Maximum*	*Skewness*	*Kurtosis*
$TFP_{i,t}$	239	13.414	0.948	10.694	16.112	0.316	3.178
$IFDI_{i,t}$	239	2.664	1.702	-3.233	7.736	0.064	3.430
$RV_{i,t}$	239	5.451	2.110	0.018	11.295	0.316	3.121
$UR_{i,t}$	239	4.323	1.076	1.667	7.656	0.379	3.298
$Scale_{i,t}$	239	2.373	0.271	0.336	3.447	-1.786	16.712
$Industry_{i,t}$	239	8.648	1.047	6.492	12.469	0.402	3.219
$Transport_{i,t}$	239	2.531	0.666	0.934	5.326	0.531	4.304
$Education_{i,t}$	239	12.862	1.166	9.131	15.636	0.106	2.777
$Investment_{i,t}$	239	7.658	0.780	5.807	10.957	0.657	3.933

Table 4-13 Summary Statistics of Variables in 2003 (Chapter 6)

Variable	***Observations***	***Mean***	***Std. Dev.***	***Minimum***	***Maximum***	***Skewness***	***Kurtosis***
$TFP_{i,t}$	239	13.730	0.942	10.626	16.296	0.175	3.289
$IFDI_{i,t}$	239	2.897	1.783	-2.221	7.783	-0.104	3.094
$RV_{i,t}$	239	5.556	2.281	-0.719	11.524	0.159	3.197
$UR_{i,t}$	239	4.401	1.109	1.755	7.774	0.356	3.239
$Scale_{i,t}$	239	2.453	0.453	0.000	3.450	-3.119	16.362
$Industry_{i,t}$	239	8.854	1.067	6.542	12.759	0.426	3.276
$Transport_{i,t}$	239	2.477	0.653	1.087	5.323	0.684	4.468
$Education_{i,t}$	239	13.072	1.133	10.748	15.666	0.253	2.482
$Investment_{i,t}$	239	8.141	0.771	6.709	11.049	0.630	3.099

Table 4-14 Summary Statistics of Variables in 2004 (Chapter 6)

Variable	***Observations***	***Mean***	***Std. Dev.***	***Minimum***	***Maximum***	***Skewness***	***Kurtosis***
$TFP_{i,t}$	239	14.021	0.917	10.821	16.543	0.159	3.355
$IFDI_{i,t}$	239	2.938	1.803	-2.553	7.691	-0.255	3.161
$RV_{i,t}$	239	6.044	2.480	0.149	13.033	0.396	3.210
$UR_{i,t}$	239	4.647	1.214	1.433	8.153	0.335	3.358
$Scale_{i,t}$	239	2.659	0.213	1.974	3.629	0.504	5.810
$Industry_{i,t}$	239	9.141	1.066	6.716	12.885	0.357	3.107
$Transport_{i,t}$	239	2.558	0.660	0.957	5.325	0.520	4.160
$Education_{i,t}$	239	13.251	1.126	10.531	15.946	0.205	2.747
$Investment_{i,t}$	239	8.395	0.778	6.870	11.100	0.529	2.807

Table 4-15 Summary Statistics of Variables in 2005 (Chapter 6)

Variable	*Observations*	*Mean*	*Std. Dev.*	*Minimum*	*Maximum*	*Skewness*	*Kurtosis*
$TFP_{i,t}$	239	14.290	0.896	11.001	16.892	0.149	3.447
$IFDI_{i,t}$	239	2.995	1.769	-2.397	7.398	-0.262	3.050
$RV_{i,t}$	239	6.080	2.486	-0.595	12.244	0.202	3.146
$UR_{i,t}$	239	4.686	1.189	1.548	8.092	0.234	3.283
$Scale_{i,t}$	239	2.626	0.242	0.993	3.371	-0.962	11.874
$Industry_{i,t}$	239	9.407	1.050	6.983	13.173	0.338	3.033
$Transport_{i,t}$	239	2.642	0.620	1.173	4.618	0.415	3.267
$Education_{i,t}$	239	13.422	1.109	10.674	16.058	0.285	2.665
$Investment_{i,t}$	239	8.641	0.752	7.137	11.081	0.429	2.666

Table 4-16 Summary Statistics of Variables in 2006 (Chapter 6)

Variable	*Observations*	*Mean*	*Std. Dev.*	*Minimum*	*Maximum*	*Skewness*	*Kurtosis*
$TFP_{i,t}$	239	14.582	0.874	11.099	17.079	-0.062	3.907
$IFDI_{i,t}$	239	3.268	1.643	-1.560	7.415	-0.126	3.067
$RV_{i,t}$	239	6.606	2.332	1.379	12.395	0.329	2.954
$UR_{i,t}$	239	4.938	1.113	1.781	8.115	0.318	3.301
$Scale_{i,t}$	239	2.640	0.179	1.808	3.329	-0.611	5.912
$Industry_{i,t}$	239	9.660	1.035	7.177	13.315	0.410	3.154
$Transport_{i,t}$	239	2.685	0.661	1.128	5.655	0.965	5.216
$Education_{i,t}$	239	13.523	1.088	10.530	16.162	0.263	2.745
$Investment_{i,t}$	239	8.841	0.734	7.073	11.078	0.379	2.701

Table 4-17 Summary Statistics of Variables in 2007 (Chapter 6)

Variable	*Observations*	*Mean*	*Std. Dev.*	*Minimum*	*Maximum*	*Skewness*	*Kurtosis*
$TFP_{i,t}$	239	14.865	0.831	11.908	17.182	-0.056	3.608
$IFDI_{i,t}$	239	3.567	1.556	-1.559	7.453	-0.143	3.197
$RV_{i,t}$	239	6.539	2.586	-1.171	12.458	-0.028	3.386
$UR_{i,t}$	239	4.934	1.202	1.513	8.125	0.068	3.409
$Scale_{i,t}$	239	2.707	0.171	1.281	3.125	-2.323	22.328
$Industry_{i,t}$	239	9.926	1.007	7.249	13.387	0.359	3.150
$Transport_{i,t}$	239	2.740	0.631	1.358	5.380	0.773	4.222
$Education_{i,t}$	239	13.641	1.046	11.257	16.215	0.391	2.619
$Investment_{i,t}$	239	9.079	0.720	7.408	11.056	0.238	2.576

Table 4-18 Summary Statistics of Variables in 2008 (Chapter 6)

Variable	*Observations*	*Mean*	*Std. Dev.*	*Minimum*	*Maximum*	*Skewness*	*Kurtosis*
$TFP_{i,t}$	239	15.013	0.804	12.064	17.164	-0.133	3.669
$IFDI_{i,t}$	239	3.843	1.483	-1.330	7.520	-0.122	3.166
$RV_{i,t}$	239	7.285	2.340	0.008	13.096	0.332	3.037
$UR_{i,t}$	239	5.238	1.110	1.796	8.290	0.294	3.277
$Scale_{i,t}$	239	2.564	0.281	0.000	3.243	-3.689	32.322
$Industry_{i,t}$	239	10.177	0.976	7.970	13.452	0.311	3.013
$Transport_{i,t}$	239	2.808	0.653	1.456	5.770	0.918	4.656
$Education_{i,t}$	239	13.716	1.024	11.656	16.267	0.410	2.595
$Investment_{i,t}$	239	9.321	0.706	7.556	11.072	0.108	2.438

Table 4-19 Summary Statistics of Variables in 2009 (Chapter 6)

Variable	***Observations***	***Mean***	***Std. Dev.***	***Minimum***	***Maximum***	***Skewness***	***Kurtosis***
$\boldsymbol{TFP_{i,t}}$	239	15.075	0.770	12.341	17.222	-0.132	3.779
$\boldsymbol{IFDI_{i,t}}$	239	3.909	1.473	-0.310	7.433	-0.080	2.818
$\boldsymbol{RV_{i,t}}$	239	7.471	2.327	0.716	13.304	0.213	3.017
$\boldsymbol{UR_{i,t}}$	239	5.368	1.066	2.384	8.263	0.326	3.051
$\boldsymbol{Scale_{i,t}}$	239	2.521	0.375	-1.609	3.258	-6.359	65.709
$\boldsymbol{Industry_{i,t}}$	239	10.300	0.938	8.113	13.348	0.269	2.954
$\boldsymbol{Transport_{i,t}}$	239	2.937	0.699	1.420	6.388	1.280	6.312
$\boldsymbol{Education_{i,t}}$	239	13.808	1.007	11.639	16.324	0.417	2.612
$\boldsymbol{Investment_{i,t}}$	239	9.630	0.665	7.803	11.149	-0.027	2.623

Tables 4.11-4.19 illustrate the summary statistics of the indicators adopted in the regressions each year, with the variation tendency of both the dependent and independent variables over the 9 years. Focusing on the dependent variable, similar to the trend in Chapter 5, $TFP_{i,t}$ increased steadily over the period from 2002-2010, as the mean value increased from 13.130 in 2002 to 15.075 in 2010. In the meantime, both the minimum and maximum values of $TFP_{i,t}$ across all of the Chinese cities also increased. Therein, the minimum value increased from 10.640 in 2002 to 12.341 in 2010, while the maximum value increased from 15.959 to 17.222 during the same period. This indicates that the indigenous technological capabilities in the Chinese cities have steadily improved, and that both developed and underdeveloped cities have made great efforts.

Focusing on the main explanatory variables, namely $IFDI_{i,t}$, $RV_{i,t}$, and $UR_{,t}$, each of these has a distinctive variation trend. First, the mean value of $IFDI_{i,t}$ dramatically increased from 2.404 in 2001 to 3.909 in 2009. During the same period, the minimum value of $IFDI_{i,t}$ dramatically decreased from -2.003 to -3.233 from 2001-2002, and then rose again to -0.310 in 2009. By contrast, the fluctuations in the maximum value of $IFDI_{i,t}$ were less. This indicates that the total amount of foreign capital utilisation in Chinese cities increased over the first decade in the 21st century, and that the regional disparity is still large. Focusing on the industrial structures, the mean value of $RV_{i,t}$ maintained steady growth from 5.556 in 2001 to 7.471 in 2009, indicating that technologically related interindustry linkages became more complete over the period 2001-2009. The mean value of $UR_{i,t}$ also increased, from 4.401 to 5.368, over the same period, but the growth rate was much less than that of $RV_{i,t}$. This is because some new sectors emerged in Chinese cities, which enlarged the cognitive distance across industries. Moreover, the value of kurtosis of $UR_{i,t}$ is slightly higher than that of $RV_{i,t}$, indicating that the fluctuation in $UR_{i,t}$ was a little bit more than that of $UR_{i,t}$ across Chinese cities.

In regard to the control variables, the mean value of $Scale_{i,t}$ increased steadily from 2001-2007, but slightly decreased over the period 2008-2009. The mean value reached a peak at 2.707 in 2007, and reduced to 2.521 in 2009. This is mainly because the 2008 international financial crisis rapidly impeded Chinese import and export trade, further reducing the GDP growth rate. Notably, the kurtosis value of $Scale_{i,t}$ is the largest among all of the variables. This reflects the great complexity and uncertainty surrounding the economic growth rate across Chinese cities. The mean value of $Industry_{i,t}$ also maintained steady growth, from 8.510 in 2001 to 10.300 in 2009. Compared with $Scale_{i,t}$, the *Std. Dev.* of $Industry_{i,t}$ is much larger, indicating that the regional disparity in industrial output is huge across Chinese cities. Focusing on $Transport_{i,t}$, although its mean value increased steadily from 2001-2009, its Std. Dev. remained relatively stable. This illustrates that Chinese urban transport density increased, but the regional disparity did not significantly increase across cities during these 9 years. The Std. Dev. of $Education_{i,t}$ is the highest among all of the control variables, but it dramatically reduced from 1.214 in 2001 to 1.007 in 2009. This reflects China's accelerated educational investment in underdeveloped cities, and the reduction in the regional disparities across cities. Finally, the mean value of $Investment_{i,t}$ also increased from 7.658 to 9.630 during the same period. This is because Chinese economic development is still greatly dependent upon increasing fixed-asset investments.

4.4. Externalities of the Foreign Expansion Process and Industrial Structures in Host City FDI Spillovers between both Government and Market-Oriented Urban Groups

4.4.1. Dataset Collections and Compiling

Chapter 7 uses data sources from both the *Chinese Urban Statistical Yearbooks* and *The Annual Industrial Survey Database*. Due to the replication of the econometric regressions in the previous chapters, the data samples used are subsets of nationwide datasets. In other words, I select cities from just two clusters, namely Beijing-Tianjin-Hebei and the Shanghai-Yangtze River Delta, to verify whether the positive relationship between inward FDI and technological upgrading still exists in distinctive regional clusters. More specifically, each cluster has two datasets corresponding to it in the previous chapters, enabling the investigation of both the intra- and inter-regional externalities of the foreign expansion process and industrial structures in technological upgrading within place-specific conditions, respectively. There are 13 cities in the datasets on Beijing-Tianjin-Hebei, including 2 metropolitan and 11 prefectural cities. Meanwhile there are 26 cities in the datasets on the Shanghai-Yangtze River Delta, including 1 metropolitan and 25 prefectural cities.

Similar to the two previous chapters, a one-year lag is implemented for all of the independent variables in the panel regressions to eliminate potential endogeneity. This chapter also uses time periods that are consistent with those in the previous chapters. Hence, within Beijing-Tianjin-Hebei, the dataset for replication of the econometric regressions in Chapter 5 includes 13 cities over 8 years, from 2004-2011 (104 city/year observations), while the dataset for replication of the econometric regressions in Chapter 6 includes 13 cities over 9 years, from 2001-2009 (117 city/year observations). In the same vein, within the Shanghai-Yangtze River Delta, the first dataset includes 26 cities over 8 years, from 2004-2011 (208 city/year observations), while the other dataset includes 26 cities over 9 years, from 2001-2009 (234 city/year observations).

4.4.2. Variable Definitions

In this chapter, both the dependent and independent variables are the same as those in the previous empirical chapters. Hence, I do not explain the calculation procedures in detail here, but just list the variables.

To investigate both the intra- and inter-regional externalities of FDI expansion time-based characteristics, namely pace and rhythm, in technological upgrading based on evidence from Chinese cities, I select $TFP_{i,t}$ as the independent variable. $IFDI_{i,t}$, $Pace_{i,t}$, and $Rhythm_{i,t}$ are key explanatory variables in the econometric analysis. The reasons why I select these variables are fully explained in Section 4.2.2. Table 4.20 lists the variable definitions.

Table 4-20 Variables to Investigate Externalities of Foreign Expansion Process

Variables	***Definitions***
$\boldsymbol{TFP_{i,t}}$	Natural log of the Total Factor Productivity of city *i* in year *t*
$\boldsymbol{IFDI_{i,t}}$	Natural log of the annual flow inward foreign direct investment per capita in US dollar of city *i* in year *t*
$\boldsymbol{Pace_{i,t}}$	The increasing rate of MNEs expansion of city *i* in year *t*
$\boldsymbol{Rhythm_{i,t}}$	The kurtosis of MNEs expansion of city *i* in year *t*
$\boldsymbol{Scale_{i,t}}$	Natural log of the GDP growth rate of city *i* in year *t*
$\boldsymbol{Output_{i,t}}$	Natural log of the value of industrial output over total gross domestic products of city *i* in year *t*
$\boldsymbol{Transport_{i,t}}$	Natural log of the passenger capacity in times per capita of city *i* in year *t*
$\boldsymbol{Population_{i,t}}$	Natural log of the population in 10,000 people per square kilometer of city *i* in year *t*
$\boldsymbol{Education_{i,t}}$	Natural log of the number of people in tertiary education over total population of city *i* in year *t*

Sources: Chinese Urban Statistical Yearbooks (2004-2013)

To investigate both the intra- and inter-regional externalities of industrial structures, namely related and unrelated variety, in technological upgrading, based on evidence from Chinese cities, I select $TFP_{i,t}$ as the independent variable. $IFDI_{i,t}$, $RV_{i,t}$, and $UR_{i,t}$ are key explanatory variables in the econometric analysis. The reasons why I select these variables are fully explained in Section 4.3.2. Table 4.21 lists the variable definitions.

Table 4-21 Variables to Investigate Externalities of Industrial Structures

Variables	***Definitions***
$\boldsymbol{TFP_{i,t}}$	Natural log of the Total Factor Productivity of city *i* in year *t*
$\boldsymbol{IFDI_{i,t}}$	Natural log of annual flow inward foreign direct investment per capita of city *i* in year *t*
$\boldsymbol{RV_{i,t}}$	Natural log of related variety of city *i* in year *t*
$\boldsymbol{UR_{i,t}}$	Natural log of unrelated variety of city *i* in year *t*
$\boldsymbol{Scale_{i,t}}$	Natural log of the GDP growth rate of city *i* in year *t*
$\boldsymbol{Industry_{i,t}}$	Natural log of the value of industrial output per capita of city *i* in year *t*
$\boldsymbol{Transport_{i,t}}$	Natural log of the passenger capacity in times per capita of city *i* in year *t*
$\boldsymbol{Education_{i,t}}$	Natural log of number of people in tertiary education over total population of city *i* in year *t*
$\boldsymbol{Investment_{i,t}}$	Natural log of fixed asset investments over total population of city *i* in year *t*

Source: Chinese Urban Statistical Yearbook (2003-2011)

4.4.3. Estimation Methods

Chapter 7 replicates the economic regressions in the previous chapters, namely pooled OLS and ML spatial panel regressions, based on the specific evidence within two clusters. Therein, the pooled OLS regression is the baseline for the econometric analysis. I first regard $TFP_{i,t}$ as a function of FDI, foreign expansion time-based characteristics as well as regional effects of cities. It is expressed in a non-spatial form as follows:

$$TFP_{i,t} = \alpha + \beta_1 IFDI_{i,t-1} + \beta_2 Pace_{i,t-1} + \beta_3 Rhythm_{i,t-1} + \beta_4 \left(IFDI_{i,t-1} * Pace_{i,t-1}\right) + \beta_5 \left(IFDI_{i,t-1} * Rhythm_{i,t-1}\right) + \beta_6 Scale_{i,t-1} + \beta_7 Output_{i,t-1} + \beta_8 Transport_{i,t-1} + \beta_9 Population_{i,t-1} + \beta_{10} Education_{i,t-1} + \varepsilon_{i,t} \quad (24)$$

Where $TFP_{i,t}$ is the dependent variable, while $\varepsilon_{i,t}$ is the random disturbance term and α denotes the individual effect. As indicated before, a one-year lag is implemented for all of the independent variables to mitigate possible endogeneity across different variables in the production function (Fu, 2008, Usai, 2011).

In order to explore both the intra- and inter-regional externalities of foreign pace and rhythm in FDI spillovers based on evidence from Chinese cities, I employ the spatial econometric model (LeSage and Pace, 2009). Based on the study of Elhorst (2014), it is necessary to first identify the existence of spatial autocorrelations to differentiate the error or lag form of spatial dependence, and determine the final model. As indicated above, this is based the use of robust versions of Lagrange multiplier tests. The determining procedures are introduced in the econometric configurations of Chapter 5 in detail, so they will not be repeated here.

Finally, I adopt a general approach to determine a Spatial Durbin Model (SDM) as follows, to examine whether it can be simplified to either a lag or error form.

$$TFP_{i,t} = \alpha + \beta \sum_{h=1}^{n} W_{i,h}\, TFP_{h,t} + \delta X_{i,t} + \theta \sum_{h=1}^{n} W_{i,h}\, X_{i,t} + \varepsilon_{i,t} \qquad (25)$$

θ denotes the corresponding estimated parameters of $\sum_{h=1}^{n} W_{i,h}\, X_{i,t}$. In order to control for the simultaneity that emerges due to spatially weighted dependent variables, I adopt Elhorst (2014) maximum likelihood method to examine all of the spatial models above. If one of the SAR and SEM tests is suitable to describe the data, we proceed with that estimation model accordingly. On the contrary, if those tests are inconsistent, then we adopt the general SDM model. Finally, we employ spatial Hausman tests following LeSage and Pace (2010) to examine whether the random effect can be used to replace the fixed effect in our estimations. In the case of fixed effects, we further test whether either spatial or time-period fixed effects ("two way" fixed effects) should be included or jointly included in the estimation models based on likelihood ratio (LR) tests.

Similarly, pooled OLS and ML spatial panel regressions are also adopted to investigate both the intra- and inter-regional externalities of industrial structures, namely related and unrelated variety, in technological upgrading based on evidence from Chinese cities. Therein, the pooled OLS regressions are the baseline for the econometric analysis. I first regard $TFP_{i,t}$ as a function of FDI, related and unrelated variety and regional effects of cities.

$$TFP_{i,t} = \alpha + \beta_1 IFDI_{i,t-1} + \beta_2 RV_{i,t-1} + \beta_3 UR_{i,t-1} + \beta_4 \left(IFDI_{i,t-1} * RV_{i,t-1}\right) + \beta_5 \left(IFDI_{i,t-1} * UR_{i,t-1}\right) + \beta_6 Scale_{i,t-1} + \beta_7 Industry_{i,t-1} + \beta_8 Transport_{i,t-1} + \beta_9 Education_{i,t-1} + \beta_{10} Investment_{i,t-1} + \varepsilon_{i,t} \qquad (26)$$

Where $TFP_{i,t}$ is the dependent variable, $\varepsilon_{i,t}$ is the random disturbance term and α denotes the individual effect. As indicated before, a one-year lag is implemented for all of the independent variables to mitigate possible endogeneity across different variables in the production function (Fu, 2008, Usai, 2011).

Then, I employ the spatial econometric model to investigate the externalities of industrial structures in technological upgrading both within and across cities. I adopt a general approach to determine a Spatial Durbin Model (SDM) as follows, to examine whether it can be simplified to either a lag or error form.

$$TFP_{i,t} = \alpha + \beta \sum_{h=1}^{n} W_{i,h} TFP_{h,t} + \delta X_{i,t} + \theta \sum_{h=1}^{n} W_{i,h} X_{i,t} + \varepsilon_{i,t} \qquad (27)$$

θ denotes the corresponding estimated parameters of $\sum_{h=1}^{n} W_{i,h} X_{i,t}$. In order to control for the simultaneity that emerges from spatially weighted dependent variables, I adopt Elhorst (2014) maximum likelihood method to examine all of the spatial models above. If one of the SAR and SEM tests is suitable to describe the data, we proceed with that estimation model accordingly. On the contrary, if those tests are inconsistent, then we adopt the general SDM model. Finally, we employ spatial Hausman tests following LeSage and Pace (2010) to examine whether the random effect can be used to replace the fixed effect in our estimations. In the case of fixed effects, we further test whether either spatial or time-period fixed effects ("two way" fixed effects) should be included or jointly included in the estimation models based on likelihood ratio (LR) tests.

4.4.4. Univariate Analysis

Beijing-Tianjin-Hebei (BTH): To investigate externalities of pace and rhythm:

Table 4-22 BTH Summary Statistics of Variables in 2004 (Chapter 7-1)

Variable	*Observations*	*Mean*	*Std. Dev.*	*Minimum*	*Maximum*	*Skewness*	*Kurtosis*
$TFP_{i,t}$	13	5.499	0.494	4.627	6.528	0.496	3.133
$IFDI_{i,t}$	13	3.604	1.087	2.108	5.580	0.659	2.486
$Pace_{i,t}$	13	0.326	4.456	-9.091	9.688	-0.044	3.956
$Rhythm_{i,t}$	13	2.012	1.596	-0.039	4.713	0.097	1.668
$Scale_{i,t}$	13	2.649	0.078	2.526	2.760	-0.118	1.777
$Output_{i,t}$	13	3.907	0.117	3.627	4.044	-1.219	3.804
$Transport_{i,t}$	13	2.430	0.572	1.482	3.734	0.648	3.404
$Population_{i,t}$	13	-3.139	0.660	-4.697	-2.548	-1.599	4.159
$Education_{i,t}$	13	4.513	0.958	2.945	6.064	0.045	1.931

Table 4-23 BTH Summary Statistics of Variables in 2005 (Chapter 7-1)

Variable	*Observations*	*Mean*	*Std. Dev.*	*Minimum*	*Maximum*	*Skewness*	*Kurtosis*
$TFP_{i,t}$	13	5.743	0.533	4.815	6.786	0.271	2.583
$IFDI_{i,t}$	13	3.754	1.121	2.298	5.870	0.656	2.466
$Pace_{i,t}$	13	21.380	20.061	-5.556	73.684	1.187	4.668
$Rhythm_{i,t}$	13	2.012	1.596	-0.039	4.713	0.097	1.668
$Scale_{i,t}$	13	2.644	0.117	2.468	2.833	0.264	1.963
$Output_{i,t}$	13	3.885	0.185	3.382	4.048	-1.718	5.256
$Transport_{i,t}$	13	2.502	0.594	1.606	3.942	0.892	3.836
$Population_{i,t}$	13	-3.130	0.664	-4.696	-2.541	-1.592	4.148
$Education_{i,t}$	13	4.654	0.956	3.101	6.119	0.043	1.828

Table 4-24 BTH Summary Statistics of Variables in 2006 (Chapter 7-1)

Variable	*Observations*	*Mean*	*Std. Dev.*	*Minimum*	*Maximum*	*Skewness*	*Kurtosis*
$TFP_{i,t}$	13	6.009	0.508	5.167	6.974	0.135	2.393
$IFDI_{i,t}$	13	3.636	1.417	1.146	6.076	0.220	2.482
$Pace_{i,t}$	13	4.486	10.053	-11.765	20.098	-0.136	1.892
$Rhythm_{i,t}$	13	2.012	1.596	-0.039	4.713	0.097	1.668
$Scale_{i,t}$	13	2.586	0.214	2.028	2.896	-1.360	4.808
$Output_{i,t}$	13	3.888	0.207	3.326	4.061	-1.735	5.266
$Transport_{i,t}$	13	2.418	0.386	1.788	3.157	0.116	2.319
$Population_{i,t}$	13	-3.120	0.666	-4.689	-2.530	-1.589	4.141
$Education_{i,t}$	13	4.726	0.937	3.142	6.138	0.031	1.886

Table 4-25 BTH Summary Statistics of Variables in 2007 (Chapter 7-1)

Variable	*Observations*	*Mean*	*Std. Dev.*	*Minimum*	*Maximum*	*Skewness*	*Kurtosis*
$TFP_{i,t}$	13	6.290	0.520	5.460	7.214	0.214	2.297
$IFDI_{i,t}$	13	3.648	1.496	1.107	6.310	0.350	2.391
$Pace_{i,t}$	13	3.325	7.856	-9.091	22.222	0.766	3.920
$Rhythm_{i,t}$	13	2.012	1.596	-0.039	4.713	0.097	1.668
$Scale_{i,t}$	13	2.524	0.385	1.281	2.797	-2.844	9.828
$Output_{i,t}$	13	3.894	0.213	3.290	4.050	-1.952	6.065
$Transport_{i,t}$	13	2.508	0.370	1.987	3.189	0.038	2.001
$Population_{i,t}$	13	-3.107	0.668	-4.680	-2.506	-1.583	4.128
$Education_{i,t}$	13	4.819	0.864	3.574	6.149	0.205	1.670

Table 4-26 BTH Summary Statistics of Variables in 2008 (Chapter 7-1)

Variable	***Observations***	***Mean***	***Std. Dev.***	***Minimum***	***Maximum***	***Skewness***	***Kurtosis***
$\boldsymbol{TFP_{i,t}}$	13	6.380	0.527	5.542	7.348	0.271	2.234
$\boldsymbol{IFDI_{i,t}}$	13	4.032	1.318	2.551	6.641	0.710	2.407
$\boldsymbol{Pace_{i,t}}$	13	5.255	3.747	0.595	13.636	0.574	3.011
$\boldsymbol{Rhythm_{i,t}}$	13	2.012	1.596	-0.039	4.713	0.097	1.668
$\boldsymbol{Scale_{i,t}}$	13	2.450	0.167	2.192	2.803	0.229	2.873
$\boldsymbol{Output_{i,t}}$	13	3.900	0.232	3.246	4.097	-1.824	5.956
$\boldsymbol{Transport_{i,t}}$	13	2.443	0.399	1.673	3.202	-0.144	2.816
$\boldsymbol{Population_{i,t}}$	13	-3.089	0.676	-4.673	-2.496	-1.559	4.082
$\boldsymbol{Education_{i,t}}$	13	4.874	0.822	3.634	6.093	0.141	1.693

Table 4-27 BTH Summary Statistics of Variables in 2009 (Chapter 7-1)

Variable	***Observations***	***Mean***	***Std. Dev.***	***Minimum***	***Maximum***	***Skewness***	***Kurtosis***
$\boldsymbol{TFP_{i,t}}$	13	6.638	0.519	5.826	7.623	0.410	2.341
$\boldsymbol{IFDI_{i,t}}$	13	4.128	1.301	2.759	6.825	0.842	2.589
$\boldsymbol{Pace_{i,t}}$	13	-0.551	9.216	-13.333	20.591	0.964	3.349
$\boldsymbol{Rhythm_{i,t}}$	13	2.012	1.596	-0.039	4.713	0.097	1.668
$\boldsymbol{Scale_{i,t}}$	13	2.392	0.138	2.251	2.803	2.077	7.316
$\boldsymbol{Output_{i,t}}$	13	3.857	0.238	3.157	4.056	-2.143	6.908
$\boldsymbol{Transport_{i,t}}$	13	2.578	0.750	1.672	4.677	1.710	5.881
$\boldsymbol{Population_{i,t}}$	13	-3.083	0.675	-4.667	-2.485	-1.572	4.101
$\boldsymbol{Education_{i,t}}$	13	4.946	0.841	3.654	6.138	0.098	1.618

Table 4-28 BTH Summary Statistics of Variables in 2010 (Chapter 7-1)

Variable	*Observations*	*Mean*	*Std. Dev.*	*Minimum*	*Maximum*	*Skewness*	*Kurtosis*
$TFP_{i,t}$	13	6.812	0.512	5.981	7.668	0.252	2.095
$IFDI_{i,t}$	13	4.224	1.285	2.931	7.004	0.967	2.795
$Pace_{i,t}$	13	-3.588	7.938	-23.077	8.108	-0.901	3.998
$Rhythm_{i,t}$	13	2.012	1.596	-0.039	4.713	0.097	1.668
$Scale_{i,t}$	13	2.568	0.127	2.332	2.856	0.421	3.627
$Output_{i,t}$	13	3.865	0.230	3.178	4.063	-2.222	7.226
$Transport_{i,t}$	13	2.691	0.685	1.952	4.717	2.104	7.138
$Population_{i,t}$	13	-3.073	0.677	-4.664	-2.480	-1.571	4.098
$Education_{i,t}$	13	4.961	0.828	3.688	6.130	0.111	1.658

Table 4-29 BTH Summary Statistics of Variables in 2011 (Chapter 7-1)

Variable	*Observations*	*Mean*	*Std. Dev.*	*Minimum*	*Maximum*	*Skewness*	*Kurtosis*
$TFP_{i,t}$	13	6.858	0.521	6.029	7.747	0.220	1.977
$IFDI_{i,t}$	13	4.197	1.615	0.782	7.178	-0.118	3.225
$Pace_{i,t}$	13	-17.403	7.487	-29.452	-6.504	-0.270	1.833
$Rhythm_{i,t}$	13	2.012	1.596	-0.039	4.713	0.097	1.668
$Scale_{i,t}$	13	2.444	0.182	2.079	2.797	-0.674	3.968
$Output_{i,t}$	13	3.885	0.249	3.139	4.096	-2.275	7.353
$Transport_{i,t}$	13	2.745	0.671	2.087	4.737	2.133	7.163
$Population_{i,t}$	13	-3.074	0.680	-4.660	-2.468	-1.526	4.007
$Education_{i,t}$	13	4.988	0.828	3.697	6.115	0.074	1.655

To investigate externalities of related and unrelated variety:

Table 4-30 BTH Summary Statistics of Variables in 2001 (Chapter 7-2)

Variable	***Observations***	***Mean***	***Std. Dev.***	***Minimum***	***Maximum***	***Skewness***	***Kurtosis***
$TFP_{i,t}$	13	13.558	0.549	12.843	14.849	0.863	3.418
$IFDI_{i,t}$	13	2.957	1.568	0.022	5.879	0.486	3.304
$RV_{i,t}$	13	6.320	2.127	2.715	10.590	0.474	2.760
$UR_{i,t}$	13	4.886	1.153	2.859	7.280	0.567	3.119
$Scale_{i,t}$	13	2.033	0.681	0.000	2.695	-2.152	7.308
$Industry_{i,t}$	13	8.786	0.755	8.084	10.379	1.110	3.015
$Transport_{i,t}$	13	2.327	0.489	1.284	3.083	-0.378	2.839
$Education_{i,t}$	13	13.295	0.937	11.977	14.925	0.280	1.870
$Investment_{i,t}$	13	7.708	0.766	6.779	9.444	0.975	3.142

Table 4-31 BTH Summary Statistics of Variables in 2002 (Chapter 7-2)

Variable	***Observations***	***Mean***	***Std. Dev.***	***Minimum***	***Maximum***	***Skewness***	***Kurtosis***
$TFP_{i,t}$	13	13.850	0.531	13.076	15.071	0.784	3.284
$IFDI_{i,t}$	13	2.895	1.628	0.756	6.106	0.901	3.090
$RV_{i,t}$	13	6.310	2.244	2.398	10.507	0.338	2.529
$UR_{i,t}$	13	4.875	1.189	2.796	7.238	0.495	2.895
$Scale_{i,t}$	13	2.353	0.074	2.251	2.526	1.027	3.449
$Industry_{i,t}$	13	8.905	0.749	8.217	10.496	1.098	2.972
$Transport_{i,t}$	13	2.377	0.514	1.325	3.218	-0.185	2.807
$Education_{i,t}$	13	13.423	0.924	11.977	15.070	0.175	2.101
$Investment_{i,t}$	13	8.117	0.625	7.366	9.678	1.283	4.113

Table 4-32 BTH Summary Statistics of Variables in 2003 (Chapter 7-2)

Variable	*Observations*	*Mean*	*Std. Dev.*	*Minimum*	*Maximum*	*Skewness*	*Kurtosis*
$TFP_{i,t}$	13	14.247	0.474	13.561	15.365	0.978	3.595
$IFDI_{i,t}$	13	3.277	1.092	1.578	5.230	0.474	2.485
$RV_{i,t}$	13	6.335	2.432	0.959	10.540	-0.307	3.295
$UR_{i,t}$	13	4.906	1.219	2.515	7.243	0.189	3.051
$Scale_{i,t}$	13	2.509	0.075	2.370	2.695	0.816	4.631
$Industry_{i,t}$	13	9.148	0.734	8.472	10.686	1.037	2.788
$Transport_{i,t}$	13	2.224	0.510	1.332	3.280	0.323	2.811
$Education_{i,t}$	13	13.631	0.966	12.045	15.183	-0.043	1.959
$Investment_{i,t}$	13	8.424	0.603	7.667	9.840	1.115	3.548

Table 4-33 BTH Summary Statistics of Variables in 2004 (Chapter 7-2)

Variable	*Observations*	*Mean*	*Std. Dev.*	*Minimum*	*Maximum*	*Skewness*	*Kurtosis*
$TFP_{i,t}$	13	14.544	0.512	13.673	15.616	0.524	3.043
$IFDI_{i,t}$	13	3.604	1.087	2.108	5.580	0.659	2.486
$RV_{i,t}$	13	7.180	1.984	4.586	10.809	0.702	2.255
$UR_{i,t}$	13	5.334	1.007	4.076	7.340	0.999	2.869
$Scale_{i,t}$	13	2.649	0.078	2.526	2.760	-0.118	1.777
$Industry_{i,t}$	13	9.514	0.686	8.829	10.962	1.016	2.753
$Transport_{i,t}$	13	2.430	0.572	1.482	3.734	0.648	3.404
$Education_{i,t}$	13	13.723	0.958	12.156	15.275	0.045	1.931
$Investment_{i,t}$	13	8.670	0.563	7.963	9.987	1.100	3.487

Table 4-34 BTH Summary Statistics of Variables in 2005 (Chapter 7-2)

Variable	*Observations*	*Mean*	*Std. Dev.*	*Minimum*	*Maximum*	*Skewness*	*Kurtosis*
$TFP_{i,t}$	13	14.777	0.554	13.848	15.865	0.315	2.503
$IFDI_{i,t}$	13	3.754	1.121	2.298	5.870	0.656	2.466
$RV_{i,t}$	13	7.248	1.923	4.242	10.691	0.511	2.273
$UR_{i,t}$	13	5.379	0.969	4.016	7.308	0.885	2.849
$Scale_{i,t}$	13	2.644	0.117	2.468	2.833	0.264	1.963
$Industry_{i,t}$	13	9.788	0.709	9.004	11.186	0.881	2.529
$Transport_{i,t}$	13	2.502	0.594	1.606	3.942	0.892	3.836
$Education_{i,t}$	13	13.864	0.956	12.311	15.330	0.043	1.828
$Investment_{i,t}$	13	8.911	0.520	8.223	10.084	0.972	3.163

Table 4-35 BTH Summary Statistics of Variables in 2006 (Chapter 7-2)

Variable	*Observations*	*Mean*	*Std. Dev.*	*Minimum*	*Maximum*	*Skewness*	*Kurtosis*
$TFP_{i,t}$	13	15.034	0.524	14.183	16.043	0.185	2.386
$IFDI_{i,t}$	13	3.636	1.417	1.146	6.076	0.220	2.482
$RV_{i,t}$	13	7.598	1.753	5.189	11.008	0.704	2.489
$UR_{i,t}$	13	5.582	0.911	4.427	7.425	0.926	2.862
$Scale_{i,t}$	13	2.586	0.214	2.028	2.896	-1.360	4.808
$Industry_{i,t}$	13	9.971	0.724	9.140	11.406	0.793	2.482
$Transport_{i,t}$	13	2.418	0.386	1.788	3.157	0.116	2.319
$Education_{i,t}$	13	13.937	0.937	12.353	15.348	0.031	1.886
$Investment_{i,t}$	13	9.073	0.526	8.504	10.245	1.023	3.006

Table 4-36 BTH Summary Statistics of Variables in 2007 (Chapter 7-2)

Variable	*Observations*	*Mean*	*Std. Dev.*	*Minimum*	*Maximum*	*Skewness*	*Kurtosis*
$TFP_{i,t}$	13	15.305	0.530	14.459	16.267	0.231	2.336
$IFDI_{i,t}$	13	3.648	1.496	1.107	6.310	0.350	2.391
$RV_{i,t}$	13	7.434	1.855	4.499	10.902	0.499	2.437
$UR_{i,t}$	13	5.503	0.921	4.203	7.378	0.906	3.003
$Scale_{i,t}$	13	2.524	0.385	1.281	2.797	-2.844	9.828
$Industry_{i,t}$	13	10.194	0.700	9.383	11.562	0.634	2.410
$Transport_{i,t}$	13	2.508	0.370	1.987	3.189	0.038	2.001
$Education_{i,t}$	13	14.030	0.864	12.785	15.359	0.205	1.670
$Investment_{i,t}$	13	9.269	0.578	8.438	10.395	0.545	2.352

Table 4-37 BTH Summary Statistics of Variables in 2008 (Chapter 7-2)

Variable	*Observations*	*Mean*	*Std. Dev.*	*Minimum*	*Maximum*	*Skewness*	*Kurtosis*
$TFP_{i,t}$	13	15.379	0.540	14.516	16.383	0.250	2.281
$IFDI_{i,t}$	13	4.032	1.318	2.551	6.641	0.710	2.407
$RV_{i,t}$	13	7.806	1.755	4.903	10.905	0.177	2.326
$UR_{i,t}$	13	5.675	0.809	4.592	7.267	0.890	2.818
$Scale_{i,t}$	13	2.450	0.167	2.192	2.803	0.229	2.873
$Industry_{i,t}$	13	10.430	0.682	9.607	11.738	0.468	2.272
$Transport_{i,t}$	13	2.443	0.399	1.673	3.202	-0.144	2.816
$Education_{i,t}$	13	14.084	0.822	12.844	15.304	0.141	1.693
$Investment_{i,t}$	13	9.480	0.559	8.626	10.467	0.358	2.082

Table 4-38 BTH Summary Statistics of Variables in 2009 (Chapter 7-2)

Variable	*Observations*	*Mean*	*Std. Dev.*	*Minimum*	*Maximum*	*Skewness*	*Kurtosis*
$TFP_{i,t}$	13	15.421	0.532	14.590	16.427	0.320	2.259
$IFDI_{i,t}$	13	4.128	1.301	2.759	6.825	0.842	2.589
$RV_{i,t}$	13	7.935	1.783	4.989	11.222	0.108	2.470
$UR_{i,t}$	13	5.733	0.830	4.489	7.422	0.748	2.851
$Scale_{i,t}$	13	2.392	0.138	2.251	2.803	2.077	7.316
$Industry_{i,t}$	13	10.467	0.685	9.602	11.802	0.562	2.294
$Transport_{i,t}$	13	2.578	0.750	1.672	4.677	1.710	5.881
$Education_{i,t}$	13	14.157	0.841	12.864	15.349	0.098	1.618
$Investment_{i,t}$	13	9.833	0.552	9.022	10.841	0.373	2.062

Shanghai-Yangtze River Delta (YRD): To investigate externalities of pace and rhythm:

Table 4-39 YRD Summary Statistics of Variables in 2004 (Chapter 7-1)

Variable	*Observations*	*Mean*	*Std. Dev.*	*Minimum*	*Maximum*	*Skewness*	*Kurtosis*
$TFP_{i,t}$	26	6.036	0.846	3.974	7.485	-0.498	2.929
$IFDI_{i,t}$	26	4.557	1.395	0.999	6.734	-0.684	2.908
$Pace_{i,t}$	26	20.871	23.323	-18.182	115.085	2.464	11.570
$Rhythm_{i,t}$	26	2.450	2.265	-1.324	7.460	0.219	2.691
$Scale_{i,t}$	26	2.733	0.229	2.342	3.629	2.010	10.521
$Output_{i,t}$	26	3.980	0.146	3.674	4.238	-0.530	2.585
$Transport_{i,t}$	26	3.032	0.705	1.519	4.417	-0.267	2.396
$Population_{i,t}$	26	-2.814	0.491	-3.975	-1.545	-0.210	4.149
$Education_{i,t}$	26	4.588	1.146	1.554	6.736	-0.439	3.284

Table 4-40 YRD Summary Statistics of Variables in 2005 (Chapter 7-1)

Variable	*Observations*	*Mean*	*Std. Dev.*	*Minimum*	*Maximum*	*Skewness*	*Kurtosis*
$TFP_{i,t}$	26	6.286	0.800	4.271	7.660	-0.508	3.135
$IFDI_{i,t}$	26	4.639	1.297	1.720	6.736	-0.611	2.639
$Pace_{i,t}$	26	29.662	23.886	-14.253	76.000	0.142	2.540
$Rhythm_{i,t}$	26	2.450	2.265	-1.324	7.460	0.219	2.691
$Scale_{i,t}$	26	2.648	0.153	2.262	2.923	-0.347	3.273
$Output_{i,t}$	26	3.946	0.178	3.608	4.199	-0.626	2.210
$Transport_{i,t}$	26	3.134	0.666	1.942	4.514	-0.006	2.150
$Population_{i,t}$	26	-2.813	0.491	-3.969	-1.571	-0.236	3.997
$Education_{i,t}$	26	4.753	1.106	1.834	6.848	-0.424	3.258

Table 4-41 YRD Summary Statistics of Variables in 2006 (Chapter 7-1)

Variable	*Observations*	*Mean*	*Std. Dev.*	*Minimum*	*Maximum*	*Skewness*	*Kurtosis*
$TFP_{i,t}$	26	6.547	0.747	4.547	7.842	-0.594	3.548
$IFDI_{i,t}$	26	4.988	1.116	2.252	6.899	-0.554	2.708
$Pace_{i,t}$	26	16.707	11.194	-10.049	39.535	-0.184	3.010
$Rhythm_{i,t}$	26	2.450	2.265	-1.324	7.460	0.219	2.691
Scalei,t	26	2.681	0.100	2.485	2.890	-0.127	2.842
$Output_{i,t}$	26	3.963	0.167	3.639	4.204	-0.592	2.223
$Transport_{i,t}$	26	3.208	0.684	2.009	4.677	0.019	2.231
$Population_{i,t}$	26	-2.805	0.494	-3.964	-1.534	-0.196	4.056
$Education_{i,t}$	26	4.899	1.072	2.197	6.930	-0.359	2.975

Table 4-42 YRD Summary Statistics of Variables in 2007 (Chapter 7-1)

Variable	*Observations*	*Mean*	*Std. Dev.*	*Minimum*	*Maximum*	*Skewness*	*Kurtosis*
$TFP_{i,t}$	26	6.766	0.658	5.074	8.044	-0.383	3.486
$IFDI_{i,t}$	26	5.275	0.997	3.141	7.045	-0.458	2.327
$Pace_{i,t}$	26	15.677	8.196	6.039	38.462	1.267	3.971
$Rhythm_{i,t}$	26	2.450	2.265	-1.324	7.460	0.219	2.691
$Scale_{i,t}$	26	2.717	0.092	2.451	2.896	-0.553	4.371
$Output_{i,t}$	26	3.967	0.163	3.628	4.216	-0.586	2.322
$Transport_{i,t}$	26	3.301	0.673	2.018	4.666	-0.125	2.189
$Population_{i,t}$	26	-2.801	0.494	-3.958	-1.526	-0.183	4.064
$Education_{i,t}$	26	5.011	1.035	2.395	7.005	-0.358	2.981

Table 4-43 YRD Summary Statistics of Variables in 2008 (Chapter 7-1)

Variable	***Observations***	***Mean***	***Std. Dev.***	***Minimum***	***Maximum***	***Skewness***	***Kurtosis***
$TFP_{i,t}$	26	6.870	0.617	5.425	8.161	-0.025	3.145
$IFDI_{i,t}$	26	5.404	1.027	3.238	7.163	-0.694	2.663
$Pace_{i,t}$	26	12.891	10.851	-5.000	53.846	1.965	9.065
$Rhythm_{i,t}$	26	2.450	2.265	-1.324	7.460	0.219	2.691
$Scale_{i,t}$	26	2.535	0.188	2.197	2.966	0.253	2.679
$Output_{i,t}$	26	3.978	0.145	3.709	4.219	-0.318	2.048
$Transport_{i,t}$	26	3.407	0.696	2.061	4.700	-0.213	2.167
$Population_{i,t}$	26	-2.796	0.494	-3.952	-1.517	-0.174	4.080
$Education_{i,t}$	26	5.126	0.991	2.537	7.057	-0.403	3.223

Table 4-44 YRD Summary Statistics of Variables in 2009 (Chapter 7-1)

Variable	***Observations***	***Mean***	***Std. Dev.***	***Minimum***	***Maximum***	***Skewness***	***Kurtosis***
$TFP_{i,t}$	26	7.131	0.549	5.899	8.318	0.136	2.989
$IFDI_{i,t}$	26	5.400	1.100	3.031	7.169	-0.665	2.546
$Pace_{i,t}$	26	8.922	11.063	-11.321	26.844	-0.118	1.773
$Rhythm_{i,t}$	26	2.450	2.265	-1.324	7.460	0.219	2.691
$Scale_{i,t}$	26	2.458	0.225	1.902	2.879	-0.523	2.863
$Output_{i,t}$	26	3.964	0.138	3.686	4.218	-0.183	2.281
$Transport_{i,t}$	26	3.449	0.654	2.274	4.755	0.038	2.368
$Population_{i,t}$	26	-2.792	0.494	-3.946	-1.510	-0.165	4.091
$Education_{i,t}$	26	5.188	0.971	2.690	7.113	-0.367	3.206

Table 4-45 YRD Summary Statistics of Variables in 2010 (Chapter 7-1)

Variable	*Observations*	*Mean*	*Std. Dev.*	*Minimum*	*Maximum*	*Skewness*	*Kurtosis*
$TFP_{i,t}$	26	7.193	0.585	5.995	8.452	-0.100	2.978
$IFDI_{i,t}$	26	5.512	1.108	3.120	7.199	-0.770	2.570
$Pace_{i,t}$	26	0.814	5.023	-10.638	10.000	-0.270	2.847
$Rhythm_{i,t}$	26	2.450	2.265	-1.324	7.460	0.219	2.691
$Scale_{i,t}$	26	2.609	0.137	2.336	2.901	0.357	2.898
$Output_{i,t}$	26	3.980	0.128	3.739	4.287	0.473	3.260
$Transport_{i,t}$	26	3.594	0.677	2.370	5.051	0.042	2.436
$Population_{i,t}$	26	-2.787	0.496	-3.943	-1.502	-0.159	4.072
$Education_{i,t}$	26	5.235	0.936	2.887	7.135	-0.258	3.153

Table 4-46 YRD Summary Statistics of Variables in 2011 (Chapter 7-1)

Variable	*Observations*	*Mean*	*Std. Dev.*	*Minimum*	*Maximum*	*Skewness*	*Kurtosis*
$TFP_{i,t}$	26	7.265	0.600	5.881	8.512	-0.157	2.888
$IFDI_{i,t}$	26	5.591	1.020	3.193	7.247	-0.645	2.703
$Pace_{i,t}$	26	-21.501	6.902	-33.679	-1.099	0.948	4.436
$Rhythm_{i,t}$	26	2.450	2.265	-1.324	7.460	0.219	2.691
$Scale_{i,t}$	26	2.464	0.159	2.079	2.773	-0.554	3.691
$Output_{i,t}$	26	3.981	0.126	3.721	4.314	0.566	4.041
$Transport_{i,t}$	26	3.617	0.674	2.495	5.080	0.159	2.668
$Population_{i,t}$	26	-2.802	0.493	-3.937	-1.497	-0.042	4.166
$Education_{i,t}$	26	2.264	0.923	0.058	4.387	-0.044	3.276

To investigate externalities of related and unrelated variety:

Table 4-47 YRD Summary Statistics of Variables in 2001 (Chapter 7-2)

Variable	***Observations***	***Mean***	***Std. Dev.***	***Minimum***	***Maximum***	***Skewness***	***Kurtosis***
$TFP_{i,t}$	26	14.116	0.946	11.704	15.428	-0.591	2.833
$IFDI_{i,t}$	26	3.554	1.522	0.194	6.255	-0.143	2.413
$RV_{i,t}$	26	7.161	2.714	0.865	11.172	-0.805	2.887
$UR_{i,t}$	26	5.216	1.347	2.357	7.615	-0.546	2.602
$Scale_{i,t}$	26	2.163	0.466	0.637	2.657	-1.670	5.651
$Industry_{i,t}$	26	9.446	0.971	6.965	10.874	-0.634	3.033
$Transport_{i,t}$	26	2.931	0.670	1.561	4.350	-0.107	2.318
$Education_{i,t}$	26	13.140	1.153	10.321	15.430	-0.278	2.957
$Investment_{i,t}$	26	7.984	0.736	6.522	9.618	-0.132	2.745

Table 4-48 YRD Summary Statistics of Variables in 2002 (Chapter 7-2)

Variable	***Observations***	***Mean***	***Std. Dev.***	***Minimum***	***Maximum***	***Skewness***	***Kurtosis***
$TFP_{i,t}$	26	14.478	0.949	12.190	15.896	-0.506	2.613
$IFDI_{i,t}$	26	3.927	1.532	0.881	6.715	-0.266	2.354
$RV_{i,t}$	26	7.451	2.665	1.739	11.295	-0.762	2.642
$UR_{i,t}$	26	5.346	1.357	2.402	7.656	-0.613	2.579
$Scale_{i,t}$	26	2.429	0.220	1.723	2.639	-1.722	5.510
$Industry_{i,t}$	26	9.615	0.975	7.201	10.991	-0.653	2.968
$Transport_{i,t}$	26	2.983	0.656	1.703	4.381	-0.089	2.247
$Education_{i,t}$	26	13.382	1.152	10.319	15.636	-0.441	3.447
$Investment_{i,t}$	26	8.175	0.730	6.656	9.705	-0.290	2.730

Table 4-49 YRD Summary Statistics of Variables in 2003 (Chapter 7-2)

Variable	*Observations*	*Mean*	*Std. Dev.*	*Minimum*	*Maximum*	*Skewness*	*Kurtosis*
$TFP_{i,t}$	26	14.784	0.903	12.605	16.257	-0.441	2.749
$IFDI_{i,t}$	26	4.421	1.472	0.793	7.049	-0.446	2.784
$RV_{i,t}$	26	7.711	2.856	1.544	11.524	-0.780	2.609
$UR_{i,t}$	26	5.478	1.393	2.431	7.774	-0.623	2.539
$Scale_{i,t}$	26	2.563	0.326	1.224	2.890	-2.899	12.149
$Industry_{i,t}$	26	9.874	0.990	7.571	11.341	-0.592	2.775
$Transport_{i,t}$	26	2.963	0.668	1.682	4.347	-0.054	2.171
$Education_{i,t}$	26	13.628	1.084	10.972	15.579	-0.330	2.845
$Investment_{i,t}$	26	8.940	0.759	7.327	10.079	-0.566	2.481

Table 4-50 YRD Summary Statistics of Variables in 2004 (Chapter 7-2)

Variable	*Observations*	*Mean*	*Std. Dev.*	*Minimum*	*Maximum*	*Skewness*	*Kurtosis*
$TFP_{i,t}$	26	15.027	0.863	12.893	16.499	-0.492	2.924
$IFDI_{i,t}$	26	4.557	1.395	0.999	6.734	-0.684	2.908
$RV_{i,t}$	26	8.647	3.274	1.513	13.033	-0.684	2.467
$UR_{i,t}$	26	5.868	1.551	2.635	8.153	-0.546	2.294
$Scale_{i,t}$	26	2.733	0.229	2.342	3.629	2.010	10.521
$Industry_{i,t}$	26	10.169	0.982	7.921	11.712	-0.582	2.750
$Transport_{i,t}$	26	3.032	0.705	1.519	4.417	-0.267	2.396
$Education_{i,t}$	26	13.799	1.146	10.765	15.946	-0.439	3.284
$Investment_{i,t}$	26	9.194	0.723	7.605	10.164	-0.692	2.690

Table 4-51 YRD Summary Statistics of Variables in 2005 (Chapter 7-2)

Variable	*Observations*	*Mean*	*Std. Dev.*	*Minimum*	*Maximum*	*Skewness*	*Kurtosis*
$TFP_{i,t}$	26	15.271	0.821	13.185	16.676	-0.491	3.103
$IFDI_{i,t}$	26	4.639	1.297	1.720	6.736	-0.611	2.639
$RV_{i,t}$	26	8.468	3.099	1.373	12.244	-0.713	2.555
$UR_{i,t}$	26	5.805	1.479	2.302	8.092	-0.646	2.617
$Scale_{i,t}$	26	2.648	0.153	2.262	2.923	-0.347	3.273
$Industry_{i,t}$	26	10.424	1.001	8.101	12.002	-0.654	2.797
$Transport_{i,t}$	26	3.134	0.666	1.942	4.514	-0.006	2.150
$Education_{i,t}$	26	13.963	1.106	11.044	16.058	-0.424	3.258
$Investment_{i,t}$	26	9.393	0.685	7.851	10.335	-0.726	2.871

Table 4-52 YRD Summary Statistics of Variables in 2006 (Chapter 7-2)

Variable	*Observations*	*Mean*	*Std. Dev.*	*Minimum*	*Maximum*	*Skewness*	*Kurtosis*
$TFP_{i,t}$	26	15.524	0.773	13.442	16.859	-0.586	3.490
$IFDI_{i,t}$	26	4.988	1.116	2.252	6.899	-0.554	2.708
$RV_{i,t}$	26	8.915	2.892	2.798	12.395	-0.586	2.291
$UR_{i,t}$	26	6.002	1.385	2.937	8.115	-0.574	2.448
$Scale_{i,t}$	26	2.681	0.100	2.485	2.890	-0.127	2.842
$Industry_{i,t}$	26	10.667	0.976	8.404	12.224	-0.677	2.841
$Transport_{i,t}$	26	3.208	0.684	2.009	4.677	0.019	2.231
$Education_{i,t}$	26	14.109	1.072	11.408	16.140	-0.359	2.975
$Investment_{i,t}$	26	9.590	0.634	8.130	10.440	-0.821	2.993

Table 4-53 YRD Summary Statistics of Variables in 2007 (Chapter 7-2)

Variable	*Observations*	*Mean*	*Std. Dev.*	*Minimum*	*Maximum*	*Skewness*	*Kurtosis*
$TFP_{i,t}$	26	15.737	0.686	13.960	17.054	-0.401	3.409
$IFDI_{i,t}$	26	5.275	0.997	3.141	7.045	-0.458	2.327
$RV_{i,t}$	26	9.029	2.988	2.222	12.458	-0.705	2.547
$UR_{i,t}$	26	6.103	1.396	2.770	8.125	-0.680	2.672
$Scale_{i,t}$	26	2.717	0.092	2.451	2.896	-0.553	4.371
$Industry_{i,t}$	26	10.920	0.950	8.631	12.448	-0.747	3.025
$Transport_{i,t}$	26	3.301	0.673	2.018	4.666	-0.125	2.189
$Education_{i,t}$	26	14.221	1.035	11.605	16.215	-0.358	2.981
$Investment_{i,t}$	26	9.811	0.550	8.582	10.543	-0.721	2.766

Table 4-54 YRD Summary Statistics of Variables in 2008 (Chapter 7-2)

Variable	*Observations*	*Mean*	*Std. Dev.*	*Minimum*	*Maximum*	*Skewness*	*Kurtosis*
$TFP_{i,t}$	26	15.833	0.643	14.293	17.164	-0.106	3.097
$IFDI_{i,t}$	26	5.404	1.027	3.238	7.163	-0.694	2.663
$RV_{i,t}$	26	9.782	2.644	3.907	13.044	-0.512	2.140
$UR_{i,t}$	26	6.469	1.266	3.827	8.290	-0.505	2.140
$Scale_{i,t}$	26	2.535	0.188	2.197	2.966	0.253	2.679
$Industry_{i,t}$	26	11.135	0.875	9.139	12.598	-0.726	2.974
$Transport_{i,t}$	26	3.407	0.696	2.061	4.700	-0.213	2.167
$Education_{i,t}$	26	14.336	0.991	11.748	16.267	-0.403	3.223
$Investment_{i,t}$	26	10.009	0.503	8.876	10.633	-0.707	2.588

Table 4-55 YRD Summary Statistics of Variables in 2009 (Chapter 7-2)

Variable	***Observations***	***Mean***	***Std. Dev.***	***Minimum***	***Maximum***	***Skewness***	***Kurtosis***
$TFP_{i,t}$	26	15.893	0.582	14.565	17.176	0.088	3.042
$IFDI_{i,t}$	26	5.400	1.100	3.031	7.169	-0.665	2.546
$RV_{i,t}$	26	10.068	2.459	4.127	13.304	-0.613	2.566
$UR_{i,t}$	26	6.594	1.161	3.983	8.263	-0.564	2.347
$Scale_{i,t}$	26	2.458	0.225	1.902	2.879	-0.523	2.863
$Industry_{i,t}$	26	11.239	0.815	9.419	12.677	-0.720	3.073
$Transport_{i,t}$	26	3.449	0.654	2.274	4.755	0.038	2.368
$Education_{i,t}$	26	14.398	0.971	11.901	16.324	-0.367	3.206
$Investment_{i,t}$	26	10.239	0.481	9.187	10.845	-0.628	2.271

This section aims to emphatically elaborate the variation trend differences in the variables between two specific clusters, namely Beijing-Tianjin-Hebei and the Shanghai-Yangtze River Delta. Focusing on dependent variable $TFP_{i,t}$, the mean value in the Shanghai-Yangtze River Delta is a little bit higher than that in Beijing-Tianjin-Hebei, indicating that the former's technological capabilities are stronger. Over the period 2002-2012, the mean values of $TFP_{i,t}$ increased in both clusters, which is consistent with the results based on evidence from the Chinese nationwide dataset. Meanwhile, the Std. Dev value of $TFP_{i,t}$ is higher in the Shanghai-Yangtze River Delta, illustrating greater regional disparity in regard to technological upgrading across the cities within this cluster. Empirically, the level of technological upgrading in cities within Anhui province is much lower than that in other developed regions e.g. Shanghai and Jiangsu. By contrast, technological gaps between Hebei and Beijing are much smaller. In other words, the regional disparity in regard to technological capabilities in the Shanghai-Yangtze River Delta is more severe.

Focusing on FDI level, the mean value of $IFDI_{i,t}$ in the Shanghai-Yangtze River Delta is much higher than that in Beijing-Tianjin-Hebei. This is because the Shanghai-Yangtze River Delta was one of the first regions in China to open up, and some cities are successful "Special Economic Zones". The local authorities in this cluster have made great efforts to encourage FDI expansion. However, the Std. Dev value of $IFDI_{i,t}$ in the Shanghai-Yangtze River Delta is lower than that in Beijing-Tianjin-Hebei, indicating that the regional disparity in regard to foreign capital utilisation is less. In terms of expansion time-based characteristics, namely pace and rhythm, although the mean value of $Pace_{i,t}$ in Beijing-Tianjin-Hebei was significantly smaller than that in the Shanghai-Yangtze River Delta before 2010, the rate of decrease in the latter cluster reached -21.501%, which is much higher than that in Beijing-Tianjin-Hebei (17.403%). By contrast, the Std. Dev value of $Pace_{i,t}$ is also higher in the Shanghai-Yangtze River Delta. The mean value of $Rhythm_{i,t}$ is slightly higher in the Shanghai-Yangtze River Delta, indicating a more irregular and unstable foreign expansion process across the cities. Focusing on the industrial structures (e.g. related and unrelated variety), the mean values of both $RV_{i,t}$ and $UR_{i,t}$ are higher in the Shanghai-Yangtze River Delta. This is because this urban group has a more complete industrial system, interlinking technologically related sectors in the local area. The higher mean value of $UR_{i,t}$ also demonstrates that the Shanghai-Yangtze River Delta has a more stable business environment, and is less likely to be affected by sector-specific shocks. Moreover, the Std. Dev values of both $RV_{i,t}$ and $UR_{i,t}$ are also higher in the Shanghai-Yangtze River Delta, indicating larger regional disparity across cities.

In terms of the control variables, the mean values of $Scale_{i,t}$ are similar between the two urban groups, and remained stable over the period 2001-2011. This illustrates that economic development within both Beijing-Tianjin-Hebei and the Shanghai-Yangtze River Delta was relatively rapid. Similarly, the mean values of $Industry_{i,t}$ and $Output_{i,t}$ are also nearly same for the two clusters, as their industrial outputs are both strong. However, the mean value of $Transport_{i,t}$ is higher in the Shanghai-Yangtze River Delta. This is because it has more complete and systematic transportation networks across its cities. By contrast, apart from several large metropolises (e.g. Beijing and Tianjin) within Beijing-Tianjin-Hebei, other cities have not fully integrated into the national transport system, thereby reducing the transportation density in local area. For $Education_{i,t}$, the mean value in Beijing-Tianjin-Hebei is much higher than that in the Shanghai-Yangtze River Delta for the period 2001-2011. This is because Beijing-Tianjin-Hebei has the most universities and colleges in the country, and attracts plenty of undergraduates from other Chinese cities. Notably, the Std. Dev value of $Education_{i,t}$ is also lower in Beijing-Tianjin-Hebei, as the local authorities have devoted themselves to balancing educational development across the cities.

4.5. Concluding Remarks

In this chapter, I have systematically introduced the datasets and methodology adopted in this PhD thesis for the purpose of conducting the econometric analysis. First, the Chinese regional administrative levels were described, and the reasons why I choose a city level analysis were explained in detail. Then, I introduced the two main databases used in this PhD thesis, namely *The Chinese Urban Statistical Yearbooks* and *The Annual Industrial Survey Database*. According to the specific research question in this thesis, I expatiated on the statistical compositions, definitions, and sources of these two databases. Second, I discussed the research design and methodology selection, namely pooled OLS and spatial regression models, for this PhD thesis. Third, I illustrated the procedures used to collect and process the datasets from the selected databases in each empirical chapter. More specifically, I explained the selection process in regard to the cities and periods of time for each panel dataset, and specified the number of city/year observations in the final dataset. After that, I defined both the dependent and independent variables adopted in the empirical chapters, as well as the econometric configurations. Finally, in order to provide more detailed characteristics about the datasets, I implemented a univariate analysis. This provides an overview of the indicators' sequential variations, corresponding to the econometric analysis in the following three empirical chapters, using the specific identified methods and datasets.

Chapter 5: FDI and Technological Upgrading in Chinese Cities: Intra- and Inter-regional Externalities of Foreign Expansion Pace and Rhythm

5.1. Introduction

In the literature review chapter, it was noted that some of the prior literature has identified that regional technological upgrading is closely correlated with foreign presence, and that FDI spillovers are also affected by a set of determinant factors such as absorptive capacity and regional effects (Marcin, 2008, Fu, 2008, Crespo and Fontoura, 2007). Nevertheless, as yet, little is known about the externalities of MNEs' foreign expansion time-based characteristics, namely pace and rhythm, in FDI spillovers, and there is even less empirical evidence from emerging economies. Hence, the first research question in this chapter is: "*What are the externalities of foreign expansion time-based characteristics, namely pace and rhythm, in FDI spillovers both within and across Chinese cities?*"

Technological upgrading has long been recognised as one of the key drivers of regional economic growth. A large amount of literature has demonstrated that technological innovation and progress is not an isolated process that relies entirely on internal knowledge stocks; it also depends to a large extent on the availability of external sources (Chesbrough, 2013, Enkel et al., 2009). Thanks to the interactions across different companies and institutions, ideas exchange and technological learning take place on the regional level (Ning et al., 2016, Tappeiner et al., 2008). In the context of emerging economies, local knowledge stocks are often too weak for companies to embark on R&D activities, so external sources are especially crucial for building up indigenous technological capabilities. Namely, it is imperative for emerging economies such as China to assimilate and exploit external knowledge sources overseas, particularly those from advanced economies (Athreye and Cantwell, 2007, Fu, 2008, Xu and Sheng, 2012).

Previously, many studies have demonstrated that inward foreign direct investment (thereafter FDI) is a key external source for host region economic growth and technological upgrading, especially for emerging economies (Blomström and Kokko, 1998, Liu and Wang, 2003, Fu and Gong, 2011). One of the critical rationales is that MNEs' international expansion allows the dissemination of newly created and advanced knowledge to host countries through technological spillover effects (Ning et al., 2016, Buckley et al., 2002, Fu, 2008). Thanks to interactive activities such as joint ventures and R&D collaborations, domestic firms benefit from technological transfers and productivity spillovers from foreign investors, further promoting regional technological capabilities (Hong and Sun, 2011, Wang et al., 2014, Cheung and Lin, 2004).

However, although previous studies have set up theoretical frameworks of FDI spillovers, the empirical results regarding FDI impacts on host region technological performance are still mixed and inconclusive. This is because FDI spillovers do not happen automatically but are often contingent upon a set of determinant factors including both MNEs' and domestic firms' characteristics, as well as some regional effects (Crespo and Fontoura, 2007, Görg and Greenaway, 2004). For example, some research has demonstrated that domestic firms need to achieve a certain level of ability, often known as absorptive capacity, to fully recognise, assimilate and exploit advanced knowledge from MNEs (Fu, 2008, Zhang et al., 2010). Another strand of the literature has put forward the idea that FDI spillovers are greatly enhanced if there is an appropriate technological gap between foreign investors and domestic firms (Wang and Blomström, 1992, Crespo and Fontoura, 2007). Focusing on regional effects, increased geographic distance diminishes technological spillovers in host countries, as the reduced intensity of the interactions makes it difficult to disseminate tacit knowledge (Boschma, 2005, Ó Huallacháin and Lee, 2011). Namely, spatial proximity is crucial to enhance knowledge spillovers between domestic firms and MNEs. However, as yet, little is known about how foreign expansion time-based characteristics affect the extent to which FDI exerts spillovers both within and across regions.

Previously, most studies have argued that host region technological upgrading is dependent merely on the density of foreign presence, and have hardly discussed how the foreign expansion process affects FDI spillovers in host countries (Fu and Gong, 2011, Ning et al., 2016). From a dynamic perspective, time-based characteristics of the FDI expansion process should be considered in regard to technological spillovers (Vermeulen and Barkema, 2002, Gao and Pan, 2010). More specifically, FDI spillovers involve an experiential learning process for domestic firms, which occurs over time during their interactions with MNEs. Namely, foreign expansions are a complex and incremental process, from the initial entry to the establishment of subsidiaries, and local firms need to spend time recognising, assimilating and exploiting advanced technologies from their foreign counterparts. Hence, the extent of FDI spillovers is also dependent on the process whereby MNEs build up their subsidiaries over time (Wang et al., 2012a, Jones and Coviello, 2005). Therein, pace and rhythm are identified as the representative characteristics of the foreign expansion process in terms of influencing the extent of FDI spillovers on a regional level (Wang et al., 2012a). Pace refers to the changing rate of the number of MNE subsidiaries, while rhythm refers to the irregularity in the degree of foreign expansions over a certain time period in host regions (Vermeulen and Barkema, 2002, Wang et al., 2012a).

To the best of our knowledge, this chapter is the first piece of research to explore both the intra- and inter-regional externalities of foreign expansion pace and rhythm in FDI spillovers based on Chinese city-level evidence. There are two main contributions to the previous theoretical framework. First, this chapter explores FDI spillover effects in regional technological upgrading from a spatial perspective, which has been mostly neglected by the prior literature (Wang et al., 2014, Fu, 2008, Fu et al., 2011). Technological upgrading does not take place in isolation, but is an open and distributed system embedded in the whole economic environment. Sources of technological activities come from both the local areas and adjacent regions (Dahlander and Gann, 2010, Berchicci, 2013). Thanks to interregional "pipelines" such as worker mobility and supplier chains, FDI spillovers are not entirely confined within a closed region, but can spread to neighbouring regions in spatial proximity. Knowledge spillover effects from MNEs in neighbouring cities can thereby become technological sources to facilitate innovation in the local area (Ning et al., 2016). Second, this chapter investigates the externalities of foreign expansion pace and rhythm in FDI spillovers, and explores whether these time-based characteristics affect technological upgrading both within and across cities. Previous literature has demonstrated that the pace and rhythm of international expansions affect MNEs' economic and financial performance in both developed and developing economies (Vermeulen and Barkema, 2002, Chang and Rhee, 2011, Kalinic and Forza, 2012). However, little is known about the externalities of foreign expansion time-based characteristics in FDI spillovers, and there is even less evidence from emerging economies. In this chapter, I move beyond to argue that foreign expansion time-based characteristics, namely pace and rhythm, exert impacts on the extent of FDI spillover effects in a given city, thereby moderating the relationship between foreign presence and technological upgrading in China. From a spatial perspective, I also investigate both the intra- and inter-regional externalities of foreign firms' expansion process in FDI spillovers, which has often been neglected in the prior literature (Wang et al., 2012a).

China, as the largest developing economy, has become the main FDI recipient country in the world. Over the last 30 years, Chinese technological upgrading has greatly accelerated, and made many remarkable achievements (Fu, 2008, Ning, 2009). Nevertheless, as a transition economy, China still has no strong internal knowledge stocks to fully satisfy the demands of S&T development, so it is necessary for it to explore and exploit overseas R&D resources to build up its indigenous technological capabilities. Inward FDI, which is regarded as a key external technological source, greatly contributes to regional innovation performance in China (Fu, 2008, Ning et al., 2016). MNEs conducting cutting-edge R&D research transfer and disseminate advanced technology to local firms through several knowledge spillover channels such as labour mobility, demonstration effects, and forward and backward linkages. During recent years, China has increased its degree of openness towards the rest of world, and both the scale and scope of FDI activities have significantly enlarged. Cities, as the main FDI recipients, are ideal regional settings to create a competitive and open environment to facilitate technology transfers and diffusions across actors (Tappeiner et al., 2008, Rosenthal and Strange, 2004). Thanks to agglomerations of infrastructure facilities and transportation systems within specific areas, cities can greatly reduce the transaction costs of knowledge production, dissemination and exploitation (Helsley and Strange, 2004, Ciccone, 2002).

Based on the evidence from developed countries, cities are the frontline of technological innovation, as they provide a richer and more knowledge-intensive environment than non-urban regions e.g. villages (Shearmur, 2012, Glaeser, 2011). Moreover, cities are not isolated but closely interlinked with each other through several inter-regional linkages such as supply chains and social networks (Simmie, 2003, Usai, 2011). In other words, cities are integral to a more complex geographic system in terms of technological upgrading, allowing knowledge spillover effects to occur across a larger region. Therefore, cities are ideal research settings in which to investigate the externalities of FDI in host region technological upgrading from both intra- and inter-regional perspectives, thereby deepening our understanding of the spatial effects of FDI spillovers based on evidence from emerging economies.

The remainder of this chapter is organised as follows. The next section presents the theoretical framework, including the hypotheses about FDI spillovers, technological upgrading, and foreign expansion pace and rhythm. The third section describes the data sample and methodology. The following section presents a descriptive and econometric analysis of the empirical results. Finally, I conclude the chapter with a discussion of the implications and limitations.

5.2. Theoretical Framework: Intra- and Inter-regional Externalities of Foreign Expansion Pace and Rhythm in FDI Spillovers

5.2.1. FDI Spillovers and Host Region Technological Upgrading

From the Literature Review in Chapter 2, it can be seen that scholars have demonstrated that inward FDI is regarded as a key resource of new technology, and strongly contributes to technological upgrading in host regions (Fu, 2008, Fu, 2012, Crespo and Fontoura, 2007). FDI brings newly created knowledge and advanced managerial patterns to host countries (Xu and Sheng, 2012, Athreye and Cantwell, 2007). For most emerging economies with weak internal knowledge bases, FDI is an important external source in terms of building up local technological capabilities (Ning, 2009). Domestic firms in host regions can reap the benefits of foreign presence by recognising, assimilating and exploiting advanced knowledge through interactions with MNEs. Such technological spillovers from MNEs to host regions are known as FDI spillover effects or FDI spillovers (Jeon et al., 2013, Ning et al., 2016, Fu et al., 2011, Fu and Gong, 2011).

Rather than directly and automatically handing over advanced technologies to domestic firms, inward FDI exerts knowledge spillovers through several technological diffusion channels (Meyer, 2004, Crespo and Fontoura, 2007). For example, host region firms can build up their technological capabilities by observing and exploiting successful technologies or managerial experience from MNEs through "demonstration and imitation effects". FDI spillovers also arise when local firms recruit skilled workers who have been trained by foreign investors (Fosfuri et al., 2001, Østergaard and Park, 2015). In addition, FDI intensifies the competition in host countries, and forces indigenous firms to increase their R&D expenditure in order to increase their own production efficiency and managerial efforts (Wei and Liu, 2006, Lin et al., 2009). The fierce competition effects arising from foreign presence also accelerate the adoption of newly created technology and management patterns in host regions (Görg and Greenaway, 2004). In some direct FDI spillover channels such as forward and backward linkages, technology transfers and disseminations take place between domestic firms and MNEs through local supplier chains. Due to demands for high-quality inputs, foreign investors often provide technical support (e.g. employee training and joint R&D activities) to local suppliers. Domestic firms, as the receivers of high-quality products and services, benefit directly from advanced technological spillovers from foreign suppliers (Liu et al., 2009a, Javorcik, 2004b, Görg and Greenaway, 2004).

Previously, plenty of studies have focused on FDI spillover effects on the national level (Álvarez and Marin, 2013), provincial level (Cheung and Lin, 2004), industrial level (Salike, 2010) and firm level (Hamida, 2013, Wang et al., 2012b). Nevertheless, the current empirical evidence on FDI spillovers remains mixed and inconclusive, and its impacts on host region technological upgrading are still the subject of a heated debate. Some of the previous literature has demonstrated that technological upgrading in host regions is positively correlated with inward FDI, as interactions between MNEs and domestic firms intensify knowledge spillover effects. For instance, using a panel dataset from 1980 to 2005, Hong and Sun (2011) demonstrated that there is a significantly positive effect of inward FDI on TFP both within and across Chinese provinces. Focusing on eight transition countries, Damijan et al. (2003) demonstrated that inward FDI has significant positive impacts on host regions, as direct linkages to MNEs are a key source for domestic firms' productivity growth. Similarly, Hanel (2000) found that international spillovers from FDI have positively affected Canada's TFP, although the effects have been weaker than both local interindustry spillovers and R&D.

Some scholars hold the opposite opinion, namely that inward FDI is not always a positive signal, as it may present no effects or even have negative impacts on the host region's technological upgrading.

On the one hand, a minimum level of absorptive capacity is required for domestic firms to recognise, assimilate and exploit advanced technologies from MNEs. A lack of knowledge stocks or capabilities can be a critical constraint in regard to positive FDI spillover effects in host regions (Fu, 2008, Imbriani et al., 2014, Zhang et al., 2010). On the other hand, foreign expansions can present "crowding-out effects" in host region markets. Indigenous firms may face fierce competition from MNEs with better productivity and innovation performance. Moreover, FDI competition also results in an increase in the intermediate input and production costs for domestic firms. Because of the pressures from MNEs, domestic firms may lose their power and control in the domestic market (Tian, 2007, Aitken and Harrison, 1999, Martinez-Noya et al., 2013). For example, using a Chinese firm-level panel dataset from 2001-2005, Fu and Gong (2011) showed that foreign-invested R&D activities may negatively affect Chinese technological upgrading. Similarly, Hu and Jefferson (2002) found that inward FDI exerts "market-stealing" effects, thereby exerting a negative impact on domestic firms' TFP. Based on a dataset on 123 countries, Ashraf et al. (2015) demonstrated that greenfield FDI may have no significant impacts on TFP in either developing or developed countries.

The reasons for such mixed empirical results are various, but one key issue is that most scholars have neglected the inter-regional externalities of FDI from a spatial perspective (Ouyang and Fu, 2012, Doh et al., 2008, Blonigen et al., 2007). As indicated above, cities are not entirely insular regions, but are embedded within the whole economy (Simmie, 2003, Shearmur, 2012). There are several inter-city "pipelines", such as labour mobility, forward and backward linkages, and individual and social networks, that facilitate knowledge spillovers across geographical boundaries (Moreno et al., 2005b, Bathelt et al., 2004). In other words, knowledge generated from one region can spread to other regions in spatial proximity through various technological diffusion channels (Usai, 2011). Based on Chinese urban evidence, Ning et al. (2016) argued that inter-regional interactions facilitate FDI spillovers across cities, and thus exert different impacts on innovation performance.

Based on the arguments above, I consider that inter-city collaborations between MNEs and domestic firms result in the transfer of advanced technologies from one region to others. Knowledge spillovers from neighbouring cities are extremely critical to local technological upgrading. Therefore, I propose that inward FDI plays both intra- and inter-city roles in Chinese technological upgrading as follows:

Hypothesis 1a: FDI has a positive intra-regional effect on local technological upgrading in Chinese cities.

Hypothesis 1b: FDI has a positive inter-regional effect on local technological upgrading in Chinese cities.

5.2.2. Foreign Expansion Process and FDI Spillovers

As well as host regional effects (e.g. absorptive capacity, and forward and backward linkages), FDI spillovers are also contingent upon the internal characteristics of foreign expansion (Crespo and Fontoura, 2007). Namely, the intensity of knowledge spillovers depends not only on the presence of foreign capital, but also on the process through which MNEs build up their subsidiaries in host countries over time (Wang et al., 2012a). Previous literature has argued that MNEs have different incentives to adopt different speeds and patterns in their foreign expansion processes, in order to either reap first mover advantage or improve their financial performance (Gao and Pan, 2010, Vermeulen and Barkema, 2002). For example, to reap benefits such as price skimming engagement and unique market establishment, MNEs set up facilities quickly and reach out to their target markets in host countries (Gao and Pan, 2010, Li et al., 2003). New ventures also accelerate their foreign expansion in host regions, for the purpose of simultaneously making trade-offs among foreign revenue exposure, country risk and entry mode commitments (Shrader et al., 2000). Moreover, global networking and higher market knowledge are also two critical factors that motivate MNEs to implement rapid internationalisation, and help them quickly adapt to the new environment in the host country (Oviatt and McDougall, 2005, Autio et al., 2000). However, Vermeulen and Barkema (2002) showed that, because of the complexity and uncertainty around international expansions, neither rapid nor irregular international expansion exerts a positive impact on MNEs' financial performance.

Hence, due to risk and uncertainty, FDI expansions do not always remain stable and constant from the initial point of entry to a certain degree of foreign presence (Gao and Pan, 2010). The pace and rhythm of the foreign expansion process not only affects MNEs' financial performance, but also exert an impact on the way in which domestic and foreign firms interact. This thus results in variations in FDI technological spillovers in host countries (Wang et al., 2012a). As indicated above, cities are not isolated, but interlinked with each other through several "pipelines" e.g. labour mobility, social networks, forward and backward linkages etc. The FDI expansion process might therefore affect the intensity of inter-city technology transfers and disseminations. Therefore, this chapter aims to investigate the moderating effects of foreign expansion time-based characteristics, namely the pace and rhythm, in the relationship between FDI and technological upgrading both within and across Chinese cities.

5.2.2.1. Pace and FDI Spillovers

Pace, as a time-based characteristic of the foreign expansion process, measures how rapidly foreign firms set up their subsidiaries in host regions at a particular point in time (Vermeulen and Barkema, 2002, Wang et al., 2012a). Different from the definition in previous literature, in which pace is defined as the changing number of subsidiaries of an individual MNE (Wagner, 2004, Vermeulen and Barkema, 2002), this chapter defines "pace" on a city level. Namely, the foreign expansion pace refers to the annual rate of change for all of the MNEs within a given city. The higher the pace in a city, the more rapid the foreign expansions have been in that city.

Previously, some of the literature has demonstrated that time compression diseconomies emerge when an individual MNE undergoes a more rapid foreign expansion process (Vermeulen and Barkema, 2002). Owing to the limited cognitive scope and bounded rationality, an individual MNE cannot evaluate its international experience and exploit it for commercial purposes over a compressed period (Cohen and Levinthal, 1994). Namely, with rapid FDI expansions, it is not only difficult for MNEs to fully explore the profit potential in host region markets, but there is also a more serious liability of foreignness. Foreign investors need to invest a great deal of time in dealing with both organisational and environmental complexities in terms of prior experience adaption, understanding the local competition and training workers in host regions. This is thus the main reason why MNEs are often reluctant to set up their subsidiaries quickly in host countries.

From the social networking perspective, network establishment is a path-dependent process, and time is needed to build up strong relationships and mutual trust between MNEs and domestic companies (Andersson et al., 2002). Both sides can access technological sources through such social networks, allowing FDI spillovers to take place. The foreign expansion pace thus affects the way in which they interact with each other. Constrained by internal rationality and cognitive scope, domestic firms need sufficient time to fully recognise, assimilate and exploit the advanced technologies of MNEs (Wang et al., 2012a). In other words, a foreign expansion process that is too rapid often brings a large amount of newly created and advanced technology within a compressed period, and is regarded as a great challenge for domestic firms in terms of reacting quickly to benefit from knowledge spillovers. In this case, I consider that foreign expansion pace has a moderating impact on FDI spillovers, and further affects host region technological upgrading.

Previously, some of the literature has defined foreign expansion pace as the annual foreign expansion of an individual MNE or specific sector (Vermeulen and Barkema, 2002, Wang et al., 2012a). In this chapter, I move beyond this concept to the regional level, and consider foreign expansion pace as the changing rate of all of the MNEs within a given city. There is reason to believe that an increased foreign expansion pace will have a positive impact on FDI spillovers. First, MNEs prefer to undertake rapid FDI to reap first mover competitive advantage in host region markets (Chang and Rhee, 2011). Building up infrastructure and production facilities quickly leads to better performance in some high-tech sectors (e.g. semi-conductors) (Salomon and Martin, 2008). Moreover, a rapid FDI expansion process can also help MNEs to quickly capture the markets in host countries, and accelerate the commercialisation of their R&D outputs. All of these incentives force foreign investors to proactively interact with local actors to satisfy the production and market demands. Thanks to the higher intensity of the interactions between MNEs and domestic firms, technological transfers and diffusions are greatly enhanced in the host regions.

Second, inter-industry linkages to upstream and downstream sectors are a key FDI spillover channel in host regions (Javorcik, 2004b, Liu et al., 2009a). In order to integrate into the supply and value chains, MNEs that are rapidly expanding need to build up both forward and backward linkages to local suppliers and customers over a compressed time. Because some industries may not have existed prior to the entry of FDI, rapid foreign entry thereby either spreads newly created and advanced technologies to extend existing sectors, or improves the production standards of the local partners.

Third, rapid foreign expansion generates intensified competition effects in host countries. In order to compete with foreign investors, local firms are forced to increase their R&D expenditure to increase their production efficiency and managerial efforts (Wei and Liu, 2006, Liu et al., 2009b). Hence, rapid foreign expansion accelerates industrialisation, commercialisation, and the adoption of advanced technologies in the local area, and further facilitates host region technological upgrading.

From the spatial perspective, I consider that the pace of foreign expansion also has an impact on FDI spillovers across cities. This is because cities, as indicated above, are not isolated from each other, but are interlinked by inter-city linkages such as transport systems, social networks, and supplier and value chains (Bathelt et al., 2004, Moreno et al., 2005a). The externalities of rapid foreign expansion are thus not geographically confined within a closed area, but can facilitate inter-city FDI spillovers in adjacent cities. First, fast foreign expansion increases the production and input demands for domestic suppliers in both the local and neighbouring areas. As indicated above, cities in spatial proximity are interlinked with each other to form a greater and more complex regional supply chain system. Host region suppliers in neighbouring cities are also forced to promote indigenous productivity efficiency to meet the increasing demands from MNEs, thus contributing to technological upgrading across cities. Second, some of the literature has argued that MNEs' international expansion is not confined within an isolated city, but spreads to adjacent regions in host countries. Foreign investors often select a preferred destination as an export-platform, and then further expand additional investments and business lines to neighbouring regions (Blonigen et al., 2007). Rapid FDI expansions are more likely to spread both within and across cities, thereby accelerating technology transfers and disseminations to local actors. Third, in order to benefit from first mover advantage, MNEs build their subsidiaries quickly and obtain a greater share of the international market (Salomon and Martin, 2008). Rapid FDI expansion is regarded as a threat in host regions, due to the increasing number of foreign rival firms. Due to interregional linkages, e.g. worker mobility and supplier chains, such conductive competition effects are able to spread to a set of regions in spatial proximity. FDI spillovers are thus not confined within a given city, but also exert an impact on technological upgrading in neighbouring areas. Hence, I consider that rapid foreign expansion processes have both intra- and inter-city impacts on FDI spillovers in China, and propose the following hypotheses:

Hypothesis 2a: The pace of foreign expansion positively moderates the relationship between intra-regional FDI and technological upgrading in Chinese cities.

Hypothesis 2b: The pace of foreign expansion positively moderates the relationship between inter-regional FDI and local technological upgrading in Chinese cities.

5.2.2.2. Rhythm and FDI Spillovers

Rhythm is another time-based characteristic of the foreign expansion process, indicating the degree of regularity. As indicated above, MNEs do not always adopt sequential and constant internationalisation over certain time, but might have sudden sharp peaks or long periods of inactivity (Lin, 2012, Vermeulen and Barkema, 2002). In this case, FDI spillovers depend not only on how fast foreign expansions take place, but also on the degree of irregularity of the foreign expansion process. Similar to pace, time compression diseconomies emerge if foreign expansions are irregular in host regions (Wang et al., 2012a). I thus argue that domestic firms can reap more benefits from knowledge spillovers when MNEs implement rhythmic and constant expansion. In other words, a more predictable and regular foreign expansion process enhances FDI spillovers, as domestic firms can fully recognise, assimilate and exploit advanced knowledge from MNEs through experiential learning.

From an intra-city perspective, the fundamental mechanism through which the rhythm of foreign expansions affects FDI spillovers is similar to that of pace. More regular foreign expansions enhance FDI spillovers for several reasons. First, sudden peaks in MNEs' expansion dramatically increase the potential risks and uncertainty in host regions, and create an unstable business environment. In such an unstable and unpredictable environment, there are few regulations or rules to enable domestic firms react quickly and implement appropriate actions. It is also difficult for domestic firms to interact or collaborate with foreign investors effectively to benefit from FDI spillovers. Faced with such irregular foreign expansions, domestic firms with weaker absorptive capacity can hardly recognise, assimilate and exploit advanced knowledge from MNEs, thus diminishing FDI spillovers (Wang et al., 2012a). Second, mutual trust is the cornerstone of social networking, joint ventures, and alliances between MNEs and local partners (Fryxell et al., 2002, Tan and Meyer, 2011). More continuous and rhythmic foreign expansions reduce the transaction costs and uncertainty involved in building up interindustry connections (e.g. forward and backward linkages) with local suppliers and customers. Thanks to strong and robust business connections, such interindustry connections foster opportunities for joint R&D and technological imports between domestic firms and MNEs. In this case, information and knowledge exchange via FDI are enhanced in host countries. Third, in order to reduce the potential risks and improve financial performance overseas, MNEs prefer to adopt rhythmic and constant business expansion strategies (Vermeulen and Barkema, 2002). This is because dramatic and unpredictable fluctuations in international expansions greatly hamper MNEs' experiential learning, as it is difficult for them to fully understand the international setting, organisational structures and evolutionary process, and further exploit their successful experience in new markets. In turn, poor financial performance constrains both the geographic and product scopes of advanced knowledge in host countries, so local firms have less opportunities to reap the benefits of FDI spillovers.

Nevertheless, although rhythmic and constant foreign expansions are preferred in host regions, as yet little is known about their impact on interregional FDI spillovers. From the spatial perspective, I consider that the rhythm of the foreign expansion process may not only exhibit impacts within a particular city, but many also influence technological upgrading across cities. De Backer and Sleuwaegen (2003) demonstrated that, due to competition effects, FDI can crowd out existing domestic entrepreneurs or prevent new entries in host regions. For this reason, more abrupt and irregular foreign expansions generate fierce competition effects, forcing local firms to escape from the city to neighbouring areas where there are fewer fluctuations in the demand and competition. This type of relocation significantly accelerates labour mobility across cities, enabling inter-regional technology transfer and dissemination. Moreover, as indicated before, inter-city linkages diffuse technologies across cities. Discontinuous and irregular foreign expansions might lead to dramatic fluctuations in demand and supply. As well as local firms within the supply chains, indigenous suppliers and customers in neighbouring regions will also struggle with such an increasingly complex and unpredictable environment. Therefore, I propose the following hypothesis regarding the intra- and inter-regional externalities of the foreign expansion rhythm in FDI spillovers:

Hypothesis 3a: The rhythm of FDI expansion negatively moderates the relationship between intra-regional FDI and technological upgrading in Chinese cities.

Hypothesis 3b: The rhythm of FDI expansion in neighbouring cities negatively moderates the relationship between inter-regional FDI and technological upgrading in Chinese cities

5.2.3. Data and Methodology

I employ a unique city-level dataset constructed from *the Chinese Urban Statistical Yearbooks*. These yearbooks are the official publications by the *National Bureau of Statistics (NBS)*. They provide detailed regional economic and social development indicators, such as GDP growth and population, as well as the amount of FDI flow. Cities are the unit of analysis in our sample. I initially identified 286 Chinese cities, including four municipalities (Beijing, Shanghai, Tianjin and Chongqing). I eliminated 42 cities with missing information. Consequently, not all of the cities in Tibet are included. In the analysis, I require all of the urban economic data in the year *t-1* to take the possible endogeneity issue into account. I also require a time lag for cities to absorb the knowledge spillovers from FDI. The final data sample covers 244 cities for the period 2004-2011. In total, I identify 1,952 city-year observations for our pooled OLS and ML spatial panel regressions.

5.3. Empirical Results

5.3.1. Descriptive Analysis

Previous literature has argued that there is significant regional disparity in terms of economic and technological development in China (Fu and Mu, 2014); thus it is necessary to illustrate the geographic distributions across Chinese cities. Tables 5.1-5.4 list a set of indicators (GDP, GDP annual growth, industrial outputs and fixed-asset investments) for the top and bottom 20 cities in both 2003 and 2012, illustrating the differences in the economic scale in China.

Table 5-1 Top 20 and Bottom 20 Chinese Cities in Total GDP Value (2003, 2012)

20 cities with highest GDP in 2012			20 cities with least GDP in 2012			20 cities with highest GDP in 2003			20 cities with least GDP in 2003		
Cities	*Location*	*Value in Billion RMB*	*Cities*	*Location*	*Value in Billion RMB*	*Cities*	*Location*	*Value in Billion RMB*	*Cities*	*Location*	*Value in Billion RMB*
Shanghai	E	2000	Hegang	NE	36	Shanghai	E	630	Zhangjiajie	C	8
Beijing	N	1800	An'shun	SW	35	Beijing	N	370	Liaoyuan	NE	8
Guangzhou	S	1400	Lincang	SW	35	Guangzhou	S	350	Pinggliang	NW	8
Tianjin	N	1300	Zhangjiajie	C	34	Shenzhen	S	290	Yingtan	E	8
Shenzhen	S	1300	Wuwei	NW	34	Suzhou	E	280	Qitaihe	NE	8
Suzhou	E	1200	Sanya	S	33	Tianjin	N	240	An'shun	SW	8
Chongqing	SW	1100	Pingliang	NW	32	Chongqing	SW	230	Simao	SW	8
Chengdu	SW	810	Wuzhong	NW	32	Hangzhou	E	210	Shangluo	NW	8
Wuhan	C	800	Qitaihe	NE	30	Wuxi	E	190	Chizhou	E	8
Hangzhou	E	780	Zhangye	NW	29	Chengdu	SW	190	Lincang	SW	7
Wuxi	E	760	Tongchuan	NW	27	Ningbo	E	180	Fangchenggang	S	7
Qingdao	E	730	Jiayuguan	NW	27	Qingdao	E	180	Shizuishan	NW	7
Nanjing	E	720	Yichun	NE	26	Wuhan	C	170	Wuhai	N	7
Dalian	NE	700	Lasa	SW	26	Shenyang	NE	160	Dingxi	NW	6
Shenyang	NE	660	Zhongwei	NW	25	Dalian	NE	160	Jinchang	NW	5
Ningbo	E	660	Jinchang	NW	24	Nanjing	E	160	Tongchuan	NW	5
Foshan	S	660	Longnan	NW	23	Shijiazhuang	N	140	Lijiang	SW	4
Changsha	C	640	Dingxi	NW	22	Harbin	NE	140	Sanya	S	4
Tangshan	N	590	Lijiang	SW	21	Quanzhou	E	140	Guyuan	NW	4
Zhengzhou	C	550	Guyuan	NW	16	Jinan	E	140	Jiayuguan	NW	3

Note: location is classified by the geographic distribution of provinces in China: E: Eastern China (Shandong, Jiangsu, Shanghai, Zhejiang, Anhui, Fujian and Jiangxi); S: Southern China (Guangdong, Guangxi, Taiwan and Hainan); C: Central China (Hunan, Hubei and Henan); N: Northern China (Beijing, Tianjin, Hebei, *Shanxi and Inner Mongolia); NW: Northwest China (Ningxia, Qinghai, Shaanxi, Gansu and Xinjiang); SW: Southwestern China (Sichuan, Guizhou, Yunnan, Chongqing and Tibet); NE: Northeastern China (Liaoning, Jilin and Heilongjiang)*

Table 5-2 Top 20 and Bottom 20 Chinese Cities in Annual GDP Growth Rate (2003, 2012)

20 cities with highest GDP growth rate in 2012			20 cities with lowest GDP growth rate in 2012			20 cities with highest GDP growth rate in 2003			20 cities with lowest GDP growth rate in 2003		
Cities	*Location*	*%*	*Cities*	*Location*	*%*	*Cities*	*Location*	*%*	*Cities*	*Location*	*%*
Beihai	S	21.8	Tsitsihar	NE	8.9	Baotou	N	31.5	Jingzhou	C	7.8
Urumchi	NW	17.3	Jiaxing	E	8.7	Ulan Qab	N	29.3	Huanggang	C	7.4
Lincang	SW	16.8	Quzhou	E	8.5	Wuhai	N	26.3	Heihe	NE	7.2
Jinchang	NW	16.5	Qitaihe	NE	8.3	Hohhot	N	24.9	Hechi	S	6.9
Jiayuguan	NW	16.4	Shiyan	C	8.2	Erdos	N	23.6	Shaotong	SW	6.6
Shaotong	SW	16.1	Foshan	E	8.2	Fuxing	NE	20.2	Kaifeng	C	6.4
Jiuquan	NW	16.1	Jiangmen	E	8.1	Dongguan	E	19.5	Bengbu	E	6.3
Liupanshui	SW	16.0	Yuncheng	N	7.8	Shenzhen	E	19.2	Qinzhou	E	5.8
Guiyang	SW	15.9	Ningbo	E	7.8	Chifeng	N	19	Lu’an	E	5.6
Zunyi	SW	15.9	Beijing	N	7.7	Zhongshan	E	18.6	Tsitsihar	N	5.1
Qingyang	NW	15.9	Shanghai	E	7.5	Pingxiang	E	18.2	Karamay	NW	5.1
Lijiang	SW	15.8	An’yang	C	7.4	Yingtan	E	18.2	Shiyan	C	4.1
Tongchuan	NW	15.8	Taizhou	E	7.1	Tongliao	N	18.1	Yuxi	SW	4
Simao	SW	15.6	Zhuhai	S	7.0	Suzhou	E	18	Chuzhou	E	3.4
An’shun	SW	15.4	Pingdingshan	C	6.8	Weihai	E	17.9	Bozhou	E	2.3
Hanzhong	NW	15.2	Wenzhou	E	6.7	Linyi	E	17.8	Suzhou	E	1.8
An’kang	NW	15.2	Dongguan	S	6.1	Zhuhai	S	17.5	Zhumadian	C	1.2
Baoshan	SW	15.1	Karamay	NW	6.0	Yantai	E	17.4	Fuyang	E	1
Baoji	NW	15.1	Qingyuan	S	5.1	Xiamen	E	17	Shangqiu	C	-0.1
Wuwei	NW	15.1	Hechi	S	-0.7	Jiaxing	E	16.9	Zhoukou	C	-3.4

Table 5-3 Top 20 and Bottom 20 Chinese Cities in Total Industrial Outputs Value (2003, 2012)

20 cities with highest Industrial Outputs in 2012			20 cities with least Industrial Outputs in 2012			20 cities with highest Industrial Outputs in 2003			20 cities with least Industrial Outputs in 2003		
Cities	*Location*	*Value in Billion RMB*	*Cities*	*Location*	*Value in Billion RMB*	*Cities*	*Location*	*Value in Billion RMB*	*Cities*	*Location*	*Value in Billion RMB*
Shanghai	SE	3200	Wuwei	NW	32	Shanghai	E	1000	Huangshan	E	4
Suzhou	SE	2900	Bazhong	SW	31	Shenzhen	S	520	Hegang	NE	4
Tianjin	N	2300	Zhongwei	NW	31	Suzhou	E	500	Qinzhou	S	3
Shenzhen	E	2100	Hezhou	S	30	Tianjin	N	400	Chizhou	E	3
Beijing	N	1600	Hechi	S	30	Guangzhou	S	400	Wuwei	NW	3
Guangzhou	E	1600	Pingliang	NW	27	Beijing	N	380	Zhangye	NW	3
Foshan	E	1500	Tianshui	NW	25	Wuxi	E	330	An’kang	SW	3
Wuxi	SE	1400	Baoshan	SW	21	Hangzhou	E	320	Pingliang	NW	3
Qingdao	SE	1400	Zhangye	NW	20	Ningbo	E	260	Simao	SW	2
Shenyang	NE	1300	Yichun	NE	18	Qingdao	E	260	Hezhou	S	2
Hangzhou	SE	1300	Simao	SW	16	Foshan	S	260	Lincang	SW	2
Chongqing	SW	1300	Lincang	SW	16	Nanjing	E	250	Heihe	NE	2
Ningbo	SE	1200	Lijiang	SW	13	Dongguan	S	210	Baoshan	SW	2
Yantai	SE	1200	Heihe	NE	12	Yantai	E	200	Zhangjiajie	C	2
Nanjing	SE	1100	Zhangjiajie	C	11	Shaoxing	E	190	Shangluo	NW	2
Tangshan	N	1000	Dingxi	NW	10	Weihai	E	170	Dingxi	NW	2
Dalian	NE	1000	Longnan	NW	10	Chongqing	SW	160	Bazhong	SW	1
Zibo	SE	1000	Lasa	SW	6	Dalian	NE	150	Guyuan	NW	1
Dongying	SE	1000	Sanya	S	6	Changchun	NE	150	Sanya	S	1
Weifang	SE	1000	Guyuan	NW	4	Changzhou	E	150	Lijiang	SW	1

Table 5-4 Top 20 and Bottom 20 Chinese Cities in Total Fixed-asset Investments Value (2003, 2012)

20 cities with highest Fixed-asset Investments in 2012			20 cities with least Fixed-asset Investments in 2012			20 cities with highest Fixed-asset Investments in 2003			20 cities with least Fixed-asset Investments in 2003		
Cities	*Location*	*Value in Billion RMB*	*Cities*	*Location*	*Value in Billion RMB*	*Cities*	*Location*	*Value in Billion RMB*	*Cities*	*Location*	*Value in Billion RMB*
Chongqing	SW	930	Jixi	NE	28	Shantou	S	250	Lincang	SW	3
Tianjin	N	830	Heyuan	S	28	Shanghai	E	220	Jingzhou	C	3
Beijing	N	640	Lasa	SW	28	Baotou	N	140	Suzhou	E	3
Chengdu	SW	590	Heihe	NE	24	Dazhou	SW	130	Qinzhou	E	3
Shenyang	NE	560	Zhongwei	NW	24	Zigong	SW	120	Hefei	E	3
Dalian	NE	560	Meizhou	S	23	Anyang	C	100	Wuwei	NW	3
Shanghai	SE	530	Lijiang	SW	23	Shenzhen	S	100	Tai’an	E	3
Suzhou	SE	510	Yichun	NE	22	Jilin	NE	95	Dezhou	E	3
Wuhan	C	500	Chaozhou	S	22	Mudanjiang	NE	95	Shuangyashan	NE	3
Nanjing	SE	460	Hechi	S	22	Zaozhuang	E	89	Liaocheng	E	3
Qingdao	SE	420	Baoshan	SW	22	Jiaozuo	C	84	Shangrao	E	3
Xi’an	NW	420	Zhangye	NW	21	Jixi	NE	79	Wuhai	N	3
Hefei	C	400	Hegang	NE	20	Lianyungang	E	74	Lanzhou	NW	2
Changsha	C	400	Tongchuan	NW	20	Hengyang	C	74	Zhangjiajie	C	2
Harbin	NE	390	Jinchang	NW	18	Huainan	E	65	Zhangye	NW	2
Guangzhou	E	380	Guyuan	NW	15	Jiaxing	E	58	Pingxiang	E	2
Shijiazhuang	N	370	Zhangjiajie	C	13	Yuncheng	N	54	Liaoyuan	NE	2
Hangzhou	SE	370	Qitaihe	NE	12	Suzhou	E	53	Ya’an	NW	2
Wuxi	SE	360	Jiayuguan	NW	9	Shiyan	C	53	Xianning	C	2
Zhengzhou	C	360	Tianshui	NW	4	Jieyang	S	52	Taiyuan	N	2

Based on the statistics regarding the economic scale of Chinese cities, it can be seen that the most economically developed cities are concentrated in eastern and southern China. Over the period 2003-2012, the differences in the economic scale of Chinese cities exhibited several evident characteristics.

First, the total economic scale of Chinese cities dramatically increased. In 2012, the total value of GDP, industrial outputs and fixed-asset investments in the top 20 cities reached 19160, 30400 and 9980 billion RMB respectively. These figures were 33.79 times, 4.86 times and 5.03 times more than the values in 2003, respectively. The most underdeveloped cities such as Qitaihe and Lincang also exhibited rapid economic development, and their economic scale (e.g. GDP) increased by approximately 4 times. Second, there exists huge regional disparity in the economic scales across cities. Similar to the GDP values, the cities with the highest industrial outputs and fixed-asset investments are also concentrated in the eastern and coastal regions such as Shanghai, Suzhou, and Guangzhou. These cities were the first cities in China to open up, and often have solid economic foundations, so they have exhibited powerful productivity. By contrast, the cities with the smallest economic scales such as Wuwei, Jinchang, and Lincang are mainly located in northwestern China. The total GDP value of these 20 bottom cities was less than one third of that of Shanghai. Third, the development speed in the northwestern and southwestern cities significantly increased. In 2012, these cities all achieved a GDP growth rate of over 15%. Ten years ago, the most rapidly-developed cities were mainly in eastern and northern China, and most of them were coastal such as Shenzhen, Suzhou, and Xiamen. This means that Chinese economic policies have been more focused on inland regions, and these cities have made more efforts to catch up in terms of economic development.

Nevertheless, the GDP growth rate dramatically decreased from 2003-2012, as China began to face bottlenecks in its economic development. In 2003, the top 5 cities achieved annual GDP growth of over 23%, and Baotou in Inner Mongolia achieved 31.5% GDP growth. By contrast, the most rapidly developed city, Beihai only had 21.8% GDP growth. This indicates that the traditional investment-oriented economic development pattern is becoming less effective, so it is necessary to explore new drivers of regional economic growth.

Tables 5.5-5.8 list a set of indicators (population, transport volume and the number of students enrolled in tertiary education) for the top and bottom 20 cities in both 2003 and 2012, illustrating the differences in social development and infrastructure construction in China.

Table 5-5 Top 20 and Bottom 20 Chinese Cities in Total Population (2003, 2012)

20 cities with most population in 2012			20 cities with least population in 2012			20 cities with most population in 2003			20 cities with least population in 2003		
Cities	*Location*	*in 10,000*	*Cities*	*Location*	*in 10,000*	*Cities*	*Location*	*in 10,000*	*Cities*	*Location*	*in 10,000*
Chongqing	SW	3343.4	Xinyu	E	120.5	Chongqing	SW	3130.1	Laiwu	E	123.88
Shanghai	E	1426.9	Zhongwei	NW	120	Shanghai	E	1341.77	Lijiang	SW	111.88
Beijing	N	1297.5	Lijiang	SW	119	Beijing	N	1148.82	Hegang	NE	110.58
Zhoukou	C	1229.2	Panzhihua	SW	111.9	Baoding	N	1076.98	Yingtan	E	109.97
Nanyang	C	1206.3	E’zhou	C	109.4	Zhoukou	C	1074.68	Xinyu	E	109.35
Chengdu	SW	1173.3	Hegang	NE	108.5	Nanyang	C	1054.38	Panzhihua	SW	106.18
Baoding	N	1172.1	Zhuhai	S	106.6	Chengdu	SW	1044.31	E’zhou	C	104.33
Linyi	E	1083.8	Jiuquan	NW	98.8	Linyi	E	1011.05	Zhoushan	E	97.12
Zhengzhou	C	1072.5	Zhoushan	E	97.2	Harbin	NE	954.31	Jiuquan	NW	91.84
Fuyang	E	1039.8	Qitaihe	NE	92.4	Tianjin	N	926	Qitaihe	NE	87.44
Shijiazhuang	N	1005.3	Fangchenggang	S	91.6	Shijiazhuang	N	910.51	Tongchuan	NW	83.98
Harbin	NE	993.5	Tongchuan	NW	85.3	Xuzhou	E	908.66	Zhuhai	S	82.02
Tianjin	N	993.2	Tongling	E	74.2	Fuyang	E	904.1	Fangchenggang	S	78.85
Handan	N	993.1	Shizuishan	NW	74.2	Heze	E	874.47	Shizuishan	NW	72.78
Xuzhou	E	990.5	Sanya	S	57.3	Handan	N	857.09	Tongling	E	70.91
Heze	E	957.3	Wuhai	N	54.8	Weifang	E	847.71	Sanya	S	50.39
Shangqiu	C	934.1	Lasa	SW	50.4	Ganzhou	E	831.2	Jinchang	NW	46.03
Ganzhou	E	926.7	Jinchang	NW	46.7	Shangqiu	C	831.02	Wuhai	N	41.6
Zhumadian	C	899.2	Karamay	NW	37.6	Zhumadian	C	826.31	Karamay	NW	30.6
Weifang	E	878.9	Jiayuguan	NW	19.8	Jining	E	798.89	Jiayuguan	NW	16.37

Table 5-6 Top 20 and Bottom 20 Chinese Cities in Total Transport Volume (2003, 2012)

20 cities with highest Transport Volume in 2012			20 cities with least Transport Volume in 2012			20 cities with highest Transport Volume in 2003			20 cities with least Transport Volume in 2003		
Cities	*Location*	*in 10,000*	*Cities*	*Location*	*in 10,000*	*Cities*	*Location*	*In 10,000*	*Cities*	*Location*	*in 10,000*
Wuwei	NW	286597	E'zhou	C	2148	Chengdu	SW	72793	Yuxi	SW	1065
Shenzhen	S	185011	Baotou	N	2085	Chongqing	SW	58290	Hebi	C	1041
Chongqing	SW	157798	Xinyu	E	2075	Dongguan	S	32588	Ulan Qab	N	1006
Beijing	N	149037	Ulan Qab	N	2071	Beijing	N	30520	Laiwu	E	966
Chengdu	SW	106874	Baoshan	SW	2023	Guangzhou	S	29751	Qingyang	NW	932
Huaihua	C	104902	Lvliang	N	1960	Ningbo	E	24938	Hezhou	S	848
Dongguan	S	79739	Jingdezhen	E	1951	Suzhou	E	24132	Zhongwei	NW	845
Guangzhou	S	76069	Bayannur	N	1914	Wenzhou	E	24108	Baoshan	SW	782
Suzhou	E	71626	Liaoyuan	NE	1713	Maoming	S	21962	Shangluo	C	721
Nanjing	E	46992	Tongchuan	NW	1667	Hangzhou	E	21349	Pingliang	NW	679
Guiyang	SW	46490	Yichun	NE	1401	Guiyang	SW	18511	Tongchuan	NW	644
Foshan	S	43119	Fuxin	NE	1313	Nanjing	E	16790	Shizuishan	NW	641
Zibo	E	42540	Qitaihe	NE	1298	Wuxi	E	15877	Lijiang	SW	604
Haikou	S	40116	Heihe	NE	1277	Zibo	E	15725	Heihe	NE	541
Changsha	C	36441	Jinchang	NW	1044	Jinhua	E	15607	Jinchang	NW	515
Xi'an	NW	36154	Lincang	SW	884	Qingdao	E	14666	Lasa	SW	513
Yantai	E	35897	Lasa	SW	860	Taizhou	E	13813	Yichun	NE	431
Hangzhou	E	35819	Karamay	NW	653	Haikou	S	13284	Hegang	NE	328
Zhengzhou	C	35660	Hegang	NE	526	Shaoxing	E	13277	Wuhai	N	267
Wenzhou	E	34501	Wuhai	N	514	Foshan	S	12027	Jiayuguan	NW	151

Table 5-7 Top 20 and Bottom 20 Chinese Cities in Enrollment Number of Students in Tertiary Education (2003, 2012)

20 cities with highest Education Volume in 2012			20 cities with least Education Volume in 2012			20 cities with highest Education Volume in 2003			20 cities with least Education Volume in 2003		
Cities	*Location*	*Number*	*Cities*	*Location*	*Number*	*Cities*	*Location*	*Number*	*Cities*	*Location*	*Number*
Wuhan	C	946991	Longnan	NW	5368	Wuhan	C	490530	Meishan	SW	2069
Guangzhou	S	939208	Yingtan	E	5148	Beijing	N	450789	Heyuan	S	2037
Xi’an	NW	723961	Chaoyang	NE	4766	Xi’an	NW	401180	Shanwei	S	2023
Zhengzhou	C	698190	Shanwei	S	4500	Shanghai	E	378517	Lincang	SW	1916
Chengdu	SW	685639	Karamay	NW	4198	Guangzhou	S	374742	Suizhou	C	1704
Chongqing	SW	670174	Shuangyashan	NE	4093	Nanjing	E	333648	Heihe	NE	1650
Jinan	E	659872	Erdos	N	3848	Jinan	E	301603	Xuancheng	E	1600
Nanjing	E	651948	Wuhai	N	3539	Chengdu	SW	300742	Dingxi	NW	1600
Beijing	N	581844	Songyuan	NE	3483	Hangzhou	E	269798	Hebi	C	1562
Changsha	C	523174	Jiayuguan	NW	3247	Changsha	C	268613	Karamay	NW	1543
Nanchang	E	509239	Baiyin	NW	2935	Harbin	NE	257136	Beihai	S	1500
Shanghai	E	506596	Tongchuan	NW	2732	Zhengzhou	C	256497	Tieling	NE	1394
Harbin	NE	482211	Wuzhong	NW	2369	Chongqing	SW	255266	Yichun	NE	1318
Tianjin	N	473114	Fangchenggang	S	1783	Tianjin	N	245213	Liaoyuan	NE	1229
Hangzhou	E	459181	Guigang	S	1716	Shenyang	NE	236080	Hegang	NE	1055
Hefei	E	417207	Jinchang	NW	1655	Changchun	NE	233558	Erdos	N	1012
Shijiazhuang	N	395542	Qitaihe	NE	1339	Guiyang	SW	219487	Jiuquan	NW	890
Guiyang	SW	391071	Baishan	NE	1200	Shijiazhuang	N	186344	Qitaihe	NE	870
Changchun	NE	387662	Yichun	NE	1104	Nanchang	E	184418	Sanya	S	313
Shenyang	NE	369285	Shuozhou	N	328	Qingdao	E	168439	Pingliang	NW	258

Based on the statistics in Tables 5.5-5.7, there exists great complexity in the geographic distribution in terms of population, transport, and education across Chinese cities. Similar to the economic scale, there are several unique features. First, from 2003-2012, plenty of educated people were still concentrated in the largest and most developed cities, such as Beijing, Shanghai, and Chongqing. For example, in 2012, the number of students enrolled in tertiary education in Chongqing reached 670,174, more than the total number in the bottom 20 cities (59,351). There is great regional disparity in terms of tertiary education between the large and small cities. However, the Chinese governments has made great efforts to achieve harmonious development in tertiary education, in particular to set up key universities in underdeveloped inland regions. Even in some southwestern and northwestern cities such as Xi'an (723,961), Guiyang (391,071) and Chengdu (685,639), there were still many students in local universities and colleges.

Second, the total transport volume dramatically increased, and the key transportation junctions gradually moved from the coastal cities to the inland cities in China. More specifically, the total transport volume for the top 20 cities reached 114.72 billion, nearly twice that (58.13 billion) in 2003. In 2012, the transport volumes in Xi'an and Zhengzhou reached 361.54 (rank 16) and 356.60 million (rank 19), respectively. These are both inland cities. This is because China has accelerated its transportation system construction, especially in inland underdeveloped regions.

Third, compared with population growth, the total number of students enrolled in tertiary education exhibited a more significant increase. Take Chengdu as an example; its population increased from 11.04 to 11.73 million, but the number of students enrolled in tertiary education more than doubled from 300,742 to 670,174 from 2003-2012. This indicates that China has accelerated its higher education growth in the cities, and some inland regions such as Chengdu, Chongqing and Xi'an have become key Chinese innovation centres.

As discussed in the previous section, China is the largest recipient of FDI nowadays, but the geographic distribution of FDI still varies across cities. Table 5.8 lists the top and bottom 20 cities in terms of FDI in China in 2003 and 2012, and exhibits the situation in regard to foreign capital utilisation in urban areas.

Table 5-8 Top 20 and Bottom 20 Chinese Cities in Total Inward FDI Value (2003, 2012)

20 cities with highest inward FDI in 2012			20 cities with least inward FDI in 2012			20 cities with highest inward FDI in 2003			20 cities with least inward FDI in 2003		
Cities	*Location*	*In 10,000 US Dollars*	*Cities*	*Location*	*In 10,000 US Dollars*	*Cities*	*Location*	*In 10,000 US Dollars*	*Cities*	*Location*	*In 10,000 US Dollars*
Tianjin	N	1500000	Lijiang	SW	2871	Suzhou	E	680511	Ya'an	NW	219
Shanghai	E	1500000	Qitaihe	NE	2826	Shanghai	E	585022	Chongzuo	S	218
Dalian	NE	1200000	Laibin	S	2418	Shenzhen	S	362300	Lijiang	SW	195
Chongqing	SW	1100000	Zigong	SW	2066	Qingdao	E	281480	Yichun	NE	183
Suzhou	E	916490	Yan'an	NW	2000	Wuxi	E	270057	Jiamusi	NE	137
Chengdu	SW	859000	Xinzhou	N	1963	Guangzhou	S	258076	Wuwei	NW	133
Beijing	N	804160	Yulin	S	1879	Shenyang	NE	224237	Baiyin	NW	123
Shenyang	NE	580435	Fangchenggang	S	1849	Dalian	NE	221126	Lincang	SW	112
Shenzhen	S	522944	Karamay	NW	1720	Nanjing	E	221022	Datong	N	96
Hangzhou	E	496061	Guigang	S	1692	Beijing	N	214675	Dazhou	SW	93
Guangzhou	S	474312	Chifeng	N	1132	Yantai	E	204995	Laibin	S	88
Qingdao	E	460027	Bazhong	SW	1100	Wuhan	C	176155	Dingxi	NW	88
Wuhan	C	444424	Baise	S	1007	Dongguan	S	175400	Heihe	NE	85
Nanjing	E	413031	Hechi	S	946	Ningbo	E	172727	Shaotong	SW	75
Wuxi	E	400953	Shaotong	SW	900	Tianjin	N	163325	An'kang	NW	75
Changchun	NE	368236	Lanzhou	NW	751	Huizhou	S	140703	Shuangyashan	NE	70
Zhengzhou	C	342898	An'kang	NW	704	Fuzhou	E	130198	An'shun	SW	43
Dongguan	S	336938	Qingyang	NW	400	Xiamen	E	124286	Qingyang	NW	42
Changzhou	E	336073	Baiyin	NW	240	Foshan	S	122508	Baicheng	NE	34
Changsha	C	297666	Dingxi	NW	118	Weihai	E	109820	Hegang	NE	12

Based on the statistics in Table 5.8, foreign presence in all of the listed cities dramatically increased from 2003-2012, and most inward FDI has been concentrated in large and developed cities such as Beijing, Shanghai, and Shenzhen. Focusing on specific cities, the growth rate in FDI varied across cities. For instance, the total value of inward FDI in Tianjin increased by over 9.18 times, while inward FDI in Suzhou increased by 34.68% during the same period. Meanwhile, the geographic distribution of foreign presence also changed. In 2003, the largest FDI recipients were eastern and coastal open cities (e.g. Foshan, Xiamen and Yantai). However, some of these cities, especially the small ones, had been replaced by more inland cities by 2012. In particular, Chongqing (rank 4), Zhengzhou (rank 17) and Changsha (rank 20) were in the top 20 FDI recipients. In terms of FDI recipients, the cities in southern China have significantly lagged behind. The number of cities in southern China in the bottom 20 increased from 2 to 6 over the period 2003-2012, and almost all of them are located in Guangxi province. Such geographic discrepancies demonstrate that FDI gradually expanded from coastal and southern cities to inland regions, and further exerted an impact on local technological upgrading.

Table 5-9 Top 20 and Bottom 20 Chinese Cities in Pace and Rhythm

20 cities with most rapid FDI in 2012			20 cities with slowest FDI in 2012			20 cities with most irregular FDI over 2003-2012			20 cities with least irregular FDI over 2003-2012		
Cities	*Location*	*Growth Rate (%)*	*Cities*	*Location*	*Growth Rate (%)*	*Cities*	*Location*	*Value*	*Cities*	*Location*	*Value*
Bozhou	E	42.857	Urumchi	NW	-15.790	Chongzuo	S	9.000	Weifang	E	-1.126
Xianning	C	40.625	Zhangjiajie	C	-16.667	Zunyi	SW	9.000	Liuzhou	S	-1.131
Hegang	NE	40.000	Pingxiang	E	-18.182	Kunmig	SW	9.000	Yuncheng	N	-1.155
Heihe	NE	33.333	Dandong	N	-19.048	Qujing	SW	9.000	Huangshi	C	-1.205
Karamay	NW	33.333	Yueyang	C	-20.455	Yuxi	SW	9.000	Hangzhou	E	-1.210
Ulan Qab	N	30.769	Yuncheng	N	-21.429	Baoshan	SW	9.000	Xiangtan	C	-1.250
Suqian	E	30.000	Xining	NW	-21.429	Lincang	SW	9.000	Shaoxing	E	-1.269
Baoshan	SW	28.571	Jiamusi	NE	-23.077	Xi’an	NW	9.000	Lvliang	N	-1.269
Jining	E	25.926	Zigong	SW	-25.000	Xianyang	NW	9.000	Jingmen	S	-1.294
Panzhihua	SW	25.000	Yulin	NW	-25.000	Hanzhong	NW	9.000	Xuancheng	E	-1.324
Neijiang	SW	23.077	Pingdingshan	C	-26.667	Yulin	NW	9.000	E’zhou	C	-1.367
Huainan	E	20.000	Longyan	E	-28.571	Jiuquan	NW	9.000	Kaifeng	C	-1.493
Shangqiu	C	20.000	Luoyang	C	-31.035	Xining	NW	9.000	Jiujiang	E	-1.543
Loudi	C	20.000	Liaoyuan	NE	-33.333	Yinchuan	NW	9.000	Changzhi	N	-1.557
Jincheng	N	18.750	Lincang	SW	-33.333	Urumchi	NW	9.000	Hezhou	S	-1.557
Huaibei	E	18.519	Jiangmen	S	-33.502	Karamay	NW	9.000	Xuchang	C	-1.584
Tonghua	NE	18.182	Guiyang	SW	-35.294	Nanchong	E	9.000	Jingzhou	C	-1.617
Fuzhou	E	17.742	Fuzhou	E	-41.598	Fuzhou	E	8.947	Anyang	C	-1.694
Suizhou	C	17.647	Songyuan	NE	-42.857	Nanchang	E	7.673	Jiamusi	NE	-2.040
Xiangyang	C	16.981	Huluodao	NE	-45.455	Zhanjiang	S	7.461	Fuxin	NE	-2.179

Table 5.9 illustrates both the pace and rhythm of foreign expansions in Chinese cities in 2012. Based on the data in the table, it can be seen that small and inland cities such as Xianning, Karamay and Hegang exhibited rapid foreign expansion in local areas. More specifically, the foreign expansion growth rates in the top three cities Bozhou (42.86%), Xianning (40.63%) and Hegang (40.00%) all surpassed 40%. This indicates that the Chinese "Develop-the-West Strategy" began to take effect, and more inland cities became destinations for FDI activities. By contrast, some eastern and coastal cities exhibited a dramatic decrease in the number of MNEs. For example, the total number of MNEs in Longyan (-28.57%), Fuzhou (-33.50%) and Jiangmen (-41.60%) decreased by over 25% over the period 2011-2012. Focusing on the rhythm of the foreign expansion process, the most irregular foreign expansions took place in southwestern (6) and northwestern (9) cities from 2003-2012. Overall, the most stable or the most irregular foreign expansions were more likely to take place in small Chinese cities, while some large cities such as Beijing and Shanghai are not on the list.

5.3.2. Econometric Analysis

Table 5.10 reports the correlation matrix of variables in the spatial regression models. Generally, the high correlation coefficients between the independent variables and regional TFP demonstrate that there is a close relationship, and indicate that these variables were well chosen. This set of independent variables make clear the determinants of TFP in Chinese cities. In addition, potential multicollinearity was checked using Variance Inflation Factors (VIF), and all of the variables are within an acceptable range, with a mean VIF value of 1.33.

Table 5-10 Summary Statistics and Correlation Matrix

Variables	***Mean***	***S.D.***	***1***	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***
1.TFP $_{i,t}$	15.264	1.019	1.000								
2.IFDI $_{i,t-1}$	0.191	2.159	0.602	1.000							
3.Pace $_{i,t-1}$	8.325	25.824	-0.166	-0.065	1.000						
4.Rhythm $_{i,t-1}$	18.395	12.044	0.260	0.143	-0.075	1.000					
5.Scale $_{i,t-1}$	2.619	0.222	-0.019	-0.050	0.112	-0.036	1.000				
6.Output $_{i,t-1}$	0.111	0.494	0.718	0.369	-0.138	0.211	0.050	1.000			
7.Transport $_{i,t-1}$	2.818	0.709	0.432	0.581	-0.097	0.117	-0.059	0.224	1.000		
8.Population $_{i,t-1}$	-3.377	0.851	0.399	0.531	-0.034	0.015	-0.069	0.362	0.212	1.000	
9.Education $_{i,t-1}$	4.270	1.251	0.192	0.324	-0.062	0.074	-0.003	0.119	0.190	0.266	1.000

The results of the LM tests demonstrate a high possibility of spatial dependence in all of the models. In addition, both the results of the LM tests and their robust forms demonstrate a significance level of 1%. However, they do not reject either SEM or SAR, although SAR and SEM illustrate a higher probability level across the different models. Therefore, if the tests are inconsistent, the regression is estimated using the SDM model (Lee and Yu, 2010). In our model, the inconsistent results confirm that the SDM model is more appropriate for use in the estimation. The results of the spatial Hauseman tests are significant in all of the spatial models. Therefore, the fixed effects are adapted in the spatial regression to control for the unobserved time and invariant urban features. Subsequently, LR tests are implemented to determine whether the spatial and time-period fixed effects should be partially or jointly included in the estimation. As shown in Table 5.11, the results of the LR tests are significant at the 1% level in all of the models, indicating the joint spatial fixed and time-period effects in our estimations.

Table 5-11 Panel regressions using TFP as dependent variable with pooled OLS, and spatial and time period fixed effects.

Variables	*Pooled OLS (1)*	*ML spatial Regression (2)*	*Pooled OLS (3)*	*ML spatial Regression (4)*	*Pooled OLS (5)*	*ML spatial Regression (6)*	*Pooled OLS (7)*	*ML spatial Regression (8)*	*Pooled OLS (9)*	*ML spatial regression (10)*
Intercept	14.232***		14.518***		14.156***		14.101***		14.024***	
	(0.000)		(0.000)		(0.000)		(0.000)		(0.000)	
Scale$_{i,t-1}$	0.093*	0.165***	0.069	0.151***	0.111**	0.150***	0.095**	0.150***	0.157***	0.157***
	(0.067)	(0.000)	(0.175)	(0.000)	(0.019)	(0.000)	(0.044)	(0.000)	(0.001)	(0.000)
Output$_{i,t-1}$	1.570***	0.743***	1.558***	0.737***	1.391***	0.737***	1.377***	0.733***	1.360***	0.732***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Transport$_{i,t-1}$	-0.191***	-0.015	-0.180***	-0.026**	-0.084***	-0.026**	-0.091***	-0.023**	-0.073***	-0.009
	(0.000)	(0.218)	(0.000)	(0.016)	(0.000)	(0.016)	(0.000)	(0.031)	(0.000)	(0.443)
Population$_{i,t-1}$	0.071***	-0.102	0.054***	0.452***	-0.097***	0.439***	-0.086***	0.444***	-0.077***	-0.136
	(0.000)	(0.252)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.123)
Education$_{i,t-1}$	0.074***	0.0003	0.063***	-0.006	0.023**	-0.008	0.011	0.023	0.018*	0.001
	(0.000)	(0.963)	(0.000)	(0.447)	(0.015)	(0.338)	(0.228)	(0.505)	(0.052)	(0.871)
IFDI$_{i,t-1}$			0.047***	0.019***	0.146***	0.019***	0.128***	0.028***	0.125***	0.038***
			(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Pace$_{i,t-1}$					-0.004***	-0.0002			-0.004***	-0.0002
					(0.000)	(0.233)			(0.000)	(0.239)
Pace$_{i,t-1}$****IFDI***$_{i,t-1}$					0.001***	0.0001			0.001***	0.0002
					(0.000)	(0.625)			(0.000)	(0.128)
Rhythm$_{i,t-1}$							-0.008***	-0.003***	-0.007***	-0.004***
							(0.000)	(0.002)	(0.000)	(0.000)
Rhythm$_{i,t-1}$****IFDI***$_{i,t-1}$							-0.001	-0.001***	-0.001**	-0.0004**
							(0.114)	(0.003)	(0.029)	(0.022)
Spatial Effects										
W*Scale$_{i,t-1}$		-0.076*		-0.093**		-0.117***		-0.104***		-0.140***
		(0.074)		(0.016)		(0.003)		(0.008)		(0.001)
W*Output$_{i,t-1}$		0.015		0.066		0.057		0.082		0.070
		(0.828)		(0.257)		(0.325)		(0.156)		(0.309)

Continued Table

W*Transport$_{i,t-1}$		-0.057*		-0.042		-0.032		-0.044		-0.019
		(0.087)		(0.158)		(0.287)		(0.142)		(0.570)
W*Population$_{i,t-1}$		-0.268		-0.190		-0.501*		-0.246		-0.761**
		(0.385)		(0.497)		(0.088)		(0.379)		(0.017)
W*Education$_{i,t-1}$		0.018		0.027**		0.027**		0.027**		0.020
		(0.227)		(0.044)		(0.045)		(0.040)		(0.165)
W*IFDI$_{i,t-1}$				0.038***		0.028**		0.034***		0.035**
				(0.002)		(0.025)		(0.010)		(0.019)
W*Pace$_{i,t-1}$						0.001***				0.002***
						(0.001)				(0.000)
W* IFDI$_{i,t-1}$****Pace***$_{i,t-1}$						0.0003***				0.001***
						(0.010)				(0.000)
W*Rhythm$_{i,t-1}$								0.003***		0.005***
								(0.007)		(0.000)
W*IFDI$_{i,t-1}$****Rhythm***$_{i,t-1}$								-0.0001		-0.0001
								(0.799)		(0.846)
W*dep.var.		0.481***		0.357***		0.347***		0.350***		0.385***
		(0.000)		(0.000)		(0.000)		(0.000)		(0.000)
LM—LAG	1164.842		1141.287		831.325		831.325		764.951	
Robust LM-LAG	476.595		464.290		388.539		388.539		345.899	
LM—ERR	882.358		863.954		563.758		563.758		537.172	
Robust LM-ERR	194.112		186.957		120.971		120.971		118.120	
LR test spatial effect	1164.842***		1141.287***		831.325***		831.325***		764.951***	
Spatial fixed effect	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES
Time period fixed effect	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES
Number of observations	1952	1952	1952	1952	1952	1952	1952	1952	1952	1952
Spatial Hausman tests		18.691*		54.899***		49.161***		140.706***		297.309***
R^2	0.766	0.967	0.768	0.984	0.804	0.984	0.805	0.984	0.811	0.981
Corrected R^2		0.750		0.564		0.569		0.571		0.488

**p-value≤0.1, **p-value≤0.05, *** p-value≤0.01*

Notes: Corrected R^2 is R^2 without the contribution of spatial and fixed time period effects in spatial regression models. Maximum likelihood (ML) methods are used to estimate the spatial regressions.

Table 5.11 reports the results of the panel regressions, pooled Ordinary Least Square (OLS) and ML spatial regression, respectively. In all 10 models, $TFP_{i,t}$ is the dependent variable, while $IFDI_{i,t}$, $Pace_{i,t}$ and $Rhythm_{i,t}$ are key explanatory variables. Therein, models 2, 4, 6, 8, 10 are ML spatial models used to indicate both intra- and inter-regional externalities of the independent variables, while models 1, 3, 5, 7, 9 are pooled OLS regressions, as the baselines. Focusing on the control variables, the coefficients of both $Scale_{i,t}$, and $Output_{i,t}$ are positively significant (β_1=0.157, P_1<0.01, β_2=0.732, P_2<0.01), in model 10. This indicates that economic scale is crucial to local technological upgrading in Chinese cities. Considering inter-regional externalities, $Scale_{i,t}$ is negatively significant (β=0.140, P<0.01) in model 10. This is because developed cities with a large economic scale generate limited spillover effects to neighbouring cities, impeding their technological upgrading.

Focusing on the intra- and inter-regional externalities of FDI, the coefficients of both $IFDI_{i,t}$ and $W*IFDI_{i,t}$ are positively significant (β_1=0.038, P_1<0.01, β_2=0.035, P_2<0.05) in model 10, while the other models also exhibit consistent with such results. This demonstrates that foreign presence in Chinese cities not only brings knowledge spillovers in local areas, but also facilitates technology transfer and dissemination to neighbouring cities. Because of weak internal knowledge stocks, FDI activities are still key external knowledge sources for technological upgrading in Chinese cities, and such spillover effects are not strictly confined within a closed region. This is consistent with some of the prior literature (Ning et al., 2016, Ouyang and Fu, 2012). In terms of the pace and rhythm of foreign expansions, they both exert an impact on FDI spillovers. More specifically, both $Rhythm_{i,t}$ and $Rhythm_{i,t-1}*IFDI_{i,t-1}$ are negatively significant (β_1=-0.004, P_1<0.01, β_2=-0.0004, P_2<0.05) in model 10. It appears that more irregular foreign expansions significantly constrain FDI spillovers in Chinese cities, which is similar to the results in the industrial level study of Wang et al. (2012a). This is because a stable business environment seems to be crucial to build up mutual trust for MNEs and domestic firms to build up mutual trust and foster opportunities in terms of interactive activities such as R&D collaboration and alliances. Hence, H3a is supported. Although the baseline OLS regressions indicate that $Pace_{i,t-1}*IFDI_{i,t-1}$ is negatively significant, it is not significant in model 10 considering both intra- and inter-regional externalities (β=-0.0002, P>0.1). This indicates that rapid foreign expansion processes do not have a positive impact on the technological spillovers of FDI, as they may overwhelm domestic firms' absorptive capacity to fully recognise and assimilate advanced technology. H2a is not supported. From the spatial perspective, both $W*Pace_{i,t}$ and $W*IFDI_{i,t-1}*Pace_{i,t-1}$ are positively significant (β_1=0.002, P_1<0.01, β_2=0.001, P_2<0.01) in model 10, indicating that more rapid foreign expansion processes enhance FDI spillovers in neighbouring cities. This result suggests that neighbouring cities can benefit from being close to cities with a rapid pace of FDI, as they increase the availability of demand and the diversity of both upstream and downstream industries utilised by foreign firms.

5.4. Concluding Remarks

In this chapter, I explored both the intra- and inter-regional externalities of inward FDI in technological upgrading, and also investigated technological spillovers from the foreign expansion process, namely the pace and rhythm of FDI, within and across Chinese cities. To obtain the empirical evidence, I used a panel dataset incorporating 244 cities over the period 2004-2011, and adopted both OLS and ML spatial regression models.

From an intra-regional perspective, the empirical results demonstrate that FDI spillovers are a key external knowledge source for local technological productivity in Chinese cities. MNEs can transfer and disseminate advanced technology to local actors through mutual interactions e.g. labour mobility and supplier chains. This is consistent with the results of most of the previous studies (Crespo and Fontoura, 2007, Meyer and Sinani, 2009). Focusing on foreign expansion pace and rhythm, irregular and unpredictable foreign expansion processes significantly diminish FDI spillovers in Chinese cities, and directly impede technological upgrading in the local area. The empirical results are consistent with Wang et al. (2012a)'s industrial level study, as time compression diseconomies emerge within an unstable business environment (Wang et al., 2012a). It is easier for domestic firms to adopt experiential learning from constant knowledge diffusion from MNEs. This is because host region actors are often constrained by bounded rationality and absorptive capacity, so it is difficult for them to adopt timely adjustments and organisational restructuring over a compressed time (Simon, 1959, Wang et al., 2012a). More rhythmic and stable foreign expansions enhance technology transfers and disseminations to domestic firms, and promote overall regional technological upgrading. By contrast, the impacts of foreign expansion pace on FDI spillovers are not yet clear. Foreign expansions that are too rapid exert little impact on local FDI technological spillovers, so further studies are needed to understand the nature of this time-based characteristic in regard to technological spillovers.

From an inter-regional perspective, inward FDI exhibits significantly positive spillover effects in regard to neighbouring cities in China. Technology transfers and disseminations of FDI are not confined within a closed region, but spread across boundaries. This empirical result further confirms the conclusions about interregional FDI spillovers in the prior literature, as interregional “pipelines” e.g. labour mobility and supplier chains interlink a set of cities in spatial proximity (Ouyang and Fu, 2012). In other words, the knowledge sources in a city come from both local and neighbouring region FDI spillovers. In terms of the inter-regional externalities of foreign expansion pace and rhythm, more rapid foreign expansions not only contribute to technological upgrading in neighbouring cities, but also enhance inter-city FDI spillovers. This is because rapid foreign entry creates demand and diversity in local industries (Chang, 1995), and neighbouring region firms seem to benefit from such knowledge transfers and diffusions via both forward and backward linkages. However, FDI spillovers are only enhanced by foreign expansion pace and not by rhythm. In other words, due to uncertainty and complexity created by abrupt and irregular FDI expansions, technological and productivity spillovers are not evident across Chinese cities.

The empirical results in this chapter will be helpful to policy makers in host regions, and have several implications as follows. First, FDI is still an important external knowledge source for technological upgrading in Chinese cities, and its spillover effects are significant both within and across cities. It is vital for policy makers to remove entry barriers and attract more FDI to local areas. Driven by inter-regional externalities of FDI, policy makers also need to build up inter-city “pipelines” (e.g. supplier chains and social networks) to facilitate ideas exchange and knowledge flows between cities, in order to promote productivity efficiency within a larger geographic scope. Second, regional authorities need to pay attention to the time-based characteristics of MNEs’ expansion, namely pace and rhythm, to maximise the positive FDI knowledge spillover effects. More specifically, local governments should avoid unpredictable and irregular FDI inflows by means of regulatory constraints, as such FDI expansion processes greatly impede the trust-based interactions between domestic firms and MNEs. Government interventions in irregular foreign expansions would create a stable business environment in local areas, thereby enabling domestic firms to effectively learn from foreign investors and drive technological spillover effects. Third, regional governments should also focus on the positive intercity externalities of foreign expansion pace on FDI spillovers. This is because rapid foreign expansions in surrounding cities could facilitate technology transfers and disseminations of FDI, and become a key technological source in local areas. The empirical results suggest that Chinese policy makers should accelerate the construction of inter-city linkages, such as transportation systems, supplier chains and social networks etc., and foster opportunities for collaborations and alliances between foreign and local firms across cities. In this case, rapid foreign expansions could further benefit technological upgrading from inter-regional FDI spillovers.

This chapter, to the best of our knowledge, is the first piece of research to explore both the intra- and inter-regional externalities of foreign expansion time-based characteristics in FDI spillovers, but it still has some limitations that need to be further investigated in future research. First, this chapter does not consider the differences in inward FDI sources. FDI expansions in high-tech industries present more new knowledge to facilitate local technological productivity (Rosenzweig and Nohria, 1994, Xia and Walker, 2015). Future studies are needed to confirm whether foreign presence from different industries exhibits similar technological spillover effects in host countries. Second, firm and industry level research may fully explain FDI spillovers through forward and backward linkages. Due to the limitations of the data sources, this chapter could not set up a more complex framework to uncover spatial technology transfers and dissemination. Third, there is still some doubt regarding the extent to which foreign expansion pace and rhythm impact on FDI spillovers in other developing and developed economies. Hence, multinational studies are necessary in order to provide a more profound understanding of the intra- and inter-regional externalities of the foreign expansion process in FDI spillovers. To summarise, this chapter provides a useful guide for future studies, and contributes to the current knowledge base by considering time compression diseconomies on aggregate city level data from a spatial perspective.

Chapter 6 FDI and Technological Upgrading in Chinese Cities: Intra- and Inter-regional Externalities of Industrial Related and Unrelated Variety

6.1. Introduction

In the last chapter, I confirmed the positive impact of FDI spillovers on Chinese technological upgrading in both local and neighbouring cities. I also demonstrated time compression diseconomies in FDI spillovers, as irregular foreign expansion processes diminish technology transfers and dissemination in the FDI receiving city. However, as indicated before, FDI spillovers are dependent not only on foreign expansion characteristics, but also on host region factors such as local absorptive capacity, openness degree, and financial development (Crespo and Fontoura, 2007). A key regional characteristic is the local industrial structures, and our understanding of its impacts on the city level in FDI spillovers still remains limited. In this chapter, I discuss the second research question of this PhD thesis: *"What are the externalities of industrial structures, namely related and unrelated variety, in FDI spillovers both within and across Chinese cities?"*

Technological upgrading has long been regarded as a key factor in regional development, and newly created knowledge drawn from various industries has a positive impact on technological development (Weitzman, 1998, Ejermo, 2005). From an agglomeration economies perspective, different industrial structures might exert different effects on regional development (Henderson, 1997, Bishop and Gripaios, 2010, Paci and Usai, 1999). Firms and industries prefer to co-locate in spatial proximity, and interact with each other to draw upon a variety of local technological sources (Ning et al., 2016). These interactions result in the transfer and dissemination of advanced technology across firms, and contribute to the overall regional technological upgrading (Melo et al., 2009, Fujita et al., 1999, Fujita and Thisse, 2002). Nevertheless, the industrial diversification (or variety), i.e. the various sectors that make up the industrial structure, may affect the rate and process of technological upgrading differently. Namely, industrial diversity per se cannot guarantee technological upgrading. This is because knowledge across technologically related sectors seems to be recombined and used in new ways. By contrast, it is difficult for firms to fully recognise, assimilate and exploit technologies from other sectors that are unrelated to their internal knowledge basis (Castaldi et al., 2015, Nooteboom, 2000). Hence, it is necessary to move beyond the concept of conventional industrial diversity, and differentiate inherent technological relatedness across different sectors. Prior literature has coined the concept of "*industrial related variety and unrelated variety*" (*related and unrelated variety* thereafter), enabling industrial diversification to be divided into two specific dimensions in a given area (Essletzbichler, 2005, Frenken et al., 2007, Boschma and Iammarino, 2009). Therein, related variety refers to industrial variety in terms of shared and complementary competences. Unrelated variety refers to the degree of technological independence across different sectors (Castaldi et al., 2015, Dettmann et al., 2015).

FDI spillovers, as indicated before, often benefit the technological upgrading in the host region through knowledge transfers and diffusions between domestic firms and MNEs (Fu et al., 2012, Zhang et al., 2010, Sinani and Meyer, 2004). As a key external knowledge source, domestic firms can obtain advanced technologies from foreign investors either through proactive imitation and collaboration, or by passively receiving intensified competition effects (Crespo and Fontoura, 2007, Tian, 2007). One of the critical knowledge diffusion channels is forward and backward linkages, as

MNEs integrate themselves into the supply and value chains in the host region (Liu et al., 2009a). To be specific, foreign investors provide technical support (e.g. human resource training) to domestic suppliers in downstream sectors, and local customers can directly receive these high-quality inputs from MNEs. Previously, Frenken et al. (2007) argued that related variety significantly facilitates technological exchanges and dissemination, as interindustry cognitive proximity enables knowledge recombination and recreation. In the same vein, it is reasonable to believe that industrial variety in high cognitive proximity enables the setting up of interindustry linkages between foreign and domestic firms, thereby enhancing FDI technological spillovers. Nevertheless, the prior literature has scarcely considered the externalities of related and unrelated variety in FDI spillovers in a given city, and there is even less empirical evidence from emerging economies. Moreover, from a spatial perspective, the understanding of related and unrelated variety, as an important aspect of the regional setting, in FDI spillovers within and across cities still remains relatively limited.

As indicated above, the underpinning assumption that regional technological development entirely benefits from local resources and knowledge stocks has long been challenged (Shearmur, 2012). Cities are not isolated from one another but integral to a complex system, and connected by plenty of inter-regional “pipelines” (Ning et al., 2016). One key inter-city linkage is forward and backward connections integrated into the regional supply chain system. More specifically, increasing production drives up demand for upstream and downstream industries both within and across cities, and thus allows intercity technological spillovers to take place. For this reason, industrial variety seems to exert an impact on technological upgrading in neighbouring cities. On the contrary, some scholars hold the opposite opinion, namely that industrial agglomerations per se do not have spatial effects, as high transaction costs evidently hamper trading activities between cities (Abdel-Rahman and Anas, 2004). Local advantages e.g. consolidated institutions, social networks, and inter-firm frequent interactions are more likely to reduce intercity trade (Boschma, 2005). These inconclusive and mixed results might be due to the fact that industrial diversification classifications on a city level have been neglected. Because of their high cognitive proximity, it is easier for knowledge spillovers to take place between cities across technologically related industries. On the contrary, unrelated variety diminishes ideas exchange and technology diffusion to other firms in neighbouring regions.

This chapter first explores the influence of both related and unrelated variety on technological upgrading, and their externalities in FDI spillovers based on evidence from Chinese cities. It makes two contributions to the previous theoretical frameworks. First, prior scholars have mainly explored related and unrelated variety within a closed area, but have often neglected intercity impacts on technological upgrading (Castaldi et al., 2015, Frenken et al., 2007, Brachert et al., 2011). To the best of our knowledge, this chapter is the first to investigate the impact of related and unrelated variety on regional technological upgrading from a spatial perspective. Due to high inter-city trading costs, the impacts of industrial agglomerations are more likely to be confined within closed geographic regions, and firms can benefit from local advantages such as social networks, institutions and production resources (Abdel-Rahman and Anas, 2004, Boschma, 2005). This chapter attempts to challenge this conventional argument, as technological upgrading in one city might not rely entirely on knowledge stocks originating from local supply chains, but may also depend on external resources across cities. I consider that a set of technologically related industries (related variety) contribute to technological upgrading within a larger region, while unrelated variety exerts limited effects on technological capabilities in neighbouring cities. Based on such a dichotomy of industrial variety, this chapter deepens our understanding of both the intra- and inter-regional impacts of industrial agglomerations on regional technological development.

Second, this chapter emphatically investigates the externalities of related and unrelated variety in FDI spillovers. Prior literature has demonstrated the impacts of industrial diversification on technology transfers and disseminations of FDI, but has often neglected the inherent technological relatedness in such an industrial structure (Ning et al., 2016). I distinguish industrial diversification into two specific dimensions, and move beyond these views to consider technological upgrading on the Chinese city level. As indicated above, industrial linkages are a critical FDI spillover channel, and help domestic firms reap the benefits of knowledge and productivity spillovers (Liu et al., 2009a). Thanks to their cognitive proximity, knowledge transfers and diffusions between MNEs and domestic firms are more likely to take place across a set of technologically related sectors. Moreover, this chapter also discusses whether related and unrelated variety strengthen (or diminish) FDI spillovers across cities from a spatial perspective, which has been neglected by most of the prior literature.

The empirical context of this chapter is China, as it has experienced the most rapid industrialisation across the world over the last three decades. Cities, as the frontlines of the industrialisation process, cannot maintain sustainable development without well-established supply and value chains (Deng et al., 2008). Since the 21st century, China has accelerated the building up of sectoral linkages in terms of shared and complementary competences both within and across cities, allowing interindustry technological spillovers to take place. As indicated above, cities are also key FDI recipients, and plenty of MNEs have integrated into urban industrial linkages to expand their businesses. FDI spillovers contribute a large extent to Chinese urban technological upgrading (Fu, 2008, Ning et al., 2016). Therefore, related and unrelated variety are considered an important regional aspect in regard to moderating FDI spillover effects. Cities are ideal research settings in which to investigate the externalities of industrial structures in FDI spillovers, thereby deepening our understanding of FDI spillovers from both intra- and inter-regional perspectives.

The remainder of this chapter is organised as follows. The next section presents the theoretical framework, and the hypothesis regarding the relationship between technological upgrading and industrial structures, as well as the externalities of both related and unrelated variety in FDI spillovers. The third section describes the data sample and methodology. The following section presents both the descriptive and econometric analysis of the empirical results. Finally, I conclude the chapter with a discussion of the implications and limitations.

6.2. Theoretical Framework: Intra- and Inter-regional Externalities of Industrial Related and Unrelated Variety in FDI Spillovers

6.2.1. Intra- and Interregional Externalities of FDI

FDI, as indicated before, is a key external source of knowledge and greatly contributes to host region technological upgrading, especially for emerging economies with weak internal knowledge stocks (Athreye and Cantwell, 2007, Xu and Sheng, 2012, Fu, 2008). This is because FDI introduces advanced technology and managerial patterns to local actors through interactive activities, and MNEs generate knowledge spillovers to domestic firms through a set of technological diffusion channels (Crespo and Fontoura, 2007, Hamida and Gugler, 2009, Fu et al., 2011). First, FDI spillovers take place when domestic firms imitate and learn about successfully exploited technological and managerial experience from foreign investors (Meyer, 2003). These “demonstration and imitation effects” reduce uncertainty and complexity during new technology transfers and disseminations. Second, worker mobility is another effective FDI spillover channel. Host region firms often recruit skilled workers who have previously worked for MNEs, and directly reap the benefits of FDI spillovers (Poole, 2013, Hale and Long, 2006). Moreover, these workers in foreign firms can also start their own businesses in the host regions, and disseminate advanced technology within a larger geographic scope. Third, competition from MNEs facilitates international technology transfers and diffusions in host countries. In order to successfully compete with MNEs, local firms are forced to promote their production efficiency and managerial efforts (Wei and Liu, 2006, Liu et al., 2009b). Finally, forward and backward linkages are also a technological diffusion channel of FDI. Domestic firms can benefit from FDI spillovers as suppliers or customers for MNEs in supplier chains (Girma and Gong, 2008, Liu et al., 2009a). Interindustry interactions thus foster opportunities for technological alliances and collaborations between domestic and foreign firms, and for the dissemination of knowledge to the local areas.

From the spatial perspective, FDI spillovers may not be confined within a closed region, but may spread to adjacent regions through interregional interactions such as labour mobility, supplier chains and transportation (Simmie, 2003, Ning et al., 2016). Cities are not insular regions, independent from each other, but are embedded in the whole economy and can absorb external resources (Simmie, 2003, Shearmur, 2012). Sources of technological upgrading are thereby localised both within and between cities (Usai, 2011). In other words, inter-city "pipelines" can disseminate knowledge from FDI across boundaries. Nevertheless, most of the prior literature has neglected the spatial effects of FDI externalities (Ouyang and Fu, 2012, Doh et al., 2008, Blonigen et al., 2007). Hence, similar to the last chapter, this chapter also investigates both intra- and inter-regional externalities of FDI based on evidence from Chinese cities. Hence:

Hypothesis 1a: FDI has a positive intra-regional effect on local technological upgrading in Chinese cities.

Hypothesis 1b: FDI has a positive inter-regional effect on local technological upgrading in Chinese cities.

6.2.2. Industrial Variety and Knowledge Spillovers

Technological upgrading is widely accepted to be a accumulative and evolutionary process through which existing knowledge is combined into newly created patterns (Arthur, 2007, Basalla, 1988). More specifically, such a process involves the recombination and recreation of existing technologically related technologies. Old ideas are reconfigured into new knowledge to facilitate technological development in a more stable and predictable way, as opposed to radical innovation. Given the regional concerns, such knowledge transfers and disseminations are promoted by industrial agglomerations in cities. Firms and industries prefer to co-locate in spatial proximity, and interindustry interactions thus draw upon a variety of technological sources (Ning et al., 2016).

Based on agglomeration economies, industrial diversification (or variety) fosters opportunities for the exchange of complementary and shared knowledge across firms in different sectors, and lays the foundation for recombinant technological upgrading (Jacobs, 1970, Glaeser et al., 1991).

In more recent literature, Frenken et al. (2007) argued that industrial variety (or industrial diversification) per se is not a sufficient condition to diffuse knowledge and facilitate technological upgrading. This is because different types and intensities of knowledge spillovers are expected to come from different types of industrial variety. Therein, ideas exchanges and transfers are more likely to take place across a set of technologically related sectors (known as related variety) in cities. In contrast, industries with limited complementary and shared competences (known as unrelated variety) might have reduced opportunities for interindustry interactions. So far, the literature has mainly concentrated on the impacts of both related and unrelated variety on regional economic or productivity performance based on evidence from developed countries. For example, using a data sample from the Netherlands over the period 1996-2002, Frenken et al. (2007) showed that related variety increases employment growth, while unrelated variety diminishes unemployment. On the contrary, based on a US patent data sample over the period 1977-1999, Castaldi et al. (2015) found that unrelated variety contributes to a large extent to technological breakthroughs, as combinations of unrelated knowledge may trigger entirely new functionalities. Moreover, as discussed above, cities are not isolated, but closely interlinked, which results in spillovers between them. I consider that both related and unrelated variety should exert an interregional impact on technological upgrading in Chinese cities.

6.2.2.1. Related Variety and Technological Upgrading

Related variety is one type of industrial diversification. It measures the intensity of technological relatedness across different industries (Boschma and Iammarino, 2009, Frenken et al., 2007). An increased amount of shared and complementary competences and knowledge between sectors promotes related variety on a regional level. The current literature has shown that interindustry knowledge spillovers do not take place unless appropriate cognitive proximity exists between sectors (Nooteboom, 2000). Given the regional concerns, existing knowledge is more likely to be recombined and recreated in a new way within an industrial structure with a high degree of related variety, thereby enabling the facilitation of technological upgrading.

Thanks to the small cognitive distance between industries that have a high degree of related variety, it seems to be easier for innovation actors to interact with each other. Hence, there are several concrete reasons to believe that related variety can facilitate knowledge spillovers, and further exhibit positive impacts on local technological upgrading. First, worker mobility is a crucial technological diffusion channel, as firms can hire skilled technicians from other firms to benefit from productivity spillovers (Stoyanov and Zubanov, 2012). Technical experts can also leave firms to set up their own businesses and become self-employed. This type of employee turnover seems to be more frequent where there is related variety, because technologically related sectors can provide more opportunities for workers to explore and exploit technical capabilities and experience that they acquired previously (Frenken et al., 2007). For example, electronic equipment manufacturing companies prefer to employ technicians from E-commerce firms, but are less likely to accept job hunters from the textile or clothing industries. Second, sectoral linkages facilitate direct or indirect knowledge flows from technology producing industries to technology using industries (Hauknes and Knell, 2009). Based on such close supply-demand relationships, technologically related industries are more likely to set up such stable linkages. Complementary and shared competences within related variety intensify knowledge spillovers, thereby enabling firms to build up their technological capabilities in both upstream and downstream sectors. Third, the rationale of the positive impacts of related variety is that technologically related industries facilitate incremental innovation. More specifically, industries in cognitive proximity accelerate the recombination of existing technology in new ways through interactions between innovation actors. In contrast to technological breakthroughs or radical innovation, related variety helps with regional technological upgrading in a less risky way (Feldman, 1999, Boschma and Iammarino, 2009).

Prior literature has demonstrated that industrial agglomerations do not have spatial effects due to high transaction costs. Local advantages like production resources and social networks are often confined with a geographic region, rather than being shared between different areas. Constrained by high interregional transaction costs, actors such as companies and institutions prefer to interact with each other within the local area, thus reducing technological spillovers across regions (Boschma, 2005, Abdel-Rahman and Anas, 2004). However, this research has often neglected internal technological relatedness within industrial structures, and the fact that different types of industrial diversification might not always exert the same impact on technological upgrading in neighbouring regions. As discussed above, cities are also interlinked with each other through "pipelines" such as supply chains, organisational collaborations and social networks (Wang et al., 2017, Ning et al., 2016).

There are several good reasons to believe that related variety enhances intercity technology transfers and disseminations, and exerts a positive effect on technological upgrading across cities. First, based on the evidence from six European countries, Dietzenbacher (2002) showed that forward and backward linkages can facilitate interregional knowledge spillovers. Firms often have an incentive to proactively interact with others in both upstream and downstream industries, and suppliers and customers in different cities are integral to establishing regional supply chains across cities. Increasing market demands from downstream sectors also drive suppliers in neighbouring cities to build up their technological capabilities. Technologically related industries further enhance such forward and backward linkages both within and across cities, thereby enabling the recreation and recombination of knowledge in new ways. Second, related variety significantly facilitates the emergence of new sectors (known as industrial branching), as shared and complementary knowledge inflows bridge existing industrial fields and facilitate the creation of new ones (Essletzbichler, 2015). Firms' spin-off dynamics help to create new but technologically related knowledge routines (Klepper, 2007, Boschma and Wenting, 2007). Due to regional expansions and social networks, industrial branching is not confined in local areas but spreads to neighbouring regions, enhancing intercity technology transfer and dissemination. Third, Boschma and Iammarino (2009) demonstrated that related variety creates more employment opportunities across technologically related sectors, thus contributing to regional growth. The increased number of workers resulting from this might not be confined within a closed region, but might spread across neighbouring regions. Related variety accelerates such labour mobility, which is known as a critical technological spillover channel, facilitating the building up of technological capabilities across cities.

6.2.2.2. Unrelated Variety and Technological Upgrading

In contrast to related variety, it is necessary to distinguish another type of industrial variety, namely *unrelated variety*. As indicated above, industrial diversification per se is not a sufficient condition to diffuse knowledge and facilitate technological upgrading, because the cognitive distance might be large between different sectors in the regional industrial structure (Frenken et al., 2007). Therefore, industrial diversification does not always contribute to technological upgrading through effective knowledge spillovers. Unrelated variety refers to a degree of cognitive independence across different industries, and an industrial composition in which the different sectors share limited complementary competences and knowledge. In other words, where there is unrelated variety there are not substantial input-output linkages, and each sector is technologically isolated from the others (Boschma and Iammarino, 2009, Frenken et al., 2007).

Constrained by the long cognitive distance within an industrial structure characterised by unrelated variety, it is difficult for firms to interact with each other across sectors, which results in diminishing technology transfer and dissemination. Different from the cognitive-based mechanism of related variety, unrelated variety exhibits a risk-spreading strategy to avoid specific-sector shocks, and is more likely to stimulate technological breakthroughs (Essletzbichler, 2005, Castaldi et al., 2015). From the intra-regional perspective, unrelated variety can contribute to technological upgrading in cities for three main reasons.

First, in contrast to incremental innovation through an accumulative process, radical technological innovation stems from the recombination of unrelated technologies, thereby enabling the expansion of new developmental trajectories or functionalities. Namely, knowledge within an industrial structure where there is unrelated variety are roots of technological breakthroughs, and could become technologically related in the future (Dosi, 1982, Castaldi et al., 2015). Actors within related variety settings often make efforts to trigger breakthrough technologies, which become more prominent than incremental technological upgrading. Second, based on the portfolio theory, assets or product diversity significantly reduce risks. The rationale is that placing bets on more than one choice reduces the potential risk of high losses in the future (Essletzbichler, 2005, Montgomery, 1994). In the same vein, unrelated variety also contributes to local technological upgrading because it spreads the risks across a broad range of sectors with limited cognitive similarity. Regions with a high-level of unrelated variety are less likely to suffer from heavy losses due to sector-specific shocks. Hence, unrelated variety protects the regional labour market and prevents sudden unemployment (Frenken et al., 2007). Thanks to this stable business environment and market, it is easier for regions with a high degree of unrelated variety to provide sustainable labour supplies for technological activities, and to allow firms to adopt appropriate technological upgrading strategies over time. Third, a cognitive distance that is too small might lead to cognitive lock-in effects (Boschma, 2005). Technologically related sectors are often connected by successful and robust linkages, and it is difficult for them to break these and unlearn their mature production routines. However, these interindustry linkages might be redundant, and hamper technological innovation in the future (Lambooy and Boschma, 2001). Hence, knowledge bases should not be too small across industries, in order to avoid lock-in in the learning process; however, related variety is still necessary in technological upgrading.

With respect to the inter-regional effects, as yet little is known about the impacts of unrelated variety on technological upgrading across cities. Cities with a high degree of unrelated variety might also be interlinked to neighbouring areas in spatial proximity. This is because a set of insular sectors within a geographical region can be technologically related to industries in other cities. Thanks to inter-city forward and backward linkages, knowledge spillovers through regional supply chains are external sources that can enable technological upgrading. Moreover, as indicated above, unrelated variety creates limited interindustry linkages, so local firms prefer to seek suppliers and customers in neighbouring regions. Some firms are forced to escape to neighbouring regions in spatial proximity. In this case, labour mobility and competition spread across different cities, and facilitate inter-city knowledge spillovers. Admittedly, unrelated technologies are the roots of further technological innovation, but take time to achieve.

6.2.3. FDI Spillovers, Related and Unrelated Variety

FDI has long been regarded as a key external knowledge source that contributes to host region technological upgrading. Advanced technologies and managerial knowledge embedded in foreign investors are usually novel to domestic firms, especially those in emerging economies (Wang et al., 2014, Fu, 2008). The main causes of the current mixed empirical results regarding FDI spillovers in host countries are related to both FDI internal characteristics and regional effects (Crespo and Fontoura, 2007). The prior literature has demonstrated that FDI spillovers are contingent on host region industrial structures, but has often neglected the impacts of the inherent technological relatedness within industrial variety (Ning et al., 2016, Wang et al., 2014). Given the effects of cognitive distance, MNEs prefer to interact with local actors that have technologically related knowledge bases. Hence, the intensity of knowledge spillovers between domestic firms and MNEs changes with variations in the technological relatedness of industrial structures. Moreover, interlinked cities also create interaction opportunities between domestic firms and MNEs across cities, enabling the facilitation of FDI spillovers across cities. I consider that both intra- and inter-regional FDI spillovers are moderated by related and unrelated variety from a spatial perspective.

6.2.3.1. Related Variety and FDI Spillovers

Elaborating upon related variety, knowledge spillovers are intensified across sectors that are technologically related. Such industrial variety drives the combination of interdependent knowledge, and further fosters recombinant and incremental technological innovation (Feldman, 1999, Frenken et al., 2007, Boschma and Iammarino, 2009). Industrial agglomeration has also been recognised as a critical factor in terms of FDI location choices, as industrial diversification may generate positive externalities and increase the economic profits of foreign investors (Chen, 2009). For example, using a firm level dataset from Portugal, Guimaraes et al. (2000) showed that regions with industrial diversity attract FDI activities in the local areas. Similar evidence has also been found in developing countries. Using an extensive Chinese data sample, Du et al. (2008) demonstrated that horizontal industrial agglomeration can even offset the negative impacts of weak institutions in host regions, and affect FDI location choices.

To take a further step, it seems likely that MNEs will prefer to invest in host regions with industrial related variety in order to reap the benefits of positive externalities. This is because agglomerations of different industries in cognitive proximity provide more opportunities for recombinant innovation (Frenken et al., 2012). From the evolutionary perspective, MNEs can increase their productivity and technological capabilities in a more predictable and gradual manner. Given the regional concerns, technological relatedness also facilitates the knowledge sharing process, leading to recombinant innovation (Zhang, 2013). MNEs in regions with a high degree of related variety are more likely to interact with local actors through R&D collaborations and alliances. Related variety also helps MNEs to become embedded into regional supply chains in host regions, enabling them to enhance their interactions with firms in both upstream and downstream industries. Therefore, these are some good reasons to believe that related variety greatly enhances FDI spillovers. First, horizontal linkages, as interactions involved in competition activities, are a key technological diffusion channel of FDI (UNCTAD, 2001). Related variety helps to build up such horizontal linkages, thereby creating a competitive environment in the local area. Both local and foreign firms in sectors with a small cognitive distance need to rapidly grab similar market shares. In order to compete with foreign investors in technologically related industries, domestic firms are forced to improve their indigenous innovative capabilities. Second, industrial diversifications provide various knowledge resources for technological upgrading within a geographical region (Ning et al., 2016). Related variety intensifies the interactions between domestic firms and MNEs, as they have shared competences and can learn from various disciplines across industries (Quatraro, 2010). Due to the small interindustry cognitive distance in related variety settings, domestic firms can incorporate foreign advanced technology and managerial experience into their production from one industry to another, thereby facilitating FDI spillovers. Third, close forward and backward linkages enhance FDI spillovers to domestic firms (Liu et al., 2009a). Given the regional concerns, related variety can foster stable and systematic supply chains, which attract MNEs to become embedded in the whole business and market environment. Thanks to connections to both upstream and downstream sectors, foreign investors either directly transfer advanced technologies to domestic suppliers or disseminate high-quality goods and services to local customer companies (Javorcik, 2004b, UNCTAD, 2001).

Moreover, as indicated above, related variety exerts interregional impacts on technological upgrading, because intercity linkages such as worker mobility facilitate knowledge spillovers across cities. The fundamental mechanism through which related variety affects FDI technological spillovers across cities is also similar. Prior literature has demonstrated both intra- and inter-regional externalities of industrial diversity in urban technological innovation, but has neglected internal technological relatedness across sectors (Ning et al., 2016). Hence, as yet little is known about whether related variety moderates the relationship between inter-regional FDI spillovers and technological upgrading, and there is even less empirical evidence from emerging economies. Chang (1995) showed that MNEs' FDI activities are not confined within one region in host countries, but are likely to expand the business and production lines in neighbouring regions. Related variety thereby enables the setting up of intercity linkages to accelerate FDI expansions, as foreign investors prefer to interact with local actors in sectors that share complementary knowledge. Moreover, FDI expansions in host region supplier chains also drive increasing demands for inputs and resources. This effects of this increased demand are not confined within an isolated region, as interregional forward and backward linkages can disseminate market demands to suppliers in neighbouring areas

(Liu et al., 2009a). As indicated above, related variety contributes to the building up of intercity industrial linkages, so it can also enhance interregional FDI spillovers across cities. However, Abdel-Rahman and Anas (2004) argued that local advantages e.g. production resources and social networks often converge within geographic regions, so inter-city transaction costs hamper firms in regard to trading with others in neighbouring regions. Due to the liability of foreignness, MNEs are often faced with great uncertainty and complexities during their FDI activities (Chang and Rhee, 2011). Hence, even if MNEs are integrated into host regional supplier chains, it is still necessary for them to make trade-offs between expanded markets and increasing transaction costs in neighbouring cities.

Hence, interindustry linkages established by related variety facilitate FDI spillovers within a city, thereby building up indigenous technological capabilities. Meanwhile, intercity technology transfers and disseminations of FDI can also take place across industries in cognitive proximity from a spatial perspective. In this case, I propose:

Hypothesis 3a: Related variety positively moderates the relationship between intra-regional FDI and technological upgrading in Chinese cities.

Hypothesis 3b: Related variety positively moderates the relationship between inter-regional FDI and technological upgrading in Chinese cities.

6.2.3.2. Unrelated Variety and FDI Spillovers

Focusing on unrelated variety, little is known about its impacts on FDI spillovers, and there is little evidence regarding this in the current literature. As indicated above, the fundamental mechanism through which unrelated variety contributes to technological upgrading is based on the portfolio strategy, namely, a set of isolated industries can spread sector-specific risks and maintain a stable business environment (Frenken et al., 2007). Unrelated variety is also more likely to trigger technological breakthroughs, as it enables the expansion of new developmental trajectories or functionalities through the recombination of different pieces of knowledge (Dosi, 1982, Castaldi et al., 2015).

However, the externalities of unrelated variety in FDI spillovers are different from that of related variety, as international technology transfers and disseminations are mainly based on interactions between MNEs and domestic firms. With respect to intracity effects, FDI technological spillovers can be constrained by unrelated variety for several reasons. More specifically, cities with a high degree of unrelated variety often do not set up sufficient forward and backward linkages, which are a crucial technological diffusion channel for FDI (Girma and Gong, 2008, Liu et al., 2009a). Hence, it is difficult for MNEs to disseminate advanced technology to domestic actors in both upstream and downstream sectors. Due to the liability of foreignness, foreign investors are more likely to suffer from market complexity and uncertainty in cities with a high degree of unrelated variety, so FDI spillovers will be costly and less effective. Meanwhile, unrelated variety is less sensitive to competition effects, because it spreads the risks across various sectors with a large cognitive distance (Montgomery, 1994, Frenken et al., 2007). Competition from FDI is confined within limited industries in host countries, so such effects of FDI on technological spillovers are scarcely felt by domestic firms in all sectors. In other words, the attenuated competition effects from foreign presence slow down new technology and management pattern adoption in host regions (Fu et al., 2011).

From the inter-city perspective, little is known about the inter-regional externalities of unrelated variety in FDI spillovers. Domestic firms in cities with a high degree of unrelated variety cannot effectively benefit from interregional FDI spillovers if they are not suppliers or customers of MNEs within regional supplier chains. Although intercity "pipelines" such as worker mobility and social networks can produce technology transfers and diffusions of FDI from one region to others, a cognitive distance between industries that is too large can still hinder communication and interactive learning (Nooteboom, 2000). Moreover, technological breakthroughs stemming from unrelated knowledge domains of FDI spillovers can be uncertain and risky across cities. Hence, I propose the following hypotheses in regard to both the intra- and inter-regional externalities of unrelated variety in technological upgrading in Chinese cities:

Hypothesis 3a: Unrelated variety negatively moderates the relationship between intra-regional FDI and technological upgrading in Chinese cities.

Hypothesis 3b: Unrelated variety negatively moderates the relationship between inter-regional FDI and technological upgrading in Chinese cities.

6.3. Data and Methodology

The data sample in this chapter mainly stems from two sources: the *Chinese Urban Statistical Yearbooks*, and the *Annual Industrial Survey Database*. These two datasets are both official publications of the *Chinese National Bureau of Statistics* (NBS), and have been widely used in previous literature (Chang and Xu, 2008, Tian, 2007, Zhang et al., 2010). I initially identified 286 cities, including four municipalities (Beijing, Shanghai, Tianjin and Chongqing), and then eliminated 47 cities with missing information. Similar to the last chapter, I require all urban economic data in the year t-1 to take the possible endogeneity issue into account, and require a time lag for cities to absorb the knowledge spillovers from FDI. The final data sample covers 239 cities over the period 2001-2009. In total, I identify 2,151 city-year observations from the pooled OLS and ML spatial panel regressions.

6.4. Empirical Results

6.4.1. Descriptive Analysis

This section aims to explore the spatial distribution of the key explanatory variables in Chinese cities. In Chapter 5, I discussed the regional disparity in FDI, foreign expansion pace and rhythm and a set of indicators regarding economic scale and social development. Hence, this section mainly focuses on the differences in regard to industrial related and unrelated variety. Table 6.1 lists the related variety degree of the top and bottom 20 cities in both 2001 and 2009, and Table 6.2 lists the unrelated variety degree of the top and bottom 20 cities in both 2001 and 2009.

Table 6-1 Top 20 and Bottom 20 Chinese Cities in Related Variety (2001, 2009)

20 cities with highest degree of related variety in 2009			20 cities with lowest degree of related variety in 2009			20 cities with highest degree of related variety in 2001			20 cities with lowest degree of related variety in 2001		
Cities	*Location*	*Value*	*Cities*	*Location*	*Value*	*Cities*	*Location*	*Value*	*Cities*	*Location*	*Value*
Suzhou	E	599799.900	Hezhou	S	74.978	Shanghai	E	71092.490	Suining	SW	14.672
Shenzhen	S	498605.900	Fuxin	NE	74.815	Tianjin	N	39746.220	Liaoyuan	NE	14.153
Shaoxing	E	484951.200	Xinyu	E	74.600	Hangzhou	E	24024.880	Urumchi	NW	13.934
Nantong	E	382450.900	Panzhihua	SW	72.514	Suzhou	E	19566.800	Anshun	SW	13.833
Jiaxing	E	329950.100	Jiuquan	NW	69.645	Chonqging	SW	19341.810	Qitaihe	NE	13.088
Shanghai	E	323779.100	Xining	NW	67.299	Quanzhou	E	16326.960	Yan’an	NW	11.073
Ningbo	E	315166.300	Tongling	E	61.968	Ningbo	E	16176.030	Jixi	NE	10.690
Chongqing	SW	224237.800	Yan’an	NW	50.968	Taizhou	E	15273.850	Yinchuan	NW	10.454
Hangzhou	E	163745.400	Datong	N	50.078	Wuxi	E	15150.500	Yingtan	E	7.824
Wenzhou	E	155605.400	Jincheng	N	50.073	Guangzhou	S	14905.940	Huaibei	E	5.328
Taizhou	E	132712.000	Yangquan	N	48.246	Wenzhou	E	13325.850	Ma’anshan	E	3.805
Quanzhou	E	115765.000	Changzhi	N	37.900	Panzhihua	SW	13207.220	Huainan	E	3.531
Foshan	S	109880.600	Anshun	SW	36.999	Shaoxing	E	12778.990	Xining	NW	2.953
Dongguan	S	99253.570	Baoshan	SW	33.450	Beijing	N	12229.550	Baoshan	SW	2.771
Dalian	NE	99046.270	Zhangjiajie	C	28.955	Shenzhen	S	12027.740	Tongling	E	2.375
Changzhou	E	92851.900	Jixi	NE	23.165	Nantong	E	10292.880	Haikou	S	2.301
Wuxi	E	80603.520	Sanya	S	15.980	Foshan	S	8020.026	Hegang	NE	2.293
Weifang	E	78644.310	Hegang	NE	7.109	Zhengzhou	C	7041.738	Dongguan	S	1.478
Tianjin	N	74749.700	Liupanshui	SW	3.063	Changzhou	E	6647.319	Liupanshui	SW	1.419
Jinhua	E	69326.790	Qitaihe	NE	2.046	Huzhou	E	4986.725	Sanya	S	1.144

Table 6-2 Top 20 and Bottom 20 Chinese Cities in Unrelated Variety (2001, 2009)

20 cities with highest degree of unrelated variety in 2009			20 cities with lowest degree of unrelated variety in 2009			20 cities with highest degree of unrelated variety in 2001			20 cities with lowest degree of unrelated variety in 2001		
Cities	*Location*	*Value*	*Cities*	*Location*	*Value*	*Cities*	*Location*	*Value*	*Cities*	*Location*	*Value*
Shanghai	E	3878.283	Yinchuan	NW	54.846	Shanghai	E	2029.119	Jixi	NE	16.475
Suzhou	E	3261.200	Beihai	SW	54.696	Tianjin	N	1450.318	Yinchuan	NW	15.576
Ningbo	E	3098.358	Anshun	SW	54.594	Panzhihua	SW	838.240	Hailar	N	15.375
Shenzhen	S	2243.837	Tongling	E	53.677	Ningbo	E	806.543	Laiwu	E	15.162
Hangzhou	E	2180.429	Yichun	NE	50.266	Guangzhou	E	805.022	Suining	SW	15.029
Nantong	E	2046.798	Jiuquan	NW	43.189	Beijing	N	792.764	Zhangjiajie	C	14.432
Wenzhou	E	1950.524	Xining	NW	42.003	Suzhou	E	763.716	Sanmenxia	C	14.010
Jiaxing	E	1865.236	Yingtan	E	35.207	Hangzhou	E	741.590	Baoshan	SW	13.101
Foshan	S	1807.032	Liupanshui	SW	34.695	Wuxi	E	718.495	Yingtan	E	13.004
Wuxi	E	1734.505	Jixi	NE	34.681	Wenzhou	E	609.419	Tongling	E	12.584
Changzhou	S	1684.396	Hezhou	S	34.252	Taizhou	E	561.974	Huainan	E	11.070
Tianjin	N	1671.850	Heihe	NE	34.017	Chongqing	SW	504.982	Haikou	S	10.984
Taizhou	E	1596.675	Datong	N	32.855	Changzhou	E	497.760	Ma’anshan	E	10.562
Shaoxing	E	1570.116	Baoshan	SW	32.507	Foshan	S	481.940	Huaibei	E	10.336
Chongqing	SW	1534.842	Yan’an	NW	31.675	Quanzhou	E	479.749	Xining	NW	10.013
Quanzhou	E	1451.302	Zhangjiajie	C	31.202	Shenyang	NE	476.406	Liupanshui	SW	9.312
Guangzhou	S	1425.381	Yangquan	N	28.084	Nantong	E	434.047	Sanya	S	7.121
Dongguan	S	1417.208	Hegang	NE	19.320	Shenzhen	S	421.308	Qitaihe	NE	6.358
Jinhua	E	1294.097	Qitaihe	NE	19.112	Qingdao	E	375.367	Hegang	NE	5.854
Dalian	NE	1287.547	Sanya	S	10.851	Shaoxing	E	365.140	Dongguan	S	4.916

Based on the statistics in Table 6.1, it can be seen that there exists huge regional disparity in terms of related variety across the whole country, and cities with a high degree of related variety are concentrated in the southern and coastal regions. First, the cities with a high degree of related variety are concentrated in developed regions such as Jiangsu, Zhejiang, and Guangdong provinces. More specifically, the top 10 cities are all in southern and eastern China. The regional disparity across cities is evident. For example, in 2009, the degree of related variety (599799.9) in Suzhou was over 293157 times more than that (2.046) in Qitaihe. This demonstrates that more developed cities often have a diversified and technologically related industrial structure, because they exhibit competitive advantage in terms of infrastructure and production facilities, transport systems and the business environment. The industrial chains in these cities are quite complete and systematic, and different sectors are closely connected through input-output linkages.

Second, the level of related variety in Chinese cities significantly increased from 2001-2009, but the growth rates are different across cities. For example, the degree of related variety in Baoshan increased by 244%, while in Suzhou it only increased by 34.12% during the same period. More specifically, the cities with the most rapidly developed related variety were mainly located in underdeveloped regions (e.g. southwestern and northwestern China). This is because the "Develop-the-West Strategy" facilitated the industrialisation process in such underdeveloped cities, and they experienced rapid construction of local industrial systems.

Third, notably, the cities with the lowest level of related variety were often resource-intensive over the period 2001-2009. For instance, Jixi (coal mining), Tongling (copper mining) and Liupanshui (coal mining) were both in the bottom 20 cities with the lowest related variety. The industrial structures in these cities are often specialised and simplistic with limited mineral manufacturing industries. Hence, resource-oriented cities usually have a diversified industrial structure, and the industrial relatedness is even less.

Table 6.2 lists the top and bottom 20 cities in terms of unrelated variety in both 2001 and 2009. Similar to the table illustrating the cities with related variety, again there is huge regional disparity across the Chinese cities. The cities with a high level of unrelated variety are also concentrated in eastern and coastal China. Some super-cities, such as Shanghai and Hangzhou, have a diversified industrial structure consisting of a set of technologically related and unrelated sectors. Nevertheless, compared with the figures for related variety, the regional disparity in the unrelated variety values is much smaller. For example, in 2009, the degree of unrelated variety in Shanghai (3878.283) was over 357.41 times that (10.851) in Sanya. Meanwhile, resource-intensive cities such as Tongling, Huainan, and Liupanshui exhibited a low degree of unrelated variety.

6.4.2. Econometric Analysis

Table 6.3 reports the correlation matrix of variables in the spatial regression models. Generally, the high correlation coefficients between the independent variables and regional TFP demonstrate that there is a close relationship, and indicate that these variables were well chosen. This set of independent variables make clear the determinants of TFP in Chinese cities. In addition, potential multicollinearity was checked by Variance Inflation Factors (VIF), and all of the variables are within an acceptable range, with a mean VIF value of 1.74.

Table 6-3 Summary Statistics of Variables and Correlation Matrix

Variables	***Mean***	***S.D.***	***1***	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***
1.TFP $_{i,t}$	14.236	1.104	1								
2.IFDI $_{i,t}$	3.165	1.734	0.665	1							
3.RV $_{i,t}$	6.260	2.449	0.672	0.528	1						
4.UV $_{i,t}$	4.754	1.186	0.706	0.525	0.564	1					
5.Scale $_{i,t}$	2.518	0.392	0.352	0.244	0.128	0.134	1				
6.Industry $_{i,t}$	9.402	1.198	0.916	0.618	0.566	0.601	0.321	1			
7.Transport $_{i,t}$	2.651	0.671	0.405	0.446	0.228	0.242	0.157	0.492	1		
8.Education $_{i,t}$	13.320	1.168	0.541	0.555	0.354	0.399	0.251	0.618	0.375	1	
9.Investment $_{i,t}$	8.576	1.014	0.827	0.583	0.475	0.501	0.391	0.679	0.482	0.657	1

The results of the LM tests demonstrate a high possibility of spatial dependence in all of the models. In addition, both the results of the LM tests and their robust forms demonstrate a significance level of 1%. However, they do not reject either SEM or SAR, although SAR and SEM illustrate a higher probability level across the different models. Therefore, if the tests are inconsistent, the regression is estimated by the SDM model (Lee and Yu, 2010). In our model, the inconsistent results confirm that the SDM model is more appropriate for use in the estimation. The results of the spatial Hauseman tests are significant in all of the spatial models. Therefore, the fixed effects are adapted in the spatial regression to control for the unobserved time and invariant features of cities. Subsequently, LR tests are implemented to determine whether the spatial and time-period fixed effects are partially or jointly included in the estimation. As shown in Table 6.4, the results of the LR tests are significant at the 1% level in all of the models, indicating the joint spatial fixed and time-period effects in our estimations.

Table 6-4 Panel regressions using TFP as dependent variable with pooled OLS, and spatial and time period fixed effects.

Variables	*Pooled OLS (1)*	*ML spatial Regression (2)*	*Pooled OLS (3)*	*ML spatial Regression (4)*	*Pooled OLS (5)*	*ML spatial Regression (6)*	*Pooled OLS (7)*	*ML spatial Regression (8)*	*Pooled OLS (9)*	*ML spatial regression (10)*
Intercept	6.299***		6.453***		6.109***		5.609***		5.476***	
	(0.000)		(0.000)		(0.000)		(0.000)		(0.000)	
Scale$_{i,t-1}$	0.153***	0.041***	0.154***	0.041***	0.166***	0.033***	0.163***	0.031***	0.160***	0.031***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.001)	(0.000)	(0.002)
Output$_{i,t-1}$	0.799***	0.694***	0.787***	0.694***	0.683***	0.685***	0.649***	0.680***	0.645***	0.676***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Transport$_{i,t-1}$	-0.101***	-0.012	-0.106***	-0.014	-0.058***	-0.007	-0.056***	-0.009	-0.061***	-0.007
	(0.000)	(0.269)	(0.000)	(0.222)	(0.000)	(0.534)	(0.000)	(0.442)	(0.000)	(0.515)
Education$_{i,t-1}$	-0.055***	-0.002	-0.059***	-0.003	-0.059***	-0.001	-0.072***	-0.001	-0.070***	-0.002
	(0.000)	(0.833)	(0.000)	(0.775)	(0.000)	(0.953)	(0.000)	(0.955)	(0.000)	(0.847)
Investment$_{i,t-1}$	0.122***	0.167***	0.117***	0.162***	0.154***	0.173***	0.166***	0.175***	0.165***	0.174***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
IFDI$_{i,t-1}$			0.018**	0.008*	0.058***	0.027***	0.162***	0.049***	0.217***	0.068***
			(0.023)	(0.089)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
RV$_{i,t-1}$					0.170***	0.012**			0.050**	0.021**
					(0.000)	(0.049)			(0.032)	(0.022)
RV$_{i,t-1}$****IFDI***$_{i,t-1}$					0.016***	0.004***			0.016**	0.005*
					(0.000)	(0.001)			(0.019)	(0.072)
UV$_{i,t-1}$							0.408***	0.038***	0.508***	0.078***
							(0.000)	(0.007)	(0.000)	(0.006)
UV$_{i,t-1}$****IFDI***$_{i,t-1}$							-0.041***	-0.010***	-0.073***	-0.021***
							(0.000)	(0.000)	(0.000)	(0.009)
Spatial Effects										
W*Scale$_{i,t-1}$		0.041*		0.049**		0.021		0.015		0.019
		(0.091)		(0.041)		(0.384)		(0.541)		(0.428)
W*Output$_{i,t-1}$		-0.395***		-0.364***		-0.334***		-0.352***		-0.348***

Continued Table

		(0.000)		(0.000)		(0.000)		(0.000)		(0.000)
$W*Transport_{i,t-1}$		-0.072**		-0.080**		-0.028		-0.038		-0.033
		(0.027)		(0.014)		(0.385)		(0.237)		(0.309)
$W*Education_{i,t-1}$		-0.005		-0.007		0.016		0.017		0.022
		(0.856)		(0.804)		(0.561)		(0.547)		(0.442)
$W*Investment_{i,t-1}$		-0.004		-0.037		0.013		0.016		0.017
		(0.904)		(0.292)		(0.700)		(0.635)		(0.621)
$W*IFDI_{i,t-1}$				0.025**		0.106***		0.172***		0.106**
				(0.031)		(0.000)		(0.000)		(0.017)
$W*RV_{i,t-1}$						0.070***				0.054*
						(0.000)				(0.087)
$W* IFDI_{i,t-1}*RV_{i,t-1}$						0.019***				0.020*
						(0.000)				(0.081)
$W*UV_{i,t-1}$								0.170***		0.068
								(0.000)		(0.314)
$W*IFDI_{i,t-1}*UV_{i,t-1}$								-0.038***		-0.002
								(0.000)		(0.943)
W*dep.var.		0.528***		0.498***		0.395***		0.397***		0.387***
		(0.000)		(0.000)		(0.000)		(0.000)		(0.000)
LM—LAG	827.184***		826.888***		610.588***		557.251***		557.419***	
Robust LM-LAG	307.167		307.224		268.865		258.582		255.241	
LM—ERR	884.981***		884.838***		603.483***		525.370***		536.654***	
Robust LM-ERR	364.963		365.174		261.760		226.701		234.476	
LR test spatial effect	827.184***		826.888***		610.588***		610.588***		557.419***	
Spatial fixed effect	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES
Time period fixed effect	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES
Number of observations	2151	2151	2151	2151	2151	2151	2151	2151	2151	2151
Spatial Hausman tests		43.154		67.135***		135.589***		198.892***		243.952***
R^2	0.850	0.987	0.850	0.987	0.891	0.987	0.891	0.987	0.898	0.987
Corrected R^2		0.577		0.581		0.609		0.611		0.612

p*-value≤0.1, ***p*-value≤0.05, * *p*-value≤0.01*

Notes: Corrected R^2 is R^2 without the contribution of spatial and fixed time period effects in spatial regression models. Maximum likelihood (ML) methods are used to estimate the spatial regressions.

Table 6.4 reports the results of the panel regressions, pooled Ordinary Least Square (OLS) and ML spatial regressions, respectively. In all 10 models, $TFP_{i,t}$ is the dependent variable, while $IFDI_{i,t}$, $RV_{i,t}$ and $UR_{i,t}$ are key explanatory variables. Therein, models 2, 4, 6, 8, 10 are ML spatial models that indicate both the intra- and inter-regional externalities of the independent variables, while models 1, 3, 5, 7, 9 are pooled OLS regressions, as the baselines. Focusing on the control variables, the coefficients of both $Scale_{i,t}$ and $Output_{i,t}$ are positively significant (β_1=0.031, P_1<0.01, β_2=0.676, P_2<0.01), in model 10, which is consistent with the results in the last empirical chapter. This is because a large and solid economic basis is the cornerstone of technological upgrading in local areas, and more economically developed cities possess a high potential for innovation activities. The coefficient of $Investment_{i,t}$ is also positively significant (β=0.174, P<0.01), indicating that local TFP will increase by 17.4% when fixed-asset investments increase by 100% in the same city. From the spatial view, $W*Output_{i,t}$ is negatively significant (β=-0.348, P<0.01), and the results in the other models are also consistent. This is because Chinese industrial developed cities often exhibit comparative advantage in terms of infrastructure and production facilities, transportation system and social networks, so firms from adjacent cities may prefer to agglomerate in these regions. In other words, technology diffusions and outflows impede technological upgrading in neighbouring cities.

Focusing on the intra- and inter-regional externalities of FDI, the coefficients of both $IFDI_{i,t}$ and $W*IFDI_{i,t}$ are positively significant (β_1=0.068, P_1<0.01, β_2=0.106, P_2<0.05) in model 10, while the other models are also consistent. The empirical results confirm the positive roles of FDI in technological upgrading both within and across Chinese cities. Based on evidence from both developed and developing economies, some of the prior literature has also found a similar positive influence on host region technological upgrading (Hong and Sun, 2011, Hanel, 2000, Damijan et al., 2013). Focusing on industrial structures, the coefficients of both $RV_{i,t}$ and $UR_{i,t}$ are positively significant (β_1=0.021, P_1<0.05, β_2=0.078, P_2<0.01), which is also similar to the findings based on developed economies (Castaldi et al., 2015). More specifically, the coefficient of $UR_{i,t}$ is slightly larger than that of $RV_{i,t}$, indicating that triggering technological breakthroughs through unrelated knowledge may exert a more effective impact on technological upgrading than knowledge spillovers across technologically related sectors. Hence, H1a and H2a are supported.

The coefficient of $RV_{i,t}*IFDI_{i,t}$ is positively significant (β=0.005, P<0.1), while $RV_{i,t}*IFDI_{i,t}$ is negatively significant (β=-0.021, P<0.01). This is because MNEs often prefer to integrate into local supplier chains and set up close connections with domestic firms across a set of technologically related industries. Namely, related variety is more likely to result in the transfer and dissemination of advanced technology from foreign investors to host regions. By contrast, cities with a high degree of unrelated variety may have an unstable business environment, which will impede technology transfer and dissemination of FDI in China. From the spatial perspective, the coefficients of both $W*RV_{i,t}$ and $W*RV_{i,t}*IFDI_{i,t}$ are both positively significant (β_1=0.054, P_1<0.1, β_2=0.020, P_2<0.1) in model 10. This is because technologically related industries (related variety) are more likely to set up inter-city linkages, and enhance FDI spillovers across cities. However, the coefficients of $W*UR_{i,t}$ and $W*UR_{i,t}*IFDI_{i,t}$ are not significant (P>0.01). Higher trading costs and local advantages such as institutions and social networks are the key reason to facilitate transactions within regions

(Abdel-Rahman and Anas, 2004). Under the condition of unrelated variety, technology transfers and diffusions may be costly and less effective across cities.

6.5. Concluding Remarks

Previously, plenty of literature has investigated FDI spillovers and industrial structures separately, but the externalities of industrial relatedness have seldom been discussed. Using a unique panel dataset from 239 Chinese cities over the period 2001-2009, I move beyond the conventional dichotomy of regional industrial agglomerations, and further divide industrial diversification into two specific dimensions, namely industrial related and unrelated variety. This chapter emphatically investigates the intra- and inter-regional externalities of industrial structures in FDI spillovers, in order to explore the relationship between foreign presence and technological upgrading both within and across Chinese cities.

From an intra-regional perspective, our results once again confirm the positive effects of foreign presence in host region technological upgrading. This evidence is consistent with the findings in prior studies (Fu, 2008, Fu and Gong, 2011, Ning et al., 2016). Technology transfers and diffusions of FDI to domestic firms are still regarded as key external sources for local technological upgrading. Focusing on industrial structures, namely related and unrelated variety, our results demonstrate that both related and unrelated variety exert a positive impact on TFP in Chinese cities. More specifically, related variety facilitates knowledge spillover effects across a set of technologically related sectors, as it can contribute to incremental innovation. In other words, close interindustry interactions and collaborations lead to completely new products or technologies. This is because a high degree of related variety implies complementary and shared competences across different industries, and thus firms can recombine and recreate new technologies in a more stable and incremental pattern (Boschma et al., 2012, Boschma and Iammarino, 2009, Frenken et al., 2007). By contrast, the positive role of unrelated variety in regional TFP mainly stems from the recombination and recreation of unrelated knowledge domains into a wholly new functionality or product. Unrelated variety, which is often regarded as technology novelty, is more likely to trigger radical technological innovation and be the root of further technological upgrading (Castaldi et al., 2015). Considering the externalities of related and unrelated variety in FDI spillovers, related variety significantly enhances FDI spillovers, while unrelated variety diminishes FDI spillovers in Chinese cities. Cities with a high degree of related variety foster opportunities for MNEs to interact and collaborate with local actors across industries in cognitive proximity, and it is also easier for foreign investors to integrate into host region supplier chains as customers or suppliers. However, unrelated variety often creates an uncertain business environment with limited interindustry linkages, thus impeding effective technological spillovers from FDI.

From the inter-regional perspective, the empirical results demonstrate that advanced knowledge from foreign presence can spread to neighbouring cities. Hence, FDI spillovers are not confined within a geographical area, but can also promote overall technological upgrading between cities. Such results once again verify that intercity technological diffusion channels such as worker mobility, social networks, and forward and backward linkages can disseminate advanced technology to domestic firms. Focusing on the externalities of related and untreated variety across Chinese cities, only related variety has a spatial effect. More specifically, related variety per se not only contributes to technological upgrading in adjacent cities, but also enhances inter-regional FDI spillovers. This moves beyond the conventional argument that industrial agglomerations do not exert spatial effects, as they are confined by high trading costs (Abdel-Rahman and Anas, 2004).

Based on the empirical results above, I would like to make some suggestions to policy makers. First, it is still necessary to attract inward FDI in Chinese cities, as it is the key source of new technology. Local authorities should remove the entry barriers to encourage MNEs' investments, and proactively build up inter-regional collaborations and interactions to facilitate FDI spillovers across cities. Second, policy makers should adjust industrial structures to promote local technological upgrading. Previous literature has suggested that related and unrelated variety contribute to technological upgrading in different ways (Frenken et al., 2007, Castaldi et al., 2015). Hence, they could accelerate the construction of linkages between industries in cognitive proximity. This is because related variety per se not only greatly promotes local productivity, but also facilitates technological upgrading in neighbouring cities. Although unrelated interindustry knowledge (unrelated variety) might trigger wholly new technology in the future, technologically related industries are still the key driving force for technological upgrading in Chinese cities. Third, in order to maximise FDI spillovers in host regions, it is necessary for authorities to profoundly understand the externalities of related and unrelated variety. This chapter suggests that an increasing degree of related variety enhances both intra- and inter-regional FDI spillovers. Local authorities should continuously encourage industrial convergence based on shared and complementary competences. Moreover, industries with a large cognitive distance (unrelated variety) significantly hinder FDI spillovers within Chinese cities. The government could reduce the degree of unrelated variety in local areas in order to maximise technology transfer and dissemination between foreign and domestic firms.

This chapter has prudently investigated the impacts of inward FDI and industrial structure, but there are still some research limitations. First, the sources of inward FDI have not been fully classified in this chapter, so little is known about whether FDI from different countries exerts the same effects in terms of technological upgrading both within and across Chinese cities. For example, previous studies have shown that MNEs from HMT (Hong Kong, Macau and Taiwan) and other western countries exert distinctive knowledge spillovers on local firms in China (Buckley et al., 2007b). Therefore, the empirical evidence on FDI spillovers would be more convincing if further research considered the influence of foreign ownership. Second, the measurements of related and unrelated variety in this chapter are based on entropy measurements. However, as indicated above, there are several alternative indicators, such as the product proximity index and the geographic distribution of interindustry employment, that could be used to further confirm the role of industrial relatedness in technology transfers and diffusions of FDI (Hidalgo et al., 2007). Finally, because of the data deficiency, this chapter only explores industrial structure effects based on Chinese city level evidence. In order to verify whether the results are the same in other countries, further research could consider a replication of this study across both developed and developing economies, and expand the empirical frameworks about the externalities of related and unrelated variety in FDI spillovers.

Chapter 7 Externalities of Foreign Expansion Process and Industrial Structures in FDI Spillovers between both Government and Market-Oriented Urban Groups

7.1. Introduction

Based on evidence from a nationwide city level dataset in China, Chapters 5 and 6 confirmed that inward FDI has a positive impact on technological upgrading both within and across Chinese cities. Moreover, the foreign expansion process and industrial structures were shown to moderate the intra- and inter-regional relationships between foreign presence and technological upgrading. Nevertheless, it is considered that empirical evidence based on nationwide datasets is not convincing enough to explain the specific relationship between foreign presence and technological upgrading, as it neglects place-specific effects. In particular for China, which is such a huge country, it is necessary to further investigate FDI spillovers within some distinctive regions, in order to provide a deeper understanding of the regional effects.

Despite the increasing economic globalisation, regionalisation still matters in terms of technological development. Certain place-specific resources and factors can strengthen firms' competitiveness in local areas (Porter, 1998a, Porter, 2000). Hence, distinctive clusters can reveal some profound insights into FDI spillovers in technological upgrading from the regional context perspective. Based on empirical results in cities, the previous two chapters confirmed that technological upgrading is positively correlated with foreign presence in China; however, they did not discuss whether such findings exist in different regional clusters. This chapter aims to expiate on distinct technological upgrading mechanisms within two specific regional clusters: namely Beijing-Tianjin-Hebei and the

Shanghai-Yangtze River Delta urban groups, to discuss the third research question of this PhD thesis: *"What are the differences in terms of both the intra- and inter-regional externalities of the foreign expansion process and industrial structures, in regard to FDI spillovers within government and market-oriented Chinese urban groups?"*

From the economic geography perspective, increasing economic globalisation has given rise to a paradox, namely whether regionalisation is still necessary in terms of economic and technological development. Thanks to modern transportation and communication systems, it is easier for firms to access technological and capital resources through global supplier chains, so there is no need for them to be located near their target marketplaces overseas. Meanwhile, faced with international competition from different economies, governments are gradually losing their administrative influence in regard to local economic and technological issues (Cairncross, 2001, Porter, 2000). By contrast, some scholars still insist on the importance of regionalisation. Distinctive local factors and resources such as institutional and business environments can play a significant role in the collective process of innovation (Florida, 1994, Prescott, 1998). Place-specific factors are crucial in firms' efforts to gain global competitiveness, enabling them to build up indigenous technological capabilities.

Because the current literature has pointed out the important role of region-specific factors in technological spillovers (Florida, 1994, Glaeser et al., 1992, Barro and Sala-I-Martin, 1995), it is widely accepted that the regionalisation argument can provide a more profound understanding of technological upgrading mechanisms. Regional clusters (also known as clusters), defined as geographically proximate groups of interlinked firms and associated institutions in terms of both complementarities and commonalities, possess some competitive advantages in regard to technology sharing and transfers. Clusters not only offer transaction cost advantages, but also allow for the expansion of the scale and scope of knowledge spillovers (Pike and Tomaney, 1999, Porter, 2000). More than single industries or firms, the geographic scope of a cluster can be a city, a state, a country, or even a set of economies in spatial proximity.

As indicated above, cities are the main FDI recipients, and disseminate technology from MNEs to local actors (Ning et al., 2016). They can provide an appropriate environment in which to innovate, as they are richer, and more diversified and labour- and knowledge-intensive than non-urban areas (Glaeser, 2011). Cities also exhibit several competitive advantages such as market accessibility and lower transaction costs (Quigley, 1998, Marshall, 1920, Glaeser, 1998). Based on the empirical evidence from developed countries, Shearmur (2012) showed that cities are the frontline of technological innovation. Hence, from the regional context perspective, cities are an ideal regional setting in which to deepen our understanding of FDI spillovers in technological upgrading, and in particular to reveal some distinctive place-specific effects. However, current studies have scarcely investigated technological upgrading mechanisms in cities (Feldman and Audretsch, 1999, Ning et al., 2016, Duranton and Puga, 2001), and there is even less empirical evidence from cities in emerging economies.

This chapter emphatically explores urban technological upgrading mechanisms within specific clusters, namely urban groups. Over the last 30 years, China has experienced a rapid urbanisation process, and promoted socioeconomic development in the cities (Pang, 2009, Zhang and Shunfeng, 2003). Benefiting from superior geographic conditions, several Chinese southern and coastal metropolises and their vicinities have pioneered the implementation of economic and institutional reforms, and agglomerated to form urban groups (Chang, 1994, Yao et al., 2006). Different from cities in isolation, these urban groups are regarded as localised networks, consisting of a set of cities that are interconnected in terms of both spatial and organisational proximity (Pang, 2009). Technological learning and knowledge sharing are intensified through intra- and inter-city "pipelines" such as worker mobility and supplier chains (Ning et al., 2016). Moreover, as the largest emerging economy, China's internal knowledge stocks are still too weak to meet its increasing technological demands (Ning et al., 2016, Athreye and Cantwell, 2007, Fu, 2008). FDI has long been a key external source for indigenous technological upgrading (Ning et al., 2016, Fu, 2008). Therefore, cities within an urban group are more likely to be integral to an innovation system and benefit from FDI technological spillovers (Shi and Ning, 2006, Pang, 2009). Namely, urban groups are an ideal research setting in which to investigate specific technological upgrading mechanisms in China.

Compared with other advanced countries, Chinese technological upgrading operates under relatively strict administration, as both central and local governments substantially control almost all large-scale R&D programmes. Since the "institutional reform and economic liberalization" in the early 1980s, plenty of structural problems have gradually emerged in China, especially conflicts around the over-centralised government and expanded market powers (Morrison, 2012). One hotly debated topic is whether the Chinese government should be decentralised and release more authorities to the markets. This is because excessive governmental interference impedes innovation, and regional technological upgrading increasingly requires market flexibility and a market orientation to maximise financial returns (Cheng, 2005, Hou and Zhao, 2008). Nevertheless, some opponents argue that regional developments cannot be entirely dependent upon market stimulation, and that the government must retain a critical role to achieve political and social stability, by setting up rules and regulations and providing infrastructure facilities and public services within clusters (Porter, 2000). These opponents not only devote themselves to safeguarding social justice, but also support domestic industrial development to meet macro-economic demands. Hence, China has to adopt a dual-track approach in its regional technological upgrading, relying on both government and market orientations (Leydesdorff and Guoping, 2001, Lu and Lazonick, 2001). The Chinese leadership needs to make a trade-off between its administrative powers and a market orientation, with the aim of creating more competitive, open and vigorous technological upgrading mechanisms within urban groups.

So far little is known about the effects of place-specific factors such as government and market orientations in the relationship between FDI and technological upgrading. Hence, this chapter hopes to examine whether FDI spillovers still contribute to technological upgrading within specific Chinese clusters (urban groups). It also investigates how government and market orientations affect the externalities of both the foreign expansion process and industrial structures in technological upgrading both within and across cities. It makes two key contributions to the existing literature. First, the chapter examines FDI spillovers in regional technological upgrading from the regional context perspective, and elaborates both government- and market-oriented technological upgrading mechanisms. The prior literature has usually focused on FDI spillovers based on nationwide evidence, but neglected specific regional clusters (Cheung and Lin, 2004, Ning et al., 2016, Crespo et al., 2009). China exhibits huge regional disparities across cities, and it seems that ubiquitous positive FDI spillovers do not exist under distinctive regional conditions. Prior research has argued that the government could adopt various administrative means to facilitate cluster developments (Porter, 2000, Hospers and Beugelsdijk, 2002). However, Chinese urban FDI activities operate under relatively strict administration and control, so technology transfers and disseminations between domestic firms and MNEs might be constrained by a set of regulatory or policy constraints. Second, I emphatically explore the externalities of foreign expansion time-based characteristics and industrial structures within both government- and market-oriented clusters. Prior research has often treated both the foreign expansion process and industrial structures as determinants of regional growth or FDI spillovers based on nationwide empirical evidence (Frenken et al., 2007, Boschma et al., 2012, Wang et al., 2012a). I thereby move beyond this view to specific clusters, namely Beijing-Tianjin-Hebei and the Shanghai-Yangtze River Delta urban groups. Moreover, I also look at both the intra- and inter-regional externalities of these factors in FDI spillovers within two representative clusters. The empirical results will provide a more profound understanding of technological upgrading mechanisms from a spatial perspective.

This chapter provides both theoretical and empirical frameworks to explore specific regional technological upgrading mechanisms in China within two regional clusters: Beijing-Tianjin-Hebei and the Shanghai-Yangtze River Delta. This chapter aims to explore whether the findings in the previous chapters still exist in government- and market-oriented clusters from a regional context perspective. The remainder of this chapter is structured as follows. First, I present a theoretical framework regarding regional clusters, and explain why urban groups are an ideal setting through which to understand technological upgrading mechanisms. Next, I expiate on both government and market orientations in FDI spillovers, the foreign expansion process, and industrial structures. After that, I conduct case studies of two representative urban groups in China, Beijing-Tianjin-Hebei and the Shanghai-Yangtze River Delta, respectively. This is followed by an econometric analysis based on data from these two clusters. Finally, I conclude the chapter with a discussion and a reflection on its limitations.

7.2. Theoretical Framework: Clusters and Regional Technological Upgrading Mechanisms

7.2.1. Regional Clusters and Technological Upgrading

Even with economic globalisation and the interlinking of companies and organisations across different nations, regionalisation is still significant in regard to creating competitive advantage in terms of economic growth and technological upgrading (Porter, 1998a, Porter, 2000). Both place-specific local resources and external knowledge enhance such competitiveness within a geographic region, and these cannot be easily duplicated or matched by distant rivals in other regions (Asheim and Isaksen, 2002). Hence, the regionalisation argument emphasizes that typical local resources and non-economic factors are crucial to understanding firms' technological innovation, as well as interpreting regional technological upgrading mechanisms from the regional context perspective.

From the geographical perspective, regional clusters (also known as clusters) are defined as geographic concentrations of interlinked economic and organisational entities (e.g. institutions, companies, industries and other organisations) within a particular region in terms of both commonalities and complementarities (Porter, 2000, Porter, 1998a). Clusters, as specific business and economic environments, possess several competitive advantages in regard to regional technological upgrading mechanisms. More specifically, in contrast to insular industries or firms with limited cognitive proximity, regional cluster companies can benefit from marketing complementarities, information accessibility, and sectoral linkages through trade associations and labour divisions (Marshall, 1920, Porter, 1998b, Adams and Jaffe, 1996). They enjoy lower transaction costs and a clearer understanding of customers' needs, and discern trends faster than their isolated competitors. (Porter, 2000). To achieve overall economic growth and technological development, governments within clusters have more decisive and inevitable impacts on regional technological upgrading by means of policies and state-led support. Thanks to such ongoing relationships and interactions, ideas and knowledge exchanges continuously take place across different entities, and are integral to a greater and more complex geographic "regional innovation system". Due to both place-specific local resources and factors in typical clusters, knowledge sharing and dissemination can be either enhanced or diminished both within and across regions (Porter, 1998b, Asheim and Isaksen, 2002).

Technological upgrading, as a key engine of regional economic and social development, does not take place in isolation, but is largely contingent upon the extent of regional knowledge spillovers (Enkel et al., 2009, Chesbrough, 2013). Because of the tacit and contextual nature of technological sharing and dissemination, knowledge spillovers are geographically bounded, and decay with increased spatial distance (Ning et al., 2016, Audretsch, 2003). Clusters are an ideal research setting, allowing for the exploration of regional technological upgrading mechanisms within a geographically bounded area. Due to the place-specific complexity within clusters, the empirical results on regional knowledge spillovers and technological upgrading are still mixed and inconclusive. Some of the literature has identified positive effects of the interconnections within clusters, which can facilitate regional knowledge spillovers in technological upgrading. For example, compared with other regions in the US, Silicon Valley presents several region-specific advantages in terms of building up indigenous technological capabilities, particularly in electronics, and the information and computer industries. Local high-tech firms have closed relationships with world-famous universities and research institutions (e.g. Stanford University and UC Berkeley), which facilitate R&D cooperation. Modern transportation systems enable firms and industries to keep in touch with both domestic and international customers quickly and effectively. In such a market-oriented cluster, strong competition and collaborations maximise the efficiency of technological source utilisation (Florida, 1994). Nevertheless, some scholars hold the opposite opinion, namely that not all clusters facilitate knowledge spillovers in technological upgrading. Groupthink may resist the adoption of newly created knowledge, and insist on traditional behaviors (Glasmeier, 1991). In order to avoid potential risks, regional clusters might also prevent radical innovation in local areas, resulting in greater barriers to triggering technological breakthroughs (Porter, 2000).

Previous literature has defined clusters at different geographic levels in cities, states, nations, and even groups of economies (Porter, 1998b). Previously, plenty of literature has emphasised that cities possess several competitive advantages in terms of technological upgrading, such as labour division, lower transport costs, and the availability of intermediate inputs (Glaeser, 1998, Quigley, 1998). Cities are the frontlines of technological innovation, as they can provide a richer and more knowledge-intensive environment than non-urban regions (Shearmur, 2012, Glaeser, 2011). More productive firms and workers prefer to agglomerate in larger and denser cities, thereby enlarging both the scale and scope of their interactions to facilitate knowledge and ideas exchanges (Combes et al., 2012, Rosenthal and Strange, 2004, Melo et al., 2009). Cities, as a typical regional cluster, are thus an ideal research setting in which to explore technological upgrading mechanisms, allowing us to obtain a clear and profound understanding of the effects of place-specific resources and factors from a regional context perspective.

However, studies on cities in isolation are problematic in terms of fully understanding regional technological upgrading mechanisms, as technological sources come not only from local knowledge stocks but also from adjacent regions (Usai, 2011). Cities, as indicated above, are not isolated from each other, but closely interlinked through interregional "pipelines" such as labour mobility, social networks, and forward and backward linkages (Ning et al., 2016). Thanks to these interregional interactions, cities in spatial proximity form a greater and specific regional cluster, often regarded as an *Urban Group*, enabling the facilitation of knowledge flows and exchanges. From a spatial perspective, I aim to expand the geographic scope of my research and move beyond insular cities to urban group analysis, to explain the regional heterogeneity in technological upgrading within clusters.

Urban groups, as concentrations of cities in terms of both spatial and organisational proximity, help firms and industries to co-locate in commonalities and complementarities, facilitating interactions to generate knowledge spillovers. Due to regional industrial labour divisions and collaborations, urban groups exhibit more competitive advantage than insular cities in terms of lower transaction costs, more effective innovative networks and modern transportation systems to facilitate overall regional technological upgrading (Pang, 2009, Lu, 2015). Previous literature has highlighted that urban groups have become the centres of technological innovation, and exhibit three main mechanisms that manifest knowledge spillovers.

First, cities within urban group are interlinked in terms of both complementarities and commonalities (Ning, 1991). This type of regional clusters is systematically structured, as technologically related cities emerge with increasing labour divisions and collaborations. In this case, such industrial co-location minimises the transaction costs of technological spillovers, and intensifies knowledge sharing and ideas exchange across different sectors (Ellison et al., 2010). It thereby promotes the efficiency of knowledge spillovers, fostering greater knowledge flows in technological upgrading. Second, urban groups co-locate to cities in spatial and organisational proximity, and expand both the scale and scope of their sectors to create a more diversified industrial structure. In contrast to insular cities, urban groups exhibit greater and more complex value chains both within and across cities, enabling all of the cities within them to have appropriate functional positions, regardless of whether they are large or small (Chaolin, 2000). Previous literature has highlighted that agglomerations of different industries in spatial proximity provide diversified knowledge sources that facilitate technological recombination and recreation, enabling radical innovation (Ning et al., 2016, Quatraro, 2010, Harrison et al., 1996). Industries with a small cognitive distance are especially favourable in terms of recombining technologically related knowledge in new ways, intensifying knowledge spillovers to facilitate overall technological upgrading (Castaldi et al., 2015, Nooteboom, 2000). Third, urban groups enable efficient sharing of individualities such as marketplaces, institutions, and infrastructure facilities. Benefiting from modern transportation and communication systems, urban groups are large and complex regional clusters, in which newly created knowledge can be spread rapidly across cities (Yao et al., 2006, Xue and Yao, 2000). Moreover, China has also established consolidated institutional systems within the same urban group, which maximise the efficiency of government administration. Previous studies have demonstrated that technological upgrading within urban groups is contingent upon a set of region-specific factors such as local R&D intensity, institutional systems, and resource allocation (Juan and Yun, 2016, Brouwer et al., 1999). Yet little is known about the impacts of government and market orientations in regard to technological upgrading mechanisms from a regional context perspective, and there is even less evidence from emerging economies.

7.2.2. Different Types of Technological Upgrading Mechanisms within Regional Clusters: Government Orientations versus Market Orientations

Because of regional complexity and heterogeneity, it is necessary to distinguish different types of clusters. Compared with advanced economies, Chinese technological upgrading operates within a strict administrative system, and is largely contingent upon policy restrictions and state-led support. After "The Reform and Opening-up Policy" in the late 1970s, China's economic reform further transformed the centrally-planned economy into a market-oriented one (Lin et al., 2011). Therefore, China is now inclined to adopt a dual-track liberalised technological upgrading mechanism, relying on both government- and market-orientations. From such a regional perspective, I distinguish two types of regional clusters in China, to help us to investigate distinctive regional effects in regard to local technological upgrading. The first type is denoted as *Government-Oriented Clusters,* where both central and local governments strictly control and administer technological upgrading and other relevant activities. Government-oriented regional clusters exhibit strong coercive powers in technological upgrading activities by means of state-led R&D budgets, policy control, and regulatory constraints. The other type is *Market-Oriented Clusters,* where market incentives dominate the interactions across innovation actors, facilitating effective and efficient behaviours in regional technological upgrading. Under the conditions of limited government intervention, market-oriented regional clusters aim to maximise their financial returns and productivity efficiency, but often neglect social responsibility or macro-level economic developments.

7.2.2.1. Government Orientation in Regional Technological Upgrading

To avoid under-investment, it is widely recognised that R&D activities cannot be entirely left to private sectors and firms. Governments inevitably play a variety of roles in regional technological upgrading (Mani, 2002). From the regional cluster point of view, Porter (2000) argued that governments accelerate economic growth by means of maintain political stability and set up long-term and distinctive economic programs. Based on evidence from both developed and developing countries, some of the literature has also shown that government support is still crucial to indigenous technological upgrading, as governments can use administrative means (e.g. financial subsidies, tax concessions and research grants) to facilitate R&D activities in both the public and private sectors

(Hsu and Chiang, 2001, Mani, 2002, Franzel, 2008). Hence, a strand of the research has explored several government orientations and incentives in cluster technological upgrading.

First, public universities and research institutions are usually the “backbones” of large-scale S&T projects. Focusing on clusters, strong “Business-Government-University” relationships create a more concrete environment in which to help to address technological upgrading within the private sector (Porter, 2000). In contrast to interest-driven and market-oriented private firms, governments often entrust non-profit universities and research institutions with undertaking long-term, risky and strategic R&D projects, with the aim of facilitating radical innovation and maintaining competitive advantage (Etzkowitz and Leydesdorff, 2000, Anselin et al., 1997). In the Chinese context, the central government has played a key role in launching and administering a set of large-scale national S&T programmes, such as the 863 Program. These centrally-planed and state-led S&T programmes are concentrated in public research institutions and universities, and have made remarkable achievements in terms of innovation. Second, based on empirical evidence from Brazil, Etzkowitz et al. (2005) showed that incubation is a new industrial policy trend that can transform regional clusters from bureaucratic and hierarchical organisations to knowledge-intensive ones. Public universities and political groups with social objectives establish “innovation incubators”, allowing the expansion of clusters so that low-tech firms can undertake R&D activities. More specifically, governments implement a set of preferential policies such as tax concessions and financial subsidies to create a more appropriate research environment for new business, and promote SMEs’ R&D activities. In this case, private SMEs have more access to external technological sources and can embark on their own R&D activities (Hsu and Chiang, 2001). Third, thanks to more efficient sharing of various individualities (e.g. production and infrastructure facilities, transport systems and institutions), knowledge spillovers are intensified in large and dense cities. Firms in these cities can benefit from cost advantages in technological innovation (Ciccone and Hall, 1996, Helsley and Strange, 2004). Governments can thereby increase state-led institutional and financial investments to improve public services and goods, with the aim of stimulating R&D activities and accelerating newly created technology commercialisation. For example, China has set up a set of national high-tech parks within some developed clusters, and provide infrastructure facilities and public services for supporting S&T innovation (Liu et al., 2011).

7.2.2.2. Market Orientation in Regional Technological Upgrading

A market orientation is as an important element that facilitates the most effective and efficient behaviours of firms, allowing them to meet both current and future customers' demands and continuously contribute to their business performance (Narver and Slater, 1990, Kohli and Jaworski, 1990). Some of the previous literature has argued that a market orientation is a key engine for firms' technological innovation (Zhang and Duan, 2010, Jaw et al., 2010, Atuahene-Gima, 1996). With "customer pull" and "competitor push" forces, firms aim to prioritise profit maximisation under low risks, and prefer to undertake incremental innovation rather than technological breakthroughs (Zhang and Duan, 2010, Li and Calantone, 1998). I move beyond these views to the regional level, and argue that a market orientation can play a variety of roles in technological upgrading mechanisms within regional clusters: namely, customer-oriented, competitor-driven, and inter-functional coordination.

First, customer-oriented strategies aim to satisfy customers' demands and reduce potential risks during the technological upgrading process (Atuahene-Gima, 1996). In other words, market-oriented strategies focus on the maximisation of R&D efficiency, emphasising customers as the key sources of new product ideas. Market-oriented R&D activities are thus unable to facilitate technological breakthroughs, but allow incremental innovation to take place.

Second, mature and open markets within regional clusters lead to fierce competition, resulting in the more frequent entry and exit of technologcial upgrading actors (Porter, 1998a, Porter, 1990b). Larger and denser cities where more productive firms and industries agglomerate further increase such competition effects in clusters (Combes et al., 2012). Tougher competition is thus conducive to technology transfer, facilitating the entry of specialised firms and regional technologcial upgrading (Jacobs, 1969, Feldman and Audretsch, 1999, Porter, 1990b).

Third, clusters exhibit competitive advantage in terms of market complementarities, enabling cost advantages for innovation entities to access multiple technological sources (Porter, 2000). With a market orientation, specialised labour divisions make innovation entities interlinked in cognitive proximity, and facilitate knowledge sharing and technological learning through interactions. Namely, such complementary coordination faciliates effective teamwork oriented towards shared goals. This teamwork exhibits a greater integration and recombination of new knowledge, especially across marketing and R&D (Atuahene-Gima, 1996, Narver and Slater, 1990).

7.2.3. FDI Spillovers, the Foreign Expansion Process, and Industrial Structures within two Regional Clusters: Government versus Market

7.2.3.1. Governmental Orientations

Since the late 1970s, China has faced increasing structural economic problems such as rising unemployment, and energy and agricultural product shortages, and technological upgrading has thus become a key driver of regional economic growth. Inward FDI, as a key external source of advanced knowledge, has long been recognised as a major engine of technological upgrading in developing economies (Fu and Gong, 2011). Thanks to "The Reform and Opening-up Policy" in the early 1980s, the Chinese leadership decided to accelerate technological imports and expand inward FDI activities in local areas. Given the concerns over national security and political desires, inward FDI and its expansion process are still strictly centrally-planned and controlled in China.

Because of the strict foreign exchange controls, both central and local authorities play a leading role in the utilisation of foreign capital, and all MNEs' FDI expansions must be registered. The Chinese reform in "opening up to the outside world" was characterised by gradual and experimental approaches. Different from "The picking a winner strategy" in some western countries (Amsden, 2001), China has enacted a set of policies and regulations to encourage FDI expansions. For example, the Chinese leadership decided to set up "Special Economic Zones" in four southeastern coastal cities, namely Shenzhen, Zhuhai, Shantou, and Xiamen, during the late 1970s. In 1984, another 14 cities were selected to become open coastal cities, with the aim of accelerating exports and introducing foreign investments. Therein, these Chinese FDI policies more focus on tax concessions and financial subsidies, but seldom build up a competitive and open business environment for MNEs' foreign expansions.

Although both central and local governments have made great efforts in regard to foreign capital utilisation in China, whether the over-centralised governmental interventions have contributed to FDI spillovers is still the subject of a heated debate. I consider that the state-led administration has not enhanced technology transfers and diffusions of FDI, as it is more likely to hinder interactions between MNEs and local actors. There are some good reasons to believe that FDI spillovers diminish within governmental-oriented clusters. First, within governmental-oriented clusters (e.g. Beijing-Tianjin-Hebei), local officials often prefer to encourage more independent R&D activities in indigenous public universities and research institutions rather than relying on technology transfers from FDI. The Chinese government is willing to retain a high-level of technological independence, but will not be enslaved to others (Ning, 2009). For this purpose, the FDI policies in these clusters are stricter than in others, and therefore restrict both the scale and scope of foreign expansions. By contrast, indigenous R&D projects are more likely to be supported, for example through fiscal subsidies and preferential policies. Constrained by both the scale and scope of FDI, local actors have few opportunities to interact with MNEs, or reap benefits from FDI technological spillovers.

Second, it is well known that China has a sophisticated bureaucratic system, and its complex and tedious approval process often prevents FDI activities in local areas. More specifically, excessive government intervention increases transaction costs by means of long-term supply contracts or the price of technological transfers'. Government-imposed barriers create market imperfections, thereby diminishing positive FDI spillovers (Brewer, 1993). Therefore, due to increasing transaction costs, FDI technological spillovers are diminished within Chinese governmental-oriented clusters.

Third, within Chinese government-oriented clusters such as Beijing-Tianjin-Hebei, the strict household registration system has restricted freedom of labour mobility across cities (Chan, 2010). In other words, migrants often do not possess the right to obtain education, medical treatment, and social insurance. Inter-regional linkages such as labour mobility and social networks in government-oriented clusters are relatively few. As indicated above, only interlinked cities in spatial proximity are likely to be integral to establishing a regional innovation system, enabling the facilitation of FDI technological spillovers across cities (Simmie, 2003, Ning et al., 2016). Hence, it is considered that foreign presence seldom exerts an inter-regional impact on technological upgrading in Chinese cities within government-oriented clusters.

Focusing on the time-based characteristics of foreign expansions, namely pace and rhythm, time is also needed in order for domestic firms to establish close relationship with MNEs and benefit from FDI spillovers (Andersson and Koster, 2010). Well-established institutions in host countries can significantly enhance organisational capabilities, and reduce experiential knowledge accumulation for foreign investors (Lu et al., 2014). As indicated above, it is also difficult for domestic firms to absorb and assimilate new knowledge introduced by MNEs within a compressed time (Wang et al., 2012a). In this case, appropriate state-led policies and regulations contribute to the setting up of a stable business and market environment, thereby enabling a reduction in the negative effects of time compression diseconomies in technology transfers and diffusions of FDI. More specifically, mutual trust is often the cornerstone of MNEs and domestic firms building up strong social relationships (Tan and Meyer, 2011, Fryxell et al., 2002).

Given the regional concerns, local authorities can minimise the potential risks caused by rapid and irregular FDI expansions, and foster opportunities to build up interactions between foreign and domestic firms. In turn, indigenous actors within government-oriented clusters are less likely to worry about time compression diseconomies from the FDI expansion process, and will proactively interact with MNEs to reap the benefits of technological spillovers. Moreover, some research has argued that irregular international expansions often lead to fluctuations in demand in host regions, thereby impeding FDI technological spillovers to local actors (Wang et al., 2017). However, Chinese local authorities often introduce appropriate policies and regulations in a timely manner to stabilise the supply-demand relationships in indigenous markets, and reduce the risk and complexity for local actors of working with foreign firms. Hence, competition effects from rapid and irregular FDI expansions are more likely to stimulate domestic firms to accelerate the adoption of newly created and advanced technology and management patterns, so I argue that both foreign expansion pace and rhythm enhance FDI spillovers.

From the spatial perspective, little is known about the interregional externalities of both pace and rhythm in technological upgrading within government-oriented clusters. Although a set of coastal cities were selected as “special economic zones” to receive rapid FDI expansions, both the scope and scale of the FDI activities in other regions are still greatly confined. For example, within representative government-oriented clusters such as Beijing-Tianjin-Hebei, rapid FDI expansions have accelerated the adoption of advanced technology and management patterns from MNEs, but have scarcely built up the technological capabilities in nearby cities (Juan and Yun, 2016). Constrained by the evident gaps in administration across cities, MNEs prefer to expand their businesses in more open and competitive regions rather than interact with domestic firms in under-developed cities. Moreover, Chinese regional authorities often possess the right to adjust local FDI policies and regulations, which greatly affects the foreign expansion process (e.g. pace and rhythm). However, these policies and regulations are often localised within a small geographic region, and seldom exert an impact on neighbouring regional foreign expansions. As indicated above, the strict household registration system within government-oriented clusters also restricts inter-regional FDI technological spillover channels, thereby further reducing the inter-regional externalities of both foreign expansion pace and rhythm.

Industrial structures, as another key FDI spillover determinant, also play distinctive roles within government-oriented clusters. Newly created knowledge drawn from different industries significantly contributes to local technological upgrading (Weitzman, 1998, Ejermo, 2005). As indicated above, industrial diversity per se is not a necessary condition for knowledge spillovers, and it is easier for firms to fully recognise, assimilate and exploit advanced technology from other sectors that have technologically related knowledge stocks (Castaldi et al., 2015, Nooteboom, 2000). In the Chinese context, both central and local government often dominate industrial restructuring and upgrading, and implement policies and regulations to adjust industrial structures. Governments focus more on policy desires and social responsibility in industrial development, and hope to accelerate the building up of indigenous technological capabilities and technological imports (Liu et al., 2011).

Based on the empirical results from a nationwide dataset, it can be seen that both related and unrelated variety contribute to technological upgrading, but only related variety enhances FDI spillovers within and across cities. Nevertheless, confined by a strict bureaucratic system and a plethora of regulatory constraints, it seems likely that these two dimensions of industrial structures can diminish FDI spillovers in Chinese cities. Focusing on related variety, there are several good reasons why it diminishes FDI spillovers within government-oriented clusters. First, due to both policy desires and national security reasons, industrial policies within government-oriented regional clusters strictly restrict the investment scope and scale for MNEs, so it is difficult for foreign firms to interact with local actors. China restricts several high-tech sectors to foreign firms, especially in the military and heavy industry fields. In other words, a high degree of related variety does not create technological diffusion channels for FDI spillovers, but is more likely to result in a regional monopoly. Local governments prefer to bear a loss from FDI technology transfers and disseminations in order to retain their independence in regard to industrial development (Ning, 2009).

Second, a high degree of related variety often means a focus on indigenous inter-industry linkages within government-oriented clusters, thereby diminishing FDI spillovers in the local area. More specifically, local authorities often prefer to build up industrial systems that are dependent upon indigenous companies rather than MNEs. Therein, SOEs often dominate Chinese manufacturing industries, and are subject to heavy bureaucratic interventions and strict administration (Jefferson et al., 2003). Moreover, Chinese SOEs often reap the benefits of superior capital and intellectual resources by means of preferential policies (Fu and Mu, 2014). This significantly increases the transaction costs of R&D collaborations between local and foreign firms, even for MNEs that are integrated into Chinese regional supplier chains. Hence, local state-led actors have few incentives to proactively interact with MNEs, and scarcely benefit from FDI technological spillovers.

Third, high transaction costs across cities greatly impede interregional trade, and that localised advantages such as consolidated institutions and social networks further facilitate knowledge spillovers in local areas (Boschma, 2005, Abdel-Rahman and Anas, 2004). Within government-oriented clusters, local advantages can be enhanced, so related variety exhibits limited intercity impacts on FDI spillovers due to insufficient technological diffusion channels. This is because Chinese officials prefer to pay more attention to local governmental achievements rather than building up regional supplier chains from a spatial perspective. For example, based on the empirical evidence within Beijing-Tian-Hebei, Juan and Yun (2016) have shown that Beijing has scarcely transferred and disseminated innovative technology to neighbouring regions, especially cities in Hebei province, because interindustry linkages across cities are still limited.

Focusing on unrelated variety, some scholars have argued that it exhibits a risk-spreading strategy in regard to avoiding specific-sector shocks, and triggers technological breakthroughs through the recombination of unrelated knowledge (Castaldi et al., 2015, Essletzbichler, 2005). Unrelated variety also reduces the negative effects of sector-specific shocks (Frenken et al., 2007). From the regional context perspective, as yet little is known about either the intra- or inter-regional externalities of unrelated variety in regard to FDI spillovers within government-oriented clusters. Through strict state-led control and restrictions, local authorities can further enhance the portfolio strategy of unrelated variety, and minimise sector-specific shocks caused by FDI. Governments can restrict both the scope and scale of FDI activities, thereby dramatically reducing FDI inflows in the local area. Hence, a high degree of unrelated variety can further spread risks across a set of technologically irrelevant sectors, and create a more stable business environment. However, excessive government intervention also hinders the building up of interindustry linkages across industries with limited shared and complementary competences. This is because the hysteresis effects of industrial policies might hinder the transformation from unrelated variety to related variety, and slow down the establishment of technological diffusion channels.

7.2.3.2. Market Orientations

Although plenty of state-led policies and regulations provide an appropriate political and institutional environment to facilitate FDI spillovers in Chinese cities, a market orientation is still considered a dominant factor in technological transfers and diffusions from MNEs to domestic firms. Based on the evidence from several market-driven developed economies, FDI significantly contributes to host regional technological upgrading (Damijan et al., 2003, Driffield, 2006, Hanel, 2000). I thereby move beyond this evidence to the Chinese context, and argue that foreign presence also exerts a positive impact on technological upgrading in cities.

First, inward FDI intensifies the regional competition in Chinese cities, which enhances incentives for local firms to upgrade their technologies and improve their productivity efficiency (Meyer and Sinani, 2009, Crespo and Fontoura, 2007). Recently, China has gradually reduced the government interference in inward FDI activities and foreign expansions, and devoted itself to establishing a fair and mature business environment, allowing more free entry. In other words, market liberalisation enhances both the opportunities and incentives for domestic firms to innovate in order to compete with foreign investors. Therefore, within market-oriented clusters, local companies are forced to build up indigenous technological capabilities, as they can scarcely obtain state-led support from local authorities.

Second, host regions often exhibit some localised advantages such as lower transaction costs and direct market access to encourage FDI activities (Wadhwa, 2011). Moreover, due to the huge demand, a large amount of MNEs have also invested in Chinese cities to exploit the market there, which is significantly larger than that in their home countries (Clegg and Wang, 2004). With the deepening of China's opening-up policy, the increasing demand for international high-quality products and services from native citizens has enabled MNEs to transfer and disseminate advanced technologies and successful experience to Chinese domestic firms. Market-seeking FDI technological spillovers are thus enhanced by more competitive and mature markets in Chinese cities, which further facilitate technological upgrading. Namely, market-oriented clusters are an ideal regional setting for MNEs to expand their FDI activities, thereby enabling both the scope and scale of FDI technological spillovers to increase.

Third, thanks to the liberalisation with regard to international trade, backward indigenous firms can proactively imitate and learn new technologies from MNEs. Therein, local authorities within market-oriented clusters encourage R&D collaborations between MNEs and indigenous private firms. Motivated by financial profit maximisation, these private companies greatly accelerate their adoption of newly created technology from MNEs as well as its commercialisation. From a spatial perspective, a market-driven business environment is more likely to build up interregional linkages e.g. supplier chains and worker mobility, so FDI spillovers from one region can also become sources for technological upgrading in neighbouring cities.

In line with findings from the prior literature, there are several good reasons to believe that pace and rhythm of the foreign expansions diminish both intra- and inter-regional FDI technological spillovers. The fundamental mechanism through which these two time-based characteristics affect FDI spillovers in market-oriented clusters is time compression diseconomies. More specifically, in more mature and open host region markets, rapid and irregular foreign expansions exhibit few rules or trajectories, enabling domestic firms to benefit from FDI spillovers. Under the condition of less governmental support, it is quite difficult for technologically backward firms to undertake appropriate strategies to compete with foreign investors over a compressed time (Wang et al., 2012a).

Moreover, rapid and irregular foreign expansion processes often lead to dramatic fluctuations in demand and competition effects, which greatly increase the risk and complexity of interactions with foreign firms (Wang et al., 2017). Due to the lack of governmental regulatory constraints, such competition effects are felt directly by domestic firms within market-oriented clusters. Furthermore, rapid and irregular foreign expansions also create an unstable business environment, and reduce the mutual trust between domestic and foreign firms in regard to R&D collaborations and alliances (Fryxell et al., 2002, Tan and Meyer, 2011). In this case, both the pace and rhythm of foreign expansions negatively moderate FDI spillovers and technological upgrading within market-oriented clusters. Pace and rhythm can also affect inter-regional relationships between foreign presence and technological upgrading through inter-regional “pipelines” such as social networks, and forward and backward linkages. More specifically, faced with rapid and irregular foreign expansions, Chinese domestic firms are often forced to escape to neighbouring areas in order to avoid fierce competition, thereby facilitating FDI technological spillovers across cities (Wang et al., 2017).

Focusing on industrial structures, namely related and unrelated variety, there are several reasons to believe that related variety positively moderates the relationship between inward FDI and technological upgrading within market-oriented clusters. First, in line with the theory of agglomeration economies, firms and industries prefer to co-locate in geographic regions with a large market size and lower transaction costs (Hewings et al., 1998, Otsuka et al., 2010). Motivated by interindustry linkages in cognitive proximity (related variety), MNEs select market-oriented regional clusters as their preferred destinations in order to easily access resources and markets in host countries. Market access also affects firms’ economic performance (Fujita et al., 1999, Thisse and Fujita, 2002). Chinese cities, especially in the southern and coastal regions, can foster plenty of opportunities for interactions between MNEs and domestic firms, thereby enabling more effective FDI spillovers through technologically related interindustry linkages. Second, companies within market-oriented regional clusters prefer to emphasise the priority of profit maximisation and implement gradual technological upgrading (Zhang and Duan, 2010, Li and Calantone, 1998). In other words, domestic firms are sensitive to MNEs' competition effects, because they have limited governmental support. Hence, a high degree of related variety within market-oriented clusters can rapidly spread competition effects to local actors across technologically related industries, thereby forcing them to imitate MNEs or increase their R&D expenditure to improve their technological capabilities. In other words, FDI competition effects are greatly enhanced by cluster market mechanisms, and occur across different industries through related variety. Third, different from government-oriented clusters, local supplier chains are more open to foreign investors within and across market-oriented cities. Therein, private companies and industries are the main forces in Chinese industrial agglomerations, as they face less challenges from large-scale SOEs (Chen and Tang, 2003). In the market-driven business environment, they have an incentive to proactively interact with MNEs in both upstream and downstream sectors, and set up close interindustry relationships. Related variety further contributes to regional supply chain construction, and thereby facilitates FDI technological spillovers across technologically related industries.

With respect to unrelated variety, little is known about either the intra- or inter-regional externalities of unrelated variety in regard to technological upgrading within market-oriented clusters. Cities with a high-level of unrelated variety are less likely to suffer from heavy losses due to sector-specific shocks, such as sudden FDI, because they spread the risks across a broad range of sectors with limited cognitive similarity (Frenken and Boschma, 2007). In turn, it is also less attractive for MNEs to increase their foreign expansion in such regions due to the small market size and incomplete regional supplier chains. Trust-based business relationships such as interpersonal interactions and ethnic kinships are crucial in terms of economic performance (Fan and Scott, 2003). A cognitive distance across industries that is too large will diminish interindustry linkages, resulting in less ideas exchanges and informal interactions between indigenous firms and foreign investors. In other words, due to the lack of shared and complementary competences, unrelated variety can hardly facilitate FDI technological spillovers in technological upgrading, especially when market forces are strong. This is because both sides - local and foreign companies - are integral to regional value chains in order to maximise the financial benefits. Otherwise, it is difficult for them to proactively disseminate knowledge to each other with limited governmental support. From an inter-regional view, it is difficult for MNEs to be integral to regional supplier chains across cities, as unrelated variety cannot facilitate the setting up of intercity forward and backward linkages. Constrained by costly inter-regional transaction costs, MNEs prefer to adopt intracity trade with domestic actors rather than intercity trade (Boschma, 2005, Abdel-Rahman and Anas, 2004). Hence, a high degree of unrelated variety negatively moderates the relationship between inter-regional FDI and technological upgrading in Chinese market-oriented clusters.

7.3. Brief Introduction to the Beijing-Tianjin-Hebei and Shanghai-Yangtze River Delta Urban Groups

So far there are 10 national-level urban groups in China (Appendix 5). Except for Chongqing-Chengdu, all of the national-level urban groups are located in developed regions. Generally, national-level urban groups have a large spatial scale and scope, and most of them consist of over 10 prefectural cities. In this study, I select two of the largest and most influential urban groups, namely Beijing-Tianjin-Hebei and the Shanghai-Yangtze River Delta, as the case studies. These two urban groups represent government- and market-oriented regional clusters, respectively, allowing for a discussion of their distinctive characteristics in terms of technological upgrading mechanisms.

7.3.1. The Beijing-Tianjin-Hebei Urban Group——A Government-Oriented Cluster

Beijing-Tianjin-Hebei is a Capital Urban Group in China, consisting of two super metropolises (Beijing and Tianjin) and one province (Hebei). Beijing-Tianjin-Hebei is the largest and most developed urban group in northern China (Figure 3), and is the political and cultural centre of China. The Beijing-Tianjin-Hebei urban group evolved from the industrial base in the region, and now it is in a core strategic position as the "Capital Economic Zone". The territorial area of Beijing-Tianjin-Hebei is 220.8 thousand square kilometres, and it comprises a total of 13 cities. Among these cities, Beijing and Tianjin are the core cities and 8 other cities (e.g. Baoding and Tangshan) in Hebei province are the crucial nodes within the urban group. Beijing-Tianjin-Hebei is a traditional advanced manufacturing and S&T research base in China. Figure 1 depicts the map of the Beijing-Tianjin-Hebei Urban Group.

Beijing-Tianjin-Hebei is one of most representative government-oriented urban groups, presenting several unique characteristics in terms of its technological upgrading mechanism. First, as the Chinese political and cultural centre, the China State Council and all of the administrative bodies i.e. national ministries and commissions are located in Beijing. Within the bureaucratic system, these administrative bodies have great powers in terms of regional technological upgrading through

R&D budget allocations and formulating regulations. Local firms have more closed relationships with government in order to obtain access to political support as well as financial subsidies (Juan and Yun, 2016). Second, Beijing-Tianjin-Hebei shoulders the responsibility for many large-scale, high-risk technological projects, which aim to build up indigenous technological capabilities. Rather than maximising profits, these projects emphasise improvements in social responsibilities. Hence, state-owned research institutions and SOEs, such as the Chinese Academy of Science, have become the "backbone" of regional technological upgrading, adhering strictly to macro-economic and technological demands. Third, compared to other Chinese urban groups, the local governments within Beijing-Tianjin-Hebei have made an effort to efficiently share infrastructure facilities and transport systems. In order to create a more stable business environment, inward FDI activities in Beijing-Tianjin-Hebei are under more severe restrictions, and cannot be entirely oriented by market incentives.

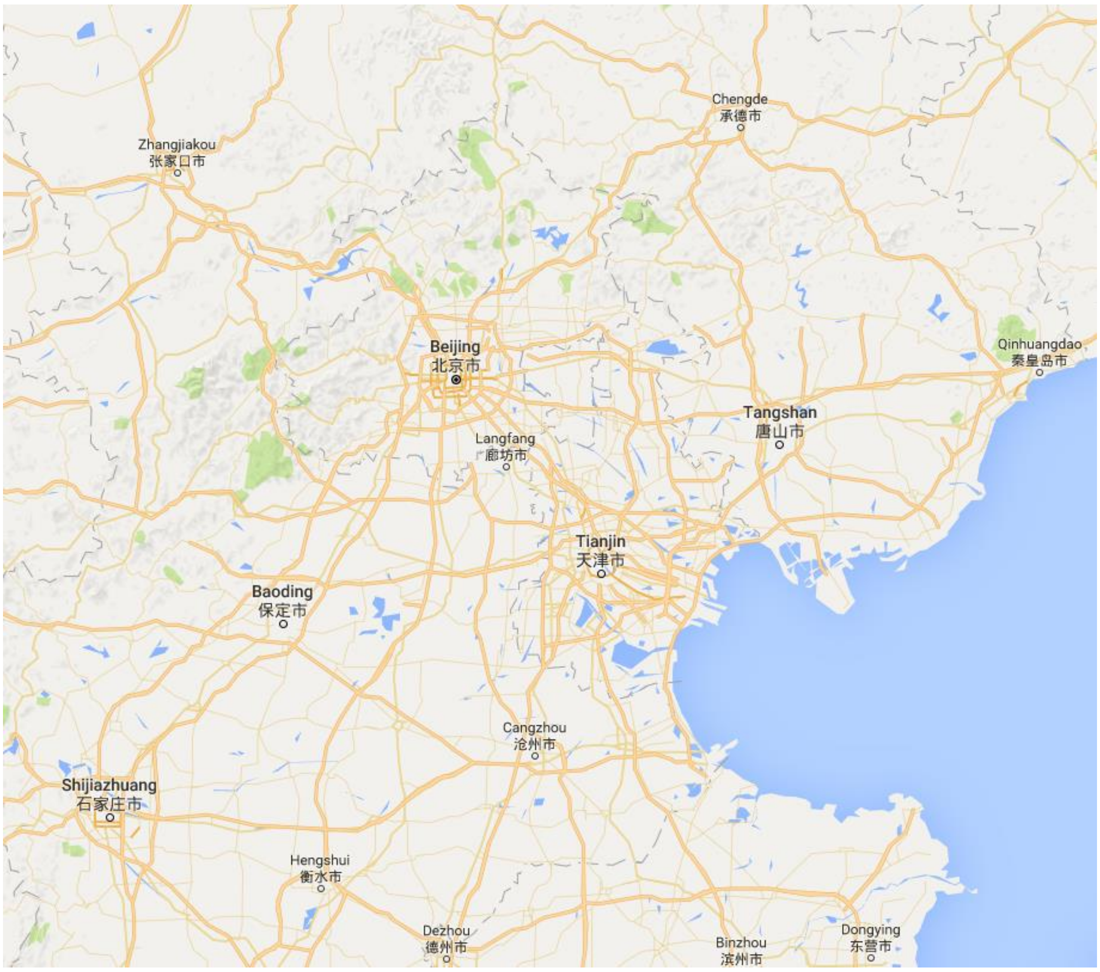

Figure 3 The Beijing-Tianjin-Hebei Urban Group

7.3.2. The Shanghai-Yangtze River Delta Urban Group——A Market-Oriented Cluster

The Shanghai-Yangtze River Delta urban group is the largest and most advanced urban group in southern and coastal China (Figure 4), and includes one super metropolis (Shanghai) and three provinces (Jiangsu, Zhejiang and Anhui). Therein, Shanghai is positioned as the central super-city, and Nanjing, Hangzhou and Hefei, as the capitals of the three provinces, are all the sub-central cities in this urban group. The total number of cities in the Shanghai-Yangtze River Delta is 26. The territorial area of this urban group is 211.7 thousand square kilometres, and the total population was over 150 million in 2014. Overall, the Shanghai-Yangtze River Delta is the most open and innovative region in China and also the economic and financial centre.

The Shanghai-Yangtze River Delta is one of the earliest urban groups, and it has become a first world-class urban group in China (Gu et al., 2007, Zheng and Bohong, 2012, Chaolin and Min, 2001). In January 1985, China decided to make the Shanghai-Yangtze River Delta the "Coastal Economic Zone" in order to facilitate inward FDI and liberalise the domestic economy. Based on the "National Development Plan on the Shanghai-Yangtze River Delta Urban Group" of 2016, cities in this urban group further integrated into the "One Belt (Silk Road Economic Belt), One Road (21st-Century Maritime Silk Road) Strategy". Thanks to its high degree of openness, compared to Beijing-Tianjin-Hebei, the Shanghai-Yangtze River Delta is a representative market-oriented urban group, aiming to facilitate local technological upgrading through market incentives.

First, the Shanghai-Yangtze River Delta was one of the earliest coastal areas in China to open up. It consists of several open cities such as Shanghai, Ningbo, Hefei etc. Since the late 1980s, these cities have formulated a set of preferential policies (e.g. tariff concessions and financial subsidies) to attract a large amount of FDI annually, allowing domestic firms to interact and cooperate with MNEs in technological activities. The Shanghai-Yangtze River Delta has thus become the frontline of international trade. For example, Shanghai established the "Pilot Free Trade Zone" in 2013, aiming to liberate domestic markets to participate globally and become a technological innovation platform with minimum state intervention. Second, the local governments have greatly simplified the examination and approval process for private firms and industries, and emphasised the leading role of market incentives. Rather than strict public administration, the local governments have accelerated the process of institutional, administrative and organisational reform to create a more open and competitive business environment in order to promote productivity efficiency. Therefore, the degree of marketisation and legislation in Shanghai-Yangtze River Delta is much higher than in other urban groups in China. (Fuxiang and Zhibiao, 2008). Third, compared to many state-led large-scale S&T projects within Beijing-Tianjin-Hebei, the Shanghai-Yangtze River Delta prefers to build up local "innovation incubators" to facilitate incremental technological upgrading in SMEs. SMEs within the Shanghai-Yangtze River Delta thus focus more on the industrialisation and commercialisation of new technologies in their target markets, in order to maximise their returns.

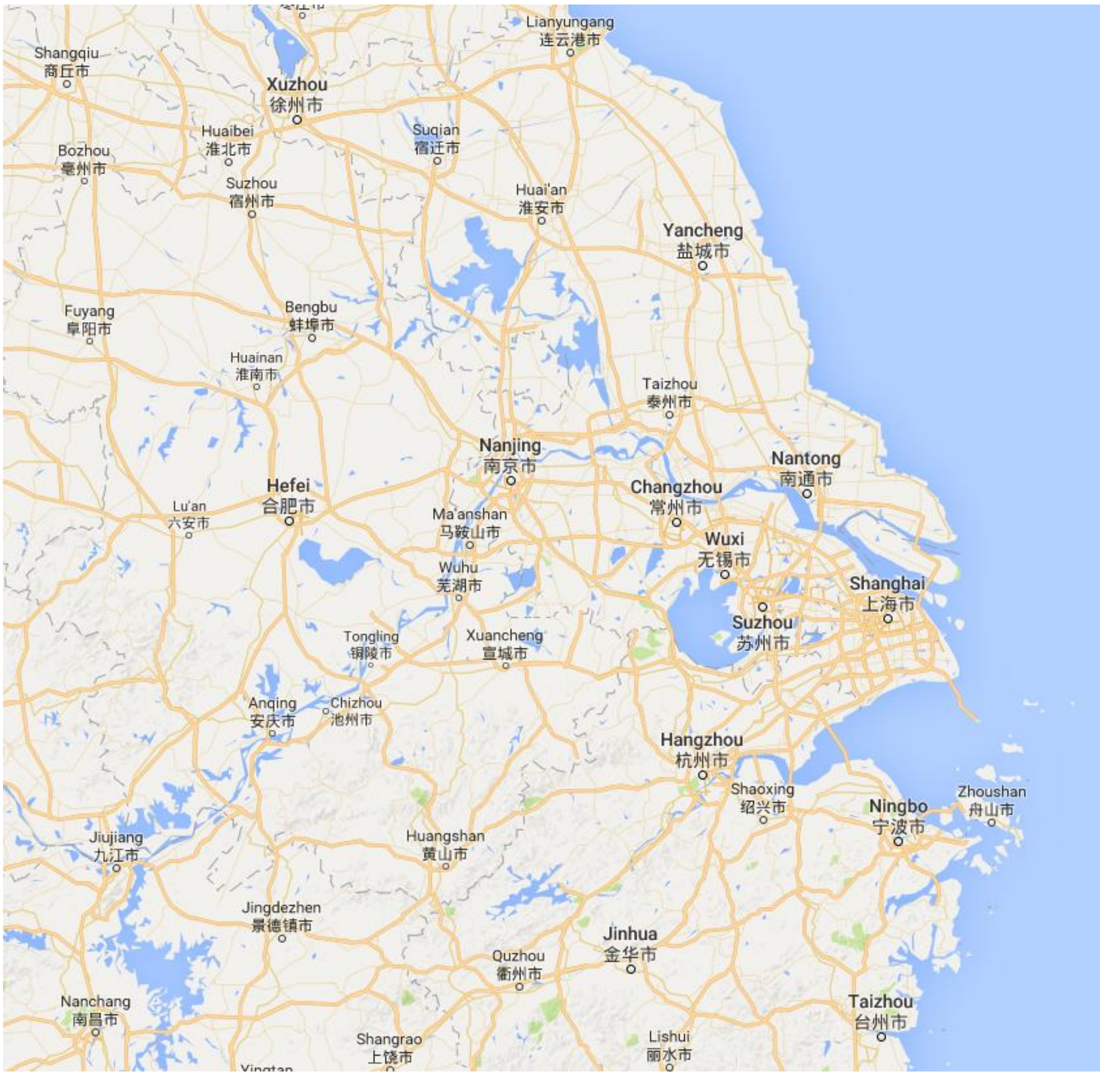

Figure 4 The Shanghai-Yangtze River Delta Urban Group

7.4. Data and Methodology

The datasets in this chapter also come from the *Chinese Urban Statistical Yearbooks* and *the Annual Industrial Survey Database*. In Contrast to the other empirical chapters, I select a regional data sample for both Beijing-Tianjin-Hebei and the Shanghai-Yangtze River, enabling the pooled OLS and ML spatial panel regressions to be replicated within the clusters. Both the dependent and independent variables are the same as those used in the previous chapters. I require all of the urban economic data in the year t-1 to take the possible endogeneity issue into account, and I require a time lag for the cities to absorb the knowledge spillovers from FDI. The time spans are also consistent with the previous chapters. Specifically, the time span of the dataset used to investigate the externalities of pace and rhythm is the period 2004-2011, while the time span of the dataset used to investigate the externalities of related and unrelated variety is the period 2001-2009.

7.5. Empirical Results

7.5.1. Econometric Analysis in the Beijing-Tianjin-Hebei Urban Group

Table 7-1 Panel regressions using TFP as dependent variable with pooled OLS, and spatial and time period fixed effects (to investigate externalities of pace and rhythm within Beijing-Tianjin-Hebei)

Variables	*Pooled OLS (1)*	*ML spatial Regression (2)*	*Pooled OLS (3)*	*ML spatial Regression (4)*	*Pooled OLS (5)*	*ML spatial Regression (6)*	*Pooled OLS (7)*	*ML spatial Regression (8)*	*Pooled OLS (9)*	*ML spatial regression (10)*
Intercept	1.400**		0.214***		0.086***		0.053***		0.446***	
	(0.020)		(0.000)		(0.000)		(0.000)		(0.000)	
$Scale_{i,t-1}$	-0.088**	-0.466*	-0.677***	-0.335*	-0.680***	-0.324*	-0.741***	-0.467***	-0.751***	-0.494***
	(0.015)	(0.020)	(0.002)	(0.074)	(0.002)	(0.078)	(0.001)	(0.004)	(0.000)	(0.002)
$Output_{i,t-1}$	0.921***	1.303***	1.495***	1.287***	1.468***	1.268***	1.507***	1.338***	1.477***	1.335***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
$Transport_{i,t-1}$	-0.201***	-0.121***	-0.094*	-0.125***	-0.099*	-0.094**	-0.071	-0.111***	-0.081	-0.083**
	(0.001)	(0.005)	(0.085)	(0.001)	(0.069)	(0.013)	(0.171)	(0.003)	(0.117)	(0.022)
$Population_{i,t-1}$	0.331***	0.367***	0.492***	0.567***	0.499***	0.572***	0.469***	0.508***	0.481***	0.532***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
$Education_{i,t-1}$	-0.223***	-0.071**	-0.082*	-0.004	-0.078*	-0.009	-0.080*	-0.008	-0.073*	-0.012
	(0.000)	(0.045)	(0.057)	(0.915)	(0.073)	(0.772)	(0.048)	(0.791)	(0.072)	(0.678)
$IFDI_{i,t-1}$			-0.206***	-0.134***	-0.197***	-0.142***	-0.190***	-0.104***	-0.187***	-0.113***
			(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.004)	(0.000)	(0.001)
$Pace_{i,t-1}$					-0.003*	-0.002			-0.004**	-0.003**
					(0.100)	(0.156)			(0.037)	(0.025)
$Pace_{i,t-1}$*$IFDI_{i,t-1}$					0.0002	0.002***			0.0001	0.001***
					(0.766)	(0.003)			(0.932)	(0.004)
$Rhythm_{i,t}$							0.008***	0.006***	0.008***	0.005***
							(0.001)	(0.001)	(0.000)	(0.001)
$Rhythm_{i,t}$*$IFDI_{i,t-1}$							-0.001	-0.001	-0.0002	-0.001

Continued Table

							(0.646)	(0.308)	(0.854)	(0.262)
Spatial Effects										
W*Scale$_{i,t-1}$		0.534		1.051		0.652		0.712		0.491
		(0.426)		(0.130)		(0.345)		(0.231)		(0.411)
W*Output$_{i,t-1}$		-0.249		-0.505		-0.096		-0.174		0.108
		(0.595)		(0.271)		(0.832)		(0.674)		(0.790)
W*Transport$_{i,t-1}$		0.101		0.071		0.163		0.029		0.115
		(0.468)		(0.584)		(0.192)		(0.806)		(0.335)
W*Population$_{i,t-1}$		0.123		0.158		0.280		0.052		0.166
		(0.590)		(0.583)		(0.307)		(0.855)		(0.539)
W*Education$_{i,t-1}$		0.015		0.029		0.028		0.029		0.017
		(0.887)		(0.782)		(0.774)		(0.759)		(0.843)
W*IFDI$_{i,t-1}$				-0.068		-0.179*		-0.031		-0.146
				(0.552)		(0.099)		(0.820)		(0.248)
W*Pace$_{i,t}$						-0.004				-0.003
						(0.156)				(0.461)
W*IFDI$_{i,t-1}$*Pace$_{i,t}$						0.003***				0.003**
						(0.003)				(0.029)
W*Rhythm$_{i,t}$								0.001		0.001
								(0.813)		(0.912)
W*IFDI$_{i,t-1}$*Rhythm$_{i,t-1}$								0.712		0.701
								(0.231)		(0.747)
W*dep.var.		-0.078***		-0.087***		-0.271***		-0.248***		-0.397***
		(0.003)		(0.000)		(0.000)		(0.000)		(0.004)
LM—LAG	5.038		5.073		5.052		4.242		4.216	
Robust LM-LAG	17.975		5.602		5.162		4.919		4.754	

Continued Table

LM—ERR	52.163		25.663		23.268		32.197		31.825	
Robust LM-ERR	70.100		31.192		28.377		36.875		36.363	
LR test spatial effect	12.853***		10.457***		9.642***		11.224***		10.314***	
Spatial fixed effect	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES
Time period fixed effect	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES
Number of observations	104	104	104	104	104	104	104	104	104	104
Spatial Hausman tests		6.799***		6.974***		6.001***		6.013***		132.605***
R^2	0.832	0.952	0.892	0.961	0.985	0.967	0.907	0.967	0.911	0.973
Corrected R^2		0.934		0.945		0.952		0.953		0.959

**p-value≤0.1, **p-value≤0.05, *** p-value≤0.01*

Notes: Corrected R^2 is R^2 without the contribution of spatial and fixed time period effects in spatial regression models. Maximum likelihood (ML) methods are used to estimate the spatial regressions.

Table 7-2 Panel regressions using TFP as dependent variable with pooled OLS, and spatial and time period fixed effects (to investigate externalities of related and unrelated variety within Beijing-Tianjin-Hebei)

Variables	*Pooled OLS (1)*	*ML spatial Regression (2)*	*Pooled OLS (3)*	*ML spatial Regression (4)*	*Pooled OLS (5)*	*ML spatial Regression (6)*	*Pooled OLS (7)*	*ML spatial Regression (8)*	*Pooled OLS (9)*	*ML spatial regression (10)*
Intercept	7.954***		6.138***		5.058***		4.698***		5.188***	
	(0.000)		(0.000)		(0.000)		(0.000)		(0.000)	
Scale$_{i,t-1}$	0.300***	0.010	0.286***	0.004	0.246***	0.005	0.232***	0.004	0.256***	0.004
	(0.001)	(0.779)	(0.001)	(0.907)	(0.001)	(0.885)	(0.002)	(0.920)	(0.001)	(0.910)
Output$_{i,t-1}$	0.778***	0.654***	0.911***	0.621***	0.975***	0.605***	0.978***	0.594***	0.937***	0.593***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Transport$_{i,t-1}$	-0.144**	-0.016	-0.131**	-0.013	-0.193***	-0.017	-0.196***	-0.012	-0.207***	-0.008
	(0.013)	(0.577)	(0.016)	(0.634)	(0.000)	(0.566)	(0.000)	(0.676)	(0.000)	(0.781)
Education$_{i,t-1}$	-0.228***	-0.069	-0.134***	-0.073	-0.132***	-0.086	-0.136***	-0.059	-0.116***	-0.053
	(0.000)	(0.384)	(0.005)	(0.344)	(0.002)	(0.275)	(0.002)	(0.447)	(0.009)	(0.494)
Investment$_{i,t-1}$	0.219**	0.081	0.193**	0.120*	0.125**	0.114*	0.117**	0.118*	0.174**	0.049
	(0.016)	(0.216)	(0.025)	(0.074)	(0.017)	(0.090)	(0.029)	(0.081)	(0.047)	(0.472)
IFDI$_{i,t-1}$			-0.147***	-0.043*	-0.210***	-0.136***	-0.036***	-0.189**	-0.190***	-0.030**
			(0.000)	(0.053)	(0.004)	(0.010)	(0.000)	(0.037)	(0.001)	(0.025)
RV$_{i,t-1}$					-0.176***	-0.034			-0.212***	-0.120
					(0.000)	(0.101)			(0.009)	(0.210)
RV$_{i,t-1}$****IFDI***$_{i,t-1}$					-0.045***	-0.034*			-0.032***	-0.053*
					(0.000)	(0.055)			(0.000)	(0.064)
UV$_{i,t-1}$							-0.316***	-0.059	-0.123***	-0.190
							(0.000)	(0.149)	(0.000)	(0.325)
UV$_{i,t-1}$****IFDI***$_{i,t-1}$							-0.085***	-0.028	-0.015***	-0.083
							(0.000)	(0.108)	(0.000)	(0.157)
Spatial Effects										
W*Scale$_{i,t-1}$		-0.038		-0.042		-0.057		-0.077		-0.066
		(0.773)		(0.746)		(0.662)		(0.568)		(0.614)

Continued Table

***W*Output**$_{i,t-1}$*		-0.237		-0.310		-0.358		-0.338		-0.416
		(0.441)		(0.310)		(0.227)		(0.305)		(0.203)
***W*Transport**$_{i,t-1}$*		-0.090		-0.066		-0.052		-0.063		-0.027
		(0.267)		(0.409)		(0.555)		(0.470)		(0.751)
***W*Education**$_{i,t-1}$*		0.416		0.460		0.205		0.176		0.169
		(0.105)		(0.068)		(0.500)		(0.563)		(0.579)
***W*Investment**$_{i,t-1}$*		-0.004		-0.104		-0.073		-0.081		-0.154
		(0.984)		(0.628)		(0.743)		(0.715)		(0.500)
***W*IFDI**$_{i,t-1}$*				-0.138		-0.180		-0.526		-0.082
				(0.167)		(0.472)		(0.227)		(0.890)
***W*RV**$_{i,t-1}$*						0.632*				0.617*
						(0.068)				(0.072)
W*IFDI**$_{i,t-1}$RV**$_{i,t-1}$*						0.002				0.019
						(0.945)				(0.250)
***W*UV**$_{i,t-1}$*								0.338**		0.322*
								(0.050)		(0.066)
W*IFDI**$_{i,t-1}$UV**$_{i,t-1}$*								0.062		0.173
								(0.422)		(0.451)
W*dep.var.		-0.087***		-0.097***		-0.061***		-0.061***		-0.089***
		(0.000)		(0.000)		(0.000)		(0.000)		(0.000)
LM—LAG	17.563		8.583		2.473		1.611		2.113	
Robust LM-LAG	12.197		6.542		1.175		0.360		1.035	
LM—ERR	6.363		2.227		2.298		3.491		1.812	
Robust LM-ERR	0.997		0.185		0.999		2.241		0.734	
LR test spatial effect	265.252***		266.132***		244.553***		245.305***		250.322***	
Spatial fixed effect	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES
Time period fixed effect	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES
Number of observations	117	117	117	117	117	117	117	117	117	117
Spatial Hausman tests		12.918***		12.838***		11.725***		12.134***		12.560***
R^2	0.882	0.992	0.897	0.993	0.922	0.993	0.921	0.993	0.924	0.994
Corrected R^2		0.706		0.719		0.733		0.734		0.757

**p-value≤0.1, **p-value≤0.05, *** p-value≤0.01*

Notes: Corrected R^2 is R^2 without the contribution of spatial and fixed time period effects in spatial regression models. Maximum likelihood (ML) methods are used to estimate the spatial regressions

Tables 7.2 reports the results of both the Pooled OLS model and the ML spatial regressions within Beijing-Tianjin-Hebei. $TFP_{i,t}$ is the dependent variable, while $IFDI_{i,t}$, $Pace_{i,t}$ and $Rhythm_{i,t}$ are key explanatory variables. Therein, models 2, 4, 6, 8, 10 are the spatial models that indicate both the intra- and inter-regional externalities of FDI and the time-based characteristics of the foreign expansion process, while models 1, 3, 5, 7, 9 are pooled OLS regressions, as the baselines. First, focusing on the control variables, the coefficient of $Output_{i,t}$ is positively significant (β=1.335, P<0.01) in model 10. This is because Beijing-Tianjin-Hebei is an advanced manufacturing industrial base, and secondary industries still capture a high proportion of the overall economic scale and gather a large amount of R&D resources. The coefficient of $Population_{i,t}$ is also positively significant (β=0.532, P<0.01), indicating that population scale is a key engine of technological upgrading. By contrast, the coefficient of $Education_{i,t}$ is negatively significant (β=-0.073, P<0.1) in model 10. This is because the number of students who enrol in tertiary education stems from the students across the nation. In other words, these individuals are mainly concentrated in universities and research institutions within Beijing-Tianjin-Hebei, and do not actually work in local areas and transfer and disseminate intellectual resources to regional technological upgrading. From a spatial perspective, the coefficients of all of the control variables are not significant (P<0.1).

Table 7.2 also indicates the intra- and inter-regional externalities of the explanatory variables, namely $IFDI_{i,t}$, $Pace_{i,t}$ and $Rhythm_{i,t}$. Notably, from an intra-regional perspective, the coefficient of $FDI_{i,t}$ is negatively significant within (β=-0.113, P<0.01) the cities in Beijing-Tianjin-Hebei, which is the opposite of the empirical results in the nationwide city level dataset. As a representative government-oriented cluster, regional technological upgrading within Beijing-Tianjin-Hebei mainly relies on state-led projects, public universities, and research institutions. With the aim of remaining technologically independent, the Chinese government has prioritised the building up of indigenous innovation capabilities, and thereby drawn up a set of policies and regulations to restrict both the scale and scope of foreign investments in local areas. Local authorities are more likely to use domestic firms to implement R&D activities rather than asking for help from MNEs. Few interactions (e.g. R&D alliances and collaborations) with foreign investors impede technology transfers and diffusions of FDI. Moreover, as a traditional industrial base, Beijing-Tianjin-Hebei is still the processing and assembly platform for low-end global value chains, so knowledge-intensive tertiary sectors have only captured a relatively small proportion of the whole economy. Therefore, it is difficult for domestic firms to reap the benefits of FDI spillovers. From a spatial point of view, the coefficient of *W*IFDI* is not significant ($P>0.1$); this differs from that based on the nationwide city level dataset. Owing to regulatory constraints, inter-regional transactions are often constrained by high trading costs, and FDI spillovers are more likely to take place within regions rather than between them.

Focusing on the pace and rhythm of foreign expansions, the coefficients of both $IFDI_{i,t-1}*Pace_{i,t}$ and $W*IFDI_{i,t-1}*Pace_{i,t}$ are positively significant ($\beta_1=0.001$, $P_1<0.01$ and $\beta_2=0.003$, $P_2<0.05$). This indicates that foreign expansion with a rapid pace enhances FDI spillovers both within and across Chinese cities. These results support the argument from prior studies, that intensified competition from rapid foreign expansion facilitates the adoption and commercialisation of advanced technologies to improve productivity efficiency (Görg and Greenaway, 2004, Javorcik, 2004b). From the regional context point of view, the state-led Beijing-Tianjin-Hebei exhibits robustness in terms of rapid FDI activities, as policy makers have maintained a stable business environment through policies and regulations. By contrast, the coefficients of both *IFDI*Rhythm* and *W*IFDI*Rhythm* are not significant within and across cities ($P>0.1$). Further studies are thus needed to understand foreign expansion regularity impacts on knowledge spillovers in regard to regional technological upgrading.

Table 7.3 reports the results of both the Pooled OLS model and the ML spatial regressions within Beijing-Tianjin-Hebei, with the aim of investigating the externalities of industrial structures, namely related and unrelated variety, in regard to FDI spillovers. Therein, $TFP_{i,t}$ is the dependent variable, while $IFDI_{i,t}$, $RV_{i,t}$ and $UR_{i,t}$ are key explanatory variables. Similarly, models 2, 4, 6, 8, 10 are spatial models that indicate both the intra- and inter-regional externalities of FDI and industrial structure, while models 1, 3, 5, 7, 9 are pooled OLS regressions, as the baselines. Focusing on FDI per se, the coefficient of $IFDI_{i,t}$ is negatively significant in model 10 ($\beta=-0.030$, $P<0.05$), which is consistent with the result in Table 7.2. This once again confirms that FDI significantly impedes regional technological upgrading within regions of Beijing-Tianjin-Hebei, and exhibits relatively limited inter-regional impacts on total factor productivity across cities.

From the intra-regional perspective, the coefficient of $RV_{i,t}*IFDI_{i,t}$ is negatively significant ($\beta=-0.053$, $P<0.1$), while the coefficient of $UR_{i,t}*IFDI_{i,t}$ is insignificant ($P>0.1$). From the inter-regional perspective, both $RV_{i,t*}IFDI_{i,t}$ and $UR_{i,t*}IFDI_{i,t}$ are insignificant. The expectation of inter-city externalities of industrial structures in FDI spillovers is therefore not supported. This is because high transaction costs across cities cause firms to prefer to focus on local trade, and benefit from the sharing of individualities such as infrastructure facilities, public service and market accessibility (Abdel-Rahman and Anas, 2004, Ning et al., 2016). In this case, industrial production is often concentrated within a specific closed area, and facilitates interactive learning and innovation (Boschma, 2005). Nevertheless, this does not mean that cities are isolated from each other, and inter-regional interactions enable a greater level of regional integration across a larger regional scope. To achieve harmonious development and reduce regional disparities, China has formulated a set of regulations and policies (e.g. Guidelines of Integration in Beijing-Tianjin-Hebei) to continuously enhance inter-city alliances and collaborations within such government-oriented clusters.

7.5.2. Econometric Analysis in the Shanghai-Yangtze River Delta Urban Group

Table 7-3 Panel regressions using TFP as dependent variable with pooled OLS, and spatial and time period fixed effects (to investigate externalities of pace and rhythm within Shanghai-Yangtze River Delta)

Variables	*Pooled OLS (1)*	*ML spatial Regression (2)*	*Pooled OLS (3)*	*ML spatial Regression (4)*	*Pooled OLS (5)*	*ML spatial Regression (6)*	*Pooled OLS (7)*	*ML spatial Regression (8)*	*Pooled OLS (9)*	*ML spatial regression (10)*
Intercept	0.547***		0.380***		0.484***		0.855***		1.006***	
	(0.007)		(0.001)		(0.006)		(0.006)		(0.008)	
Scale$_{i,t-1}$	-0.252	-0.084	-0.267*	-0.126	-0.269	-0.091	-0.258	-0.087	-0.276*	-0.059
	(0.127)	(0.547)	(0.099)	(0.343)	(0.108)	(0.498)	(0.105)	(0.477)	(0.095)	(0.632)
Output$_{i,t-1}$	0.953***	1.004***	0.827***	0.866***	0.826***	0.854***	0.767***	0.818***	0.774***	0.807***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Transport$_{i,t-1}$	-0.150***	-0.002	-0.123***	-0.002	-0.130***	-0.017	-0.117***	-0.014	-0.119***	-0.029
	(0.001)	(0.976)	(0.007)	(0.965)	(0.005)	(0.765)	(0.010)	(0.796)	(0.010)	(0.604)
Population$_{i,t-1}$	0.109*	-1.961***	-0.025	-1.863***	-0.015	-1.799***	-0.022	-1.904***	-0.018	-1.843***
	(0.068)	(0.000)	(0.732)	(0.000)	(0.840)	(0.000)	(0.757)	(0.000)	(0.805)	(0.000)
Education$_{i,t-1}$	-0.024	-0.281***	-0.042**	-0.269***	-0.041**	-0.244***	-0.053***	-0.280***	-0.050***	-0.258***
	(0.163)	(0.002)	(0.018)	(0.002)	(0.034)	(0.004)	(0.003)	(0.000)	(0.010)	(0.001)
IFDI$_{i,t-1}$			0.123***	0.110***	0.113***	0.111***	0.134***	0.132***	0.124***	0.131***
			(0.002)	(0.001)	(0.005)	(0.001)	(0.003)	(0.000)	(0.008)	(0.000)
Pace$_{i,t-1}$					-0.003	-0.001			-0.002	0.001
					(0.167)	(0.460)			(0.288)	(0.417)
Pace$_{i,t-1}$*IFDI$_{i,t-1}$					-0.001*	-0.0004*			-0.001*	-0.0003*
					(0.063)	(0.098)			(0.087)	(0.077)
Rhythm$_{i,t}$							-0.006	-0.004	-0.005	-0.0003
							(0.136)	(0.204)	(0.204)	(0.308)
Rhythm$_{i,t}$*IFDI$_{i,t-1}$							-0.0002	-0.001*	-0.0004	-0.001*
							(0.869)	(0.091)	(0.757)	(0.081)
Spatial Effects										
W*Scale$_{i,t-1}$		1.117***		0.912***		0.706**		0.782**		0.585*
		(0.001)		(0.007)		(0.041)		(0.012)		(0.064)

Continued Table

W*Output$_{i,t-1}$		-0.670***		-0.738***		-0.705***		-0.614***		-0.574**
		(0.008)		(0.003)		(0.003)		(0.008)		(0.012)
W*Transport$_{i,t-1}$		0.099		0.080		0.122		0.107		0.144*
		(0.201)		(0.284)		(0.106)		(0.140)		(0.052)
W*Population$_{i,t-1}$		2.914***		3.044***		2.715***		2.413***		2.112**
		(0.005)		(0.002)		(0.006)		(0.010)		(0.022)
W*Education$_{i,t-1}$		0.195		0.194		0.195		0.267*		0.261
		(0.267)		(0.247)		(0.233)		(0.100)		(0.102)
W*IFDI$_{i,t-1}$				0.267***		0.220***		0.237***		0.188**
				(0.001)		(0.007)		(0.002)		(0.017)
W*Pace$_{i,t}$						0.002				0.002
						(0.301)				(0.292)
W*IFDI$_{i,t-1}$****Pace***$_{i,t}$						0.001**				0.001**
						(0.014)				(0.018)
W*Rhythm$_{i,t}$								-0.005		-0.006
								(0.516)		(0.421)
W*IFDI$_{i,t-1}$****Rhythm***$_{i,t-1}$								0.004*		0.004*
								(0.073)		(0.075)
W*dep.var.		0.407***		0.266***		0.215**		0.224*		0.175*
		(0.000)		(0.002)		(0.015)		(0.011)		(0.052)
LM—LAG	68.726		73.570		72.752		63.872		63.135	
Robust LM-LAG	32.844		32.826		34.252		24.894		26.520	
LM—ERR	49.880		58.029		53.288		55.002		52.797	
Robust LM-ERR	13.800		17.285		14.789		16.024		14.182	
LR test spatial effect	255.786***		255.754***		252.657***		267.792***		264.826***	
Spatial fixed effect	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES
Time period fixed effect	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES
Number of observations	208	208	208	208	208	208	208	208	208	208
Spatial Hausman tests		23.948***		43.630***		33.164***		52.967***		54.440***
R^2	0.855	0.973	0.862	0.975	0.863	0.977	0.869	0.976	0.870	0.978
Corrected R^2		0.656		0.702		0.721		0.711		0.730

**p-value≤0.1, **p-value≤0.05, *** p-value≤0.01*

Notes: Corrected R^2 is R^2 without the contribution of spatial and fixed time period effects in spatial regression models. Maximum likelihood (ML) methods are used to estimate the spatial regressions.

Table 7-4 Panel regressions using TFP as dependent variable with pooled OLS, and spatial and time period fixed effects (to investigate externalities of related and unrelated variety within Shanghai-Yangtze River Delta)

Variables	*Pooled OLS (1)*	*ML spatial Regression (2)*	*Pooled OLS (3)*	*ML spatial Regression (4)*	*Pooled OLS (5)*	*ML spatial Regression (6)*	*Pooled OLS (7)*	*ML spatial Regression (8)*	*Pooled OLS (9)*	*ML spatial regression (10)*
Intercept	6.865***		7.781***		6.916***		6.507***		6.182***	
	(0.000)		(0.000)		(0.000)		(0.000)		(0.000)	
Scale$_{i,t-1}$	0.293***	0.220***	0.262***	0.210***	0.323***	0.153***	0.324***	0.161***	0.314***	0.161***
	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Output$_{i,t-1}$	0.837***	0.681***	0.727***	0.618***	0.574***	0.677***	0.547***	0.671***	0.540***	0.666***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Transport$_{i,t-1}$	-0.153***	0.004	-0.145***	0.001	-0.146***	0.040	-0.132***	0.042	-0.125***	0.053
	(0.000)	(0.921)	(0.000)	(0.989)	(0.000)	(0.355)	(0.000)	(0.335)	(0.000)	(0.226)
Education$_{i,t-1}$	-0.134***	0.113**	-0.149***	0.113**	-0.062***	0.060	-0.070***	0.058	-0.077***	0.061
	(0.000)	(0.041)	(0.000)	(0.037)	(0.002)	(0.257)	(0.000)	(0.274)	(0.000)	(0.245)
Investment$_{i,t-1}$	0.132***	0.212***	0.131***	0.194***	0.171***	0.223***	0.189***	0.222***	0.198***	0.210***
	(0.008)	(0.000)	(0.007)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
IFDI$_{i,t-1}$			0.107***	0.048**	0.104**	0.102***	0.324***	0.140***	0.190***	0.073***
			(0.001)	(0.013)	(0.016)	(0.000)	(0.008)	(0.000)	(0.002)	(0.000)
RV$_{i,t-1}$					0.139***	0.010			0.111***	0.057
					(0.000)	(0.622)			(0.000)	(0.566)
RV$_{i,t-1}$****IFDI***$_{i,t-1}$					0.011**	0.009***			0.012***	0.015***
					(0.011)	(0.007)			(0.010)	(0.008)
UV$_{i,t-1}$							0.306***	0.009	0.541***	0.016
							(0.000)	(0.859)	(0.000)	(0.611)
UV$_{i,t-1}$****IFDI***$_{i,t-1}$							-0.023***	-0.020***	-0.049***	-0.013***
							(0.006)	(0.006)	(0.004)	(0.007)
Spatial Effects										
W*Scale$_{i,t-1}$		-0.151*		-0.161*		-0.245***		-0.233***		-0.177**
		(0.067)		(0.053)		(0.004)		(0.005)		(0.048)
W*Output$_{i,t-1}$		-0.626***		-0.664***		-0.441***		-0.452***		-0.367**

Continued Table

		(0.000)		(0.000)		(0.005)		(0.004)		(0.022)
***W*Transport**$_{i,t-1}$*		-0.144*		-0.138*		-0.097		-0.099		-0.066
		(0.055)		(0.064)		(0.184)		(0.180)		(0.379)
***W*Education**$_{i,t-1}$*		0.192		0.177		0.032		0.059		0.026
		(0.145)		(0.190)		(0.818)		(0.668)		(0.853)
***W*Investment**$_{i,t-1}$*		0.189*		0.172*		0.293***		0.292***		0.278**
		(0.064)		(0.093)		(0.005)		(0.005)		(0.014)
***W*IFDI**$_{i,t-1}$*				0.020*		0.023*		0.070*		0.306*
				(0.097)		(0.064)		(0.066)		(0.078)
***W*RV**$_{i,t-1}$*						-0.008				-0.509
						(0.872)				(0.817)
W*IFDI**$_{i,t-1}$RV**$_{i,t-1}$*						0.010**				0.106**
						(0.019)				(0.017)
***W*UV**$_{i,t-1}$*								-0.083		-1.010
								(0.431)		(0.014)
W*IFDI**$_{i,t-1}$UV**$_{i,t-1}$*								-0.019**		-0.192**
								(0.026)		(0.033)
W*dep.var.										
LM—LAG	75.778		82.801		39.205		40.563		52.791	
Robust LM-LAG	61.769		64.041		17.135		20.441		30.806	
LM—ERR	14.380		20.239		44.551		40.469		35.279	
Robust LM-ERR	0.372		1.478		22.481		23.347		13.295	
LR test spatial effect	401.708***		388.139***		313.545***		283.730***		291.068***	
Spatial fixed effect	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES
Time period fixed effect	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES
Number of observations	234	234	234	234	234	234	234	234	234	234
Spatial Hausman tests		11.193***		9.635***		31.818***		46.619***		34.316***
R^2	0.913	0.992	0.917	0.992	0.950	0.993	0.953	0.993	0.954	0.993
Corrected R^2		0.684		0.691		0.789		0.785		0.801

**p-value≤0.1, **p-value≤0.05, *** p-value≤0.01*

Notes: Corrected R^2 is R^2 without the contribution of spatial and fixed time period effects in spatial regression models. Maximum likelihood (ML) methods are used to estimate the spatial regressions

Table 7.4 reports the results of both the pooled OLS and ML spatial panel regressions within the Shanghai-Yangtze River Delta, indicating both the intra- and inter-regional externalities of foreign expansion pace and rhythm in regard to FDI spillovers. Similar to the results for Beijing-Tianjin-Hebei, the coefficient of $Output_{i,t}$ is positively significant in all of the models, as local industrial scale is also crucial to technological upgrading. Although the tertiary industries in some cities, such as Shanghai and Nanjing, have gradually become the backbone of local economic development, most cities within this urban group, especially in Anhui province, are still important manufacturing bases. Technological sources still come from secondary industries. By contrast, the coefficient of $Population_{i,t}$ is negatively significant in model 10 (β=-1.843, $P<0.01$). Due to market-oriented aspects such as efficiency maximisation, knowledge-intensive industries may crowd out labour-intensive ones, and the latter may not contribute to local technological upgrading. Different from the empirical results within Beijing-Tianjin-Hebei, $W*Population_{i,t}$ and $W*Scale_{i,t}$ exhibit positively significant coefficients in model 10 (β_1=2.112, $P_1<0.05$ and β_2=0.585, $P_2<0.1$). From the regional context view, mature, open and competitive markets within the Shanghai-Yangtze River Delta have already set up inter-regional linkages to achieve synergic technological upgrading. More specifically, inter-city labour mobility of skilled workers has facilitated technological upgrading in neighbouring regions (Lundquist and Trippl, 2013), while the large economic scale is a key engine of nearby urban technological upgrading. This further demonstrates that a market orientation will significantly accelerate the mobility of intellectual resources in technological upgrading both within and across cities.

Focusing on the explanatory variables, $FDI_{i,t}$ is positively significant both within and across cities in the Shanghai-Yangtze River Delta (β_1=0.131, $P_1<0.01$ and β_2=0.188, $P_2<0.05$). This result is consistent with that based on the nationwide city level dataset, indicating that FDI spillovers are still a key source of technological upgrading. Within such market-oriented regional clusters, MNEs exhibit intensified competition effects and force domestic firms to improve their productivity efficiency with limited governmental intervention. Moreover, pushed by customers' demands, interactions between MNEs and domestic firms are more frequent and flexible, allowing knowledge spillovers. From the intra-regional perspective, both *FDI*Pace* and *FDI*Rhythm* are negatively significant, a result that is consistent with conclusions in the previous literature (Wang et al., 2012a). This is because foreign expansion processes that are too rapid and irregular may lead to an unstable business environment, impeding the building up of mutual trust and interactive activities between domestic firms and MNEs (Tan and Meyer, 2011, Fryxell et al., 2002). By contrast, from the spatial point of view, the coefficients of *W*FDI*Pace* and *W*FDI*Rhythm* are negatively significant. Under the conditions of intensified market competition within the Shanghai-Yangtze River Delta, local firms may escape to neighbouring regions to avoid uncertainty and risks, allowing knowledge spillovers across cities. Thanks to limited government intervention, market incentives facilitate inter-city linkages such as supplier chains and labour mobility, and time-based characteristics are thus more likely to exhibit impacts on technological upgrading in neighbouring regions.

Table 7.5 reports on the pooled OLS and ML spatial panel regressions within the Shanghai-Yangtze River Delta, indicating both the intra- and inter-regional externalities of related and unrelated variety in FDI spillovers. The coefficients of both $FDI_{i,t}$ and $W*FDI_{i,t}$ are positively significant in model 10 (β_1=0.073, P_1<0.01 and β_2=0.306, P_2<0.1), which is consistent with the empirical results above. This means that if FDI intensity increases by 100%, local TFP and TFP in neighbouring cities will increase by 7.3% and 30.6% respectively. From the intra-regional point of view, the coefficient of $RV_{i,t-1}*IFDI_{i,t-1}$ is positively significant (β=0.015, P<0.01), and $UR_{i,t-1}*IFDI_{i,t-1}$ is negatively significant (β=-0.013, P<0.01). This is consistent with the empirical results from nationwide datasets and our expectation, because small cognitive distance facilitates technological spillovers between local and foreign firms. By contrast, unrelated variety significantly diminishes technology transfers and exchanges of FDI in the Shanghai-Yangtze River Delta. The results indirectly confirm that a cognitive distance that is too large can scarcely facilitate knowledge spillovers (Boschma and Iammarino, 2009). From the interregional point of view, the coefficient of $W*RV_{i,t-1}*IFDI_{i,t-1}$ is positively significant (β=0.106, P<0.05), and $W*UR_{i,t-1}*IFDI_{i,t-1}$ is negatively significant (β=-0.192, P<0.05). Owing to inter-regional pipelines such as labour mobility and supplier chains, FDI spillovers occur across cities. Local TFP will increase by 10.6% when the intensity of the related variety increases by 100% in adjacent cities. By contrast, local TFP will increase by 19.2% when the intensity of unrelated variety in neighbouring cities increases by 100%. This indicates that related variety is a positive signal in regard to inter-regional FDI spillovers within the Shanghai-Yangtze River Delta.

7.6. Concluding Remarks

In order to obtain a more profound understanding of regional technological upgrading mechanisms in China, this chapter addresses the question, *"What are the intra- and inter-regional externalities of foreign expansion time-based characteristics and industrial structures in FDI spillovers within both government and market-oriented Chinese urban groups?"* From the regional context view, this chapter verifies whether the positive relationship between FDI and technological upgrading still exists in distinctive regional clusters. Moreover, it also explores the roles of government and market orientations in the externalities of the foreign expansion process and industrial structures, in regard to

FDI spillovers both within and across Chinese cities. Within two representative clusters, Beijing-Tianjin-Hebei and the Shanghai-Yangtze River Delta, this chapter exhibits empirical evidence of the specific regional technological upgrading mechanisms.

From the government-oriented perspective, the empirical results contradict the widely-accepted conclusion that FDI spillovers surely contribute to technological upgrading. Within government-oriented clusters, local authorities prefer to prioritise indigenous R&D activities rather than technological imports in order to remain technologically independent. Therefore, local authorities often establish regulatory constraints to restrict both the scale and scope of inward FDI activities. Constrained by such state-led administration and policies, there are few technological diffusion channels between local and foreign firms. Namely, it is difficult for indigenous firms to fully recognise, assimilate and exploit advanced technologies from MNEs within government-oriented clusters. Such negative impacts have also been verified by some of the previous literature (Hu and Jefferson, 2002, Fu and Gong, 2011). Furthermore, the externalities of the foreign expansion process and industrial structures in regard to FDI spillovers are also different within government-oriented urban groups. More specifically, fast and regular foreign expansions can enhance FDI spillovers within cities within Beijing-Tianjin-Hebei, indicating that strong state-led regulations and policies effectively impede time compression diseconomies in China. The positive externalities of foreign expansion pace are also contribute to inter-regional FDI spillovers, and promote technological upgrading in adjacent cities. Focusing on industrial structures, only related variety exerts intra-city negative externalities in FDI spillovers within Beijing-Tianjin-Hebei. By contrast, unrelated variety is more likely to create an uncertain business environment and cannot significantly enhance technology transfers and diffusions of FDI, either within or across cities.

From the market-oriented perspective, regional specific resources and factors are crucial to facilitate FDI spillovers within the Shanghai-Yangtze River Delta. Based on the empirical results, I confirm that inward FDI is still a key engine of Chinese technological upgrading, which is consistent with the findings in Chapters 5 and 6 and most of the prior literature (Crespo and Fontoura, 2007, Meyer and Sinani, 2009). Focusing on the pace and rhythm of the foreign expansion process, more rapid and irregular FDI diminishes technology transfers and disseminations to local firms. Time compression diseconomies emerge when foreign entry takes place over a compressed period, as fierce competition pressures often overload domestic firms' absorptive capacity. This is also consistent with the results in the previous chapters and some of the literature (Wang et al., 2012a). Hence, FDI competition effects are more evident within market-oriented clusters, and only domestic firms with a strong absorptive capacity can benefit from rapid and unpredictable FDI. From the inter-regional perspective, fast and regular foreign expansions enhance FDI technological spillovers across cities. This is because, with minimum governmental intervention, inter-regional "pipelines" such as worker mobility and supplier chains can be easily built up. Hence, domestic firms faced with unstable and rapid FDI expansions in one region can easily escape to neighbouring cities with fewer fluctuations in terms of urgent demand and foreign competition, and thus enhance FDI spillovers. Moreover, industrial related variety enhances both intra- and inter-regional FDI spillovers, while unrelated variety diminishes intra- and inter-regional FDI spillovers within the Shanghai-Yangtze River Delta. The empirical results confirm that industries in cognitive proximity are more likely to facilitate technology transfers and diffusions, further contributing to technological upgrading (Boschma and Iammarino, 2009, Frenken et al., 2007). It is worth noting that in contrast to government-oriented clusters, the inter-regional externalities of the foreign expansion process and industrial structures are more evident within the Shanghai-Yangtze River Delta. This is because under the condition of market incentives, local firms often proactively interact with MNEs in neighbouring cities through intercity pipelines such as labour mobility, social networks, and supplier chains, thereby enabling technological spillovers to take place across cities.

Based on the findings above, this chapter also has several implications for policy makers. In policy terms, I propose several suggestions that local authorities in government-oriented clusters could consider. On the one hand, the empirical results demonstrate that inward FDI impedes technological upgrading within government-oriented Chinese urban groups, which contradict the widely-accepted conclusion about positive FDI spillovers in previous studies (Crespo and Fontoura, 2007, Görg and Greenaway, 2004, Hong and Sun, 2011, Damijan et al., 2013, Meyer and Sinani, 2009, Meyer, 2004). Hence, regional authorities must limit FDI inflows, for example by drawing up policies and regulatory constraints to restrict FDI activities in the local areas. Focusing on time-based characteristics of the foreign expansion process, more rapid FDI expansions positively moderate international knowledge transfers and disseminations both within and across Chinese cities. Policy makers are not supposed to implement restrictions regarding foreign entry speed and patterns, in order to enable greater idea exchanges and productivity spillovers to domestic companies. Moreover, because related variety significantly diminishes FDI spillovers within cities, regional authorities should accelerate industrial restructuring in local areas. More specifically, they should facilitate the emergence of new sectors in local areas to maintain appropriate interindustry cognitive distance. In other words, reducing the level of related variety can diminish its negative impacts on FDI spillovers.

On the other hand, policy makers should adopt different strategies to facilitate technological upgrading within market-oriented regional clusters. In contrast to government-oriented clusters, such as Beijing-Tianjin-Hebei, it is vital for regional officials to make great efforts to maximise positive FDI spillovers, as foreign presence is still a key engine of technological development. Thanks to governmental intervention, domestic firms can reap the benefits of FDI spillovers through several channels such as competition and demonstration effects. It is therefore necessary for regional authorities to continue to remove the regulatory constraints to foreign entry. However, time compression diseconomies are more likely to emerge within market-oriented regional clusters, so policy makers still need to pay attention to foreign expansions that are too rapid and irregular within cities. In other words, our empirical results suggest that a stable and mutual-trusted business environment is an ideal regional setting for FDI spillovers in Chinese cities, allowing greater technology transfers and diffusions of FDI to take place. Focusing on industrial structures, international technology transfers and exchanges take place across industries with a small cognitive distance. Therefore, local governments should increase the level of related variety within market-oriented clusters.

This chapter, to my knowledge, is the first piece of work to explore both the intra- and inter-regional externalities of the foreign expansion process and industrial structures in regard to FDI spillovers within specific Chinese regional clusters. However, this research does have some limitations. First, the definitions regarding market and government-oriented clusters are worthy of more discussion. This is because even in a representative market-oriented cluster, such as the Shanghai-Yangtze River Delta, governmental interventions cannot be neglected in terms of local technological upgrading. Both the scale and scope of FDI activities are under strict surveillance. Local authorities can impose regulatory restrictions on free foreign entry, so some interactive activities are impeded. In other words, because government and market orientations are closely intertwined, it is highly recommended that future research should explore how government and market orientations work together in regard to regional technological upgrading. Second, the empirical contexts in this Chapter are confined to Chinese cities, and little is known about whether these empirical results are applicable to clusters in other countries. Hence, further research is required to replicate this study in other developed and developing economies, with the aim of elaborating on more generalised technological upgrading mechanisms on regional levels. Third, similar to Chapters 5 and 6, alternative indicators of both the independent and explanatory variables could not be adopted in this chapter due to data source deficiency. In future studies, it is recommended that large-scale industrial and firm-level data sources are used in order to provide more profound evidence for practical analysis.

Chapter 8 Conclusions and Discussions

This PhD thesis aimed to deepen our understanding about the relationship between inward FDI and technological upgrading from a contingency perspective by considering both intra- and interregional externalities of foreign expansion process and industrial structures. It also extends the theoretical framework about spatial dimension of FDI spillovers in explaining host city technological upgrading. My findings help us to explain examine why, although China has greatly accelerated its technological upgrading over the last three decades, its technological capabilities are still too weak to meet the increasing demands, either within the cities or across the whole country. FDI spillovers are widely recognised as a key external knowledge source to host region technological upgrading, because MNEs can disseminate advanced technology to local firms through interactive activities e.g. R&D collaborations and alliances (Xu and Sheng, 2012, Ning et al., 2016, Fu, 2008). However, although some of the literature has investigated the relationship between FDI and host region technological upgrading, very little of it has focused on specific city level evidence. Inspired by both theoretical and practical concerns, this PhD thesis examines the externalities of the foreign expansion process and industrial structures in both Chinese intra- and intercity FDI spillovers. It contributes to the understanding of FDI and technological upgrading from a contingency perspective.

Cities are the key FDI recipients, and therefore they are an ideal research setting in which to understand knowledge spillovers between MNEs and domestic companies (Ning et al., 2016). Different from non-urbanised areas, cities create an energetic and stable business environment in which social networks, infrastructure facilities and diversified marketplaces are available and can be shared. They also facilitate the colocation of both local and foreign firms in spatial proximity, and reduce the transaction costs during ideas exchanges and knowledge spillovers (Ciccone and Hall, 1996, Helsley and Strange, 2004). In particular, for some large emerging economies e.g. China, its provinces are larger than most European countries (Ning et al., 2016). Provincial level studies have often overlooked urban heterogeneity, and intercity externalities within provinces cannot be clearly explained at this level. In other words, it is quite difficult to fully understand intercity FDI spillovers in host regions from provincial level studies. Hence, I take a further step and examine FDI knowledge transfers and dissemination at an aggregate city level. I hope to identify the relationship between FDI and host city technological upgrading in China from a spatial perspective, as cities are closely inter-linked with each other through several channels e.g. worker mobility and supplier chains (Wang et al., 2017).

More importantly, a direct implication of time compression diseconomies is that MNEs may encounter difficulties in their interactions with local firms due to rapid and irregular FDI expansions (Vermeulen and Barkema, 2002, Wang et al., 2012a). By contrast, the pace and rhythm of foreign expansions in host cities do not reflect the expansion of a particular MNE, but reflect the overall change in the number of foreign firms within a specific geographic region. This PhD thesis moves from an individual firm to aggregate city level, and considers that FDI spillovers are enhanced in Chinese cities with a stable and rhythmic foreign expansion process. Therefore, I argue that the extent of FDI spillovers depends upon time-based characteristics of MNEs' expansion process within the FDI receiving city and adjacent regions. Cities also matter in FDI spillovers because local industrial agglomerations can promote interactions between local and foreign firms (Ning et al., 2016). Although prior literature has shown that industrial diversifications diminish FDI spillovers, little is known about whether such an argument is tenable if the industrial structure of the host city is characterised by related variety or unrelated variety. The investigation of interindustry cognitive distance effects extends the literature on FDI spillovers, assuming that local firms only effectively benefit from knowledge spillovers from MNEs across a set of technologically related sectors. Hence, this PhD thesis hopes to provide a better understanding of FDI spillovers within and across cities by examining the externalities of the foreign expansion process and industrial structures based on evidence from China.

8.1. Findings regarding Foreign Expansion Process Externalities in Host City FDI Spillovers

In Chapter 5, I found that FDI in Chinese cities contributed consistently to local technological upgrading over the period 2004-2011. The findings confirm the existence of positive FDI spillover effects in host cities, as MNEs can disseminate advanced technology to local firms (Ning et al., 2016, Wang et al., 2017). Cities that receive more FDI activities often possess greater technological capabilities. I also found that FDI spillovers are not confined within a specific region, but can spread to other cities in spatial proximity. These findings further contradict the argument that cities are insular entities, and highlight that urban technological upgrading is dependent on localised knowledge sources both within and across cities. Cities that have only small scale foreign presence can still reap the benefits of FDI spillovers, as they are interlinked and establish a “regional innovation system”, which enables intercity ideas exchanges and technological diffusions (Simmie, 2003).

Moreover, I found strong evidence that the extent of intra- and intercity FDI spillovers is contingent on the foreign expansion pace and rhythm. Cities with regular FDI expansions can maximise technology transfer and dissemination in the local area, which indicates that effective FDI spillovers require a stable urban business environment. By contrast, rapid MNE expansions often lead to fierce competition effects, forcing local firms to accelerate their adoption of advanced technology, and facilitating FDI technological spillovers across cities. However, the findings oppose the arguments put forward in prior studies regarding time compression diseconomies in an individual firm or a specific sector (Wang et al., 2012a, Vermeulen and Barkema, 2002). This is because the pace at the aggregate city level reflects the overall change in the number of MNEs, rather than foreign expansions of a particular firm in the city (Wang et al., 2017). In particular for China, as an emerging economy, rapid FDI activities bring advanced technology and accelerate market commercialisation in host cities, overwhelming the negative impacts on interactions with local firms. My findings explain the mechanism through which the foreign expansion pace and rhythm affect intra- and intercity FDI spillovers; regular but quick foreign expansions allow Chinese cities to benefit more from knowledge spillovers from MNEs.

Chapter 5 also has three policy implications. First, my findings indicate that FDI is still a key external knowledge source for technological upgrading in Chinese cities. Cities, as the main inward FDI recipients, are important platforms for interactions between local and foreign firms, enabling the dissemination and transfer of cutting-edge technology in China. Policy makers in the cities should remove foreign entry barriers and regulatory constraints to encourage FDI activities in the local areas. For example, local authorities are urged to set up large “special economic zones” in cities, so that foreign investors can enjoy preferential policies such as tax concessions and financial subsidies within these areas. Indigenous firms also possess opportunities to proactively interact with MNEs through R&D collaborations and alliances, and learn from advanced technology. Moreover, in the Chinese context, local authorities should adopt deregulations in regard to intercity worker mobility and supplier chain establishment, which could lead to cities in spatial proximity being integral to an "innovation system" within a larger geographic region. Firms in different cities could therefore be interlinked through several channels e.g. social networks, and forward and backward linkages, thereby enabling FDI technological diffusions across cities.

Second, policy makers should also pay attention to MNEs' foreign expansion processes, especially in regard to the time-based characteristics such as pace and rhythm. The strength of the interactions between foreign and local firms attenuates when the pace and rhythm of FDI expansions increase. Only a rhythmic and sequential expansion process can reduce the potential uncertainty and risks of learning-by-doing; if this is not the case, it is difficult to build up mutual trust during joint ventures or R&D alliances. Governments should enact policies and regulations to avoid unstable and irregular FDI inflows over a compressed time, to help to create a stable business environment in local areas. For example, local authorities could make timely adjustments to their local FDI strategies by imposing restrictions on the total amount of foreign entry based on previous situations, in order to prevent sudden changes in the number of MNEs' subsidiaries.

Third, intercity FDI spillovers seem to be enhanced by rapid foreign expansions in China. Policy makers should build up linkages, such as transportation systems, supplier chains and social networks, to allow worker mobility across cities. Policies should facilitate collaborations and alliances between foreign and local firms within a larger geographic region, thereby accelerating the adoption and commercialisation of advanced technology in host cities. Local authorities are also urged to promote the absorptive capacity of domestic firms, in order that they can effectively assimilate and apply knowledge from MNEs. This would help local firms to better understand advanced technology and managerial patterns, and maximise FDI technological spillovers both within and across cities.

8.2. Findings on Industrial Structure Externalities in Host City FDI Spillovers

In Chapter 6, I found that FDI spillovers greatly contributed to technological upgrading in 239 Chinese cities over the period 2001-2009. The findings confirm that China, as one of the largest emerging economies, possesses weak knowledge stocks, and that technology transfers and diffusions of FDI to local firms are still a key external knowledge source in host cities (Fu, 2008, Fu and Gong, 2011, Ning et al., 2016). My results indicate that advanced knowledge from foreign presence in neighbouring cities can spread to local areas, and promote host city total factor productivity. This is consistent with the findings in Chapter 5, indicating that FDI spillovers are not confined within an insular city but can also benefit neighbouring cities' technological upgrading through several intercity channels (e.g. worker mobility, social networks, and supplier chains).

The findings in Chapter 6 also indicate that related and unrelated variety directly promote technological upgrading in Chinese cities. My results contradict the argument that unrelated variety is less likely to promote urban technological capabilities (Boschma et al., 2014). This difference in my findings might because of unique dataset selections. Namely, for cities in developed countries e.g. the US, the domestic knowledge stocks are strong enough to meet local innovation demands, so further technological upgrading is dependent upon incremental technical reforms rather than radical and breakthrough innovation. By contrast, plenty of Chinese cities are still underdeveloped, and prefer to adopt technological catch-up strategies by facilitating breakthrough innovation. Unrelated variety enables the building up of technically unrelated knowledge domains, and creates the cornerstone for technological breakthroughs (Castaldi et al., 2015). My results therefore contribute to the understanding of the relationship between industrial structures and technological upgrading, based on evidence from Chinese cities.

More importantly, I found that only related variety enhances FDI spillovers within Chinese cities; unrelated variety does not. My results indicate that FDI knowledge transfers and disseminations require cities to possess a set of technologically related sectors in order to set up a diversified industrial structure. Interindustry cognitive proximity helps build up interactive opportunities between local and foreign firms, thereby enabling technology transfers and disseminations to host cities through both forward and backward linkages (Liu et al., 2009a). By contrast, unrelated variety greatly diminishes FDI spillovers, as technologically isolated industries build up limited connections between domestic firms and MNEs, so foreign investors can scarcely disseminate advanced technology in host cities. Different from other countries e.g. the US and the UK, I consider that MNEs are still faced with difficulties in penetrating Chinese city marketplaces, because local industry chains are often incomplete. My findings therefore challenge the conventional argument that industrial agglomeration effects remain internal within a geographic region because of high intercity trading costs (Abdel-Rahman and Anas, 2004, Ning et al., 2016). FDI knowledge spillovers cannot be enhanced unless the sectors in an urban diversified industrial structure are technologically related. From a spatial perspective, I find that only related variety enhances intercity FDI spillovers, indicating that knowledge spillovers through interindustry channels e.g. forward and backward linkages are based on cognitive proximity across cities.

In policy terms, three implications can be drawn from this chapter. First, I suggest policy makers to continue to attract FDI inflows to Chinese cities, in order to benefit technological upgrading. Governments also need to build up FDI spillover channels such as worker mobility, and forward and backward linkages, to help domestic firms to proactively interact and collaborate with foreign investors such as customers, distributors, and suppliers. For example, local authorities in different cities are urged to set up institutional systems within larger geographic regions, to facilitate a reduction in intercity transaction costs. For cities that hope to benefit from FDI technological spillovers but possess relatively weak infrastructure facilities, local policy makers should facilitate communications with neighbouring cities with a large foreign presence, and learn from MNEs' advanced technology across boundaries. This could improve local technological capabilities in a less costly way.

Second, it is also important for host city policy makers to pay more attention to industrial restructuring. Previous literature has demonstrated that industrial diversification might impede regional innovation (Ning et al., 2016, Wang et al., 2014). This chapter moves beyond such an argument, and argues that it is necessary to distinguish between two specific dimensions of industrial diversification (e.g. related and unrelated variety), because they affect technological upgrading in different ways. Policy makers should make great efforts to increase the degree of related variety in cities. To be specific, it is suggested that upstream and downstream industries should co-locate in high-tech industry parks, to enable effective ideas exchanges and knowledge spillovers within a specific city. Governments should also enact policies to accelerate industrial branching in cognitive proximity. This would help unrelated variety to become the root of technologically related knowledge domains, thereby enabling breakthrough innovation to be triggered in the future.

Third, local authorities are encouraged to accelerate the creation of technologically related interindustry linkages, and foster opportunities for interactions between local and foreign firms. To be specific, policy makers should expand supplier chains to larger geographic regions across cities, and create an open and fair market environment to attract FDI activities in order to set up close demand-supply relationships with local suppliers and customers. More support from governments could enable the creation of a diversified industrial structure with a small cognitive distance rather than the development of emerging industries in cities. For example, policy makers should be cautious about investing large amounts of capital in new industries that are not technologically related to the existing ones, especially in cities with a high degree of foreign presence. This could improve FDI knowledge spillovers in regard to host city technological upgrading.

8.3. Findings on the Externalities of the Foreign Expansion Process and Industrial Structures in Host City FDI Spillovers between Government- and Market-Oriented Urban Groups

In Chapter 7, I found that the externalities of the foreign expansion process and industrial structures are quite different for government- and market-oriented urban groups, and thereby affect the relationship between FDI spillovers and technological upgrading in Chinese cities. This is because in spite of the trend of economic globalisation, the regionalisation argument still highlights that place-specific resources and factors can promote local competitive advantage, enabling the building up of indigenous technological capabilities in cities (Asheim and Coenen, 2005, Cooke, 2001). Therefore, this chapter narrows down the nationwide analysis to two specific Chinese clusters, namely the Beijing-Tianjin-Hebei and the Shanghai-Yangtze River Delta Urban Groups, in order to investigate the intra- and inter-regional externalities of foreign expansion time-based characteristics and industrial structures in regard to FDI spillovers from a regional context perspective.

There are two main aspects of the findings in Chapter 7. In regard to the government orientation, I find that inward FDI significantly impedes local technological upgrading in cities within the Beijing-Tianjin-Hebei urban group, which contradicts the widely-accepted conclusion about the positive impacts of FDI spillovers (Ning et al., 2016, Fu, 2008). The findings indicate that foreign presence does not contribute to host city technological upgrading if local government orientations are strong. The reason for this is that, constrained by strict state-led policies and regulatory constraints, local authorities prefer to prioritise indigenous R&D activities rather than technological imports, and therefore foster few opportunities for domestic companies to interact with MNEs. In this case, MNEs are less motivated to disseminate advanced technology and managerial experience to host cities. This reveals that state-led administrations, especially through the use of restrictive controls, can overwhelm FDI technological spillovers and constrain technological upgrading.

Moreover, I also indicate some unique findings regarding the externalities of both the foreign expansion process and industrial structures in regard to host city FDI spillovers within the Beijing-Tianjin-Hebei urban group. Focusing on foreign expansion pace and rhythm, I find that rapid foreign entry not only enhances FDI spillovers in the local region, but also facilitates intercity technology transfers and disseminations. This could be because the Chinese government often enacts policies to stabilise the business environment in cities, so local firms within such government-oriented clusters are less likely to encounter the time compression diseconomies associated with a rapid foreign expansion process. On the contrary, FDI spillovers are strengthened by rapid foreign expansions because of the increasing demands and industrial diversification (Chang, 1995, Wang et al., 2017). I also find that although rhythm per se strengthens positive FDI spillovers in the local areas, its moderating effects on the relationship between FDI and technological upgrading are still unclear. This is different from the negative impact of irregular foreign expansions on host city technological upgrading that was identified based on the evidence from the nationwide dataset. It might be that the governments in the Beijing-Tianjin-Hebei urban group have made great efforts to foster interactive opportunities between local and foreign firms, as mutual trust is the cornerstone of building up strong social relationships between MNEs and domestic firms (Tan and Meyer, 2011, Fryxell et al., 2002). Furthermore, such endeavours minimise time compression diseconomies caused by irregular and unstable FDI expansions.

In regard to industrial structures, I find that related variety enhances FDI spillovers within Chinese cities, which is different from the findings based on the nationwide empirical results. Government orientations impede inter-industry technological sharing and transfers between local and foreign firms in cognitive proximity. This is because local firms might already be interlinked through supplier chains under governmental guidance within the Beijing-Tianjin-Hebei urban group, but have limited motivation to interact with MNEs. By contrast, the findings indicate that unrelated variety is likely to create an uncertain business environment and impede technology transfers and diffusions of FDI in cities. From an inter-regional perspective, neither related nor unrelated variety has a spatial effect in FDI spillovers. This confirms that MNEs prefer to interact with local firms rather than across cities because of the high transaction costs of intercity trade (Abdel-Rahman and Anas, 2004). This contributes to the understanding that excessive government intervention often constrains intercity technological diffusion channel construction, and isolates cities, even those in spatial proximity.

In regard to the market orientation, I confirm that FDI is still a key engine of technological upgrading within the Shanghai-Yangtze River Delta urban group. This finding is consistent with the nationwide findings in Chapters 5 and 6 and most of the prior literature (Crespo and Fontoura, 2007, Meyer and Sinani, 2009). The results show that with limited governmental intervention, FDI spillover channels (e.g. competition and demonstration effects) more effectively disseminate advanced technology to local firms through interactive activities. Notably, FDI spillovers make a greater contribution to local technological upgrading within market-oriented urban groups than the overall situation in Chinese cities. In an open and competitive market, domestic firms that do not benefit from state-led financial subsidies or preferential policies are often forced to make great efforts to build up their own technological capabilities and increase their production efficiency. Within such a market-oriented cluster, domestic firms are motivated to interact with MNEs to benefit from FDI spillovers. Different from the Beijing-Tianjin-Hebei urban group, FDI technological spillovers can spread from the recipient city to neighbouring ones. This is because the demand effects from MNEs can be felt directly by domestic suppliers in neighbouring cities, as inter-regional sectoral linkages make cities in proximity integral to supplier chains within a larger geographic region (Liu et al., 2009a).

Focusing on the externalities of the foreign expansion process in regard to FDI spillovers within the Shanghai-Yangtze River Delta urban group, I find that rapid and irregular FDI expansions diminish technology transfers and disseminations between MNEs and domestic firms, which is consistent with the arguments in prior studies (Wang et al., 2012a). This is because irregular and rapid international expansions often create an unstable business environment, leading to time compression diseconomies in Chinese cities. Compared with MNEs, the internal knowledge stocks of Chinese domestic firms are still weak, so such increasing environmental complexity and uncertainty can overload the absorptive capacity of domestic firms, and impede FDI spillovers in host cities (Wang et al., 2012a, Vermeulen and Barkema, 2002). More importantly, market orientations further strengthen MNEs' competitive effects in Chinese cities, as local firms are under great pressure, due to limited state-led protective and preferential policies. Therefore, domestic enterprises cannot fully recognise, assimilate and exploit advanced technology from foreign investors, further hindering technological upgrading in cities.

Focusing on industrial structures, I find that related and unrelated variety exert opposite impacts on FDI spillovers within the Shanghai-Yangtze River Delta urban group. Therein, related variety greatly enhances FDI spillovers, while unrelated variety negatively moderates FDI spillovers within Chinese cities. These results once again confirm that sectors in cognitive proximity are more likely to facilitate technology transfers and diffusions, thereby enabling technological upgrading (Boschma and Iammarino, 2009, Frenken et al., 2007). Notably, both foreign expansion time-based characteristics and industrial structures exert significant inter-regional externalities on FDI spillovers within the Shanghai-Yangtze River Delta urban group. This might be because the limited governmental intervention makes it easier for interregional "pipelines" e.g. worker mobility and supplier chains to be established across Chinese cities. In other words, MNEs' demand and supply effects are not confined within an insular area, but spread to local firms in adjacent cities. I also find that rapid and regular foreign expansions enhance FDI technological spillovers across cities. Wang et al. (2017) have argued that domestic firms facing unstable and rapid FDI expansions in one city are often forced to escape to neighbouring cities with less demand fluctuation and competition, in order to build up their overall technological capabilities within a larger geographic region. Market orientations further strengthen such interindustry linkages between local and foreign firms, and help to facilitate technological upgrading within the urban group. The results reveal that a market orientation can promote technological sharing and transfer across cities, as R&D collaborations between local and foreign firms can take place freely.

This chapter has three main implications for policy makers. First, the local authorities in government- and market-oriented urban groups should adopt different FDI strategies. Governments should introduce FDI activities in local areas discreetly, as MNE expansions might not benefit indigenous technological upgrading. Policy makers are urged to establish barriers in the form of regulatory constraints to reduce both the scale and scope of foreign presence in host cities. This could minimise the negative impacts, such as "crowding out effects" and "competition effects", that accompany international expansions. By contrast, governments within market-oriented clusters should continuously encourage FDI activities in host cities, and remove barriers to foreign entry. For example, they could increase financial subsidies to create an open and stable business environment in "special economic zones", to help facilitate interactions between foreign and local firms, which might lead to R&D collaborations and alliances.

Second, policy makers should also take different actions to control the FDI expansion process, in order to facilitate knowledge sharing and transfers in host cities. Local authorities should reduce foreign entry barriers if local government powers are strong. A more open and freer business environment will attract rapid foreign expansions, leading to increasing demand effects on local suppliers. It is important for domestic firms to proactively interact with MNEs, and benefit from technological spillovers. Due to strong state-led regulations and public administration, local firms are less likely to be constrained by time compression diseconomies. Nevertheless, a dilemma may emerge for policy makers in regard to adopting appropriate strategies within market-oriented clusters. Due to a lack of state-led policy support, it is often difficult for domestic firms to establish strong relationships based on mutual trust with foreign investors. Hence, local authorities should avoid FDI expansions with a faster pace in host cities. For example, they could establish an upper limit for foreign expansions within a specific period, thereby hindering sudden increases in the number of MNEs' subsidiaries in host cities.

Third, my results suggest that policy makers should adopt appropriate strategies in regard to industrial restructuring based on the local circumstances. Therein, local authorities should retain a cognitive distance that is neither too large nor too small across industries within government-oriented urban groups, as related variety enhances intracity FDI spillovers but diminishes knowledge sharing and transfers across cities. For instance, it is highly recommended that the industrial branching process from existing sectors is accelerated, and that some new emerging industries are developed. This would help to maintain the degree of related variety at an appropriate level. Governments could build up linkages across a set of technologically relevant sectors, because related variety enhances both intra- and intercity FDI spillovers within market-oriented clusters. They should also be cautious about making massive investments in new industries that are not related to local firms' knowledge stocks.

8.4. Contributions to the Literature on FDI spillovers in Host Cities

This PhD thesis makes several theoretical contributions and deepens our understanding of FDI spillovers in host cities. I hope that this thesis fills some of the research gaps indicated in the Literature Review, and provides some insightful empirical evidence. First, it proposes that the extent of FDI spillovers depends not only on the degree of foreign presence, but also on the process through which MNEs build up subsidiaries in host cities over time. Prior literature has mainly focused on the benefits and disadvantages of foreign expansion time-based characteristics in an individual firm or sector (Wang et al., 2012a, Vermeulen and Barkema, 2002), but has seldom discussed how FDI expansion pace and rhythm affect knowledge transfers and dissemination in host cities. My findings move beyond the argument of time compression diseconomies from the firm or industrial-level to an aggregate city level. This is because the foreign expansion process per se can affect the interactions between foreign and local firms, which results in FDI spillover variations (Wang et al., 2017). Therefore, I link the FDI spillover literature to host city foreign expansion process externalities from a process-dependent perspective, and expand the existing theoretical frameworks of determinant factors in FDI spillovers. Moreover, this PhD thesis also extends the empirical analysis of FDI spillovers from a spatial perspective by examining intercity knowledge diffusions. This thesis argues that host city technological upgrading is dependent on both intra- and inter-regional FDI spillovers, and that rapid foreign expansions can enhance FDI technological disseminations across cities.

Second, this thesis contributes to our understanding of industrial structure externalities in FDI spillovers by examining specific dimensions of industrial diversification, namely related and unrelated variety. Host cities matter in FDI spillovers as urban industrial structures can promote local firms' demands for external knowledge sources from MNEs (Ning et al., 2016). It has also shown that a diversified industrial structure creates an unstable business environment in cities, which impedes interindustry knowledge transfers to local firms. This PhD thesis therefore takes a further step towards showing that FDI spillovers are enhanced by related variety, but diminished by unrelated variety in Chinese cities. This is because knowledge spillovers are likely to take place across a set of technologically related industries (related variety), while sectors with a large cognitive distance (unrelated variety) scarcely contribute to FDI technological dissemination (Castaldi et al., 2015, Nooteboom, 2000). My findings expand the conventional notion of "industrial diversity", and classify it into two specific dimensions, thereby enabling a better understanding of the effects of interindustry cognitive distance in host city technological upgrading.

Third, this PhD thesis extends the recent FDI spillover literature based on city level evidence from an emerging economy. Prior literature has indicated that FDI spillovers are a key external source for host region technological upgrading (Fu, 2008, Xu and Sheng, 2012), but has seldom discussed such effects in cities, as smaller economic entities, considering specific characteristics both within and across urban boundaries. As indicated above, China has several unique characteristics that make it different from developed economies in terms of its political system, knowledge stocks, organisational structures, and institutional settings. Cities are also the main FDI recipients and the frontlines of technological upgrading, which makes them integral to larger regional innovation systems (Shearmur, 2012, Ning et al., 2016). Therefore, this PhD thesis shifts the FDI spillover theoretical framework from developed countries to emerging markets, and contributes to the understanding of FDI spillovers from a spatial perspective. In addition, I also adopt an updated dataset on Chinese cities from a recent period, and provide several insights regarding the externalities of both the foreign expansion process and industrial structures for future studies.

Fourth, this PhD thesis contributes to the clustering argument by linking FDI spillovers to specific Chinese urban groups. Cluster theory argues that regionalisation is still significant in terms of creating competitive advantage in regard to technological upgrading even under the condition of increasing economic globalisation. Place-specific resources and factors can enhance the competitive advantage within a geographic region, which cannot be easily duplicated or matched by distant rivals in other regions (Asheim and Isaksen, 2002). China is the largest emerging economy in the world, and its provinces are even larger than most European countries (Ning et al., 2016). Hence, it is necessary to investigate urban heterogeneity in FDI spillovers, which are overlooked in provincial analysis. Moreover, I propose that urban groups are the ideal research setting in which to understand both intra- and intercity FDI spillovers in technological upgrading, as the cities in such clusters are closely interlinked in terms of complementarities and commonalities (Pang, 2009). This PhD thesis extends the nationwide empirical analysis of FDI spillovers to two representative clusters, namely Beijing-Tianjin-Hebei and the Shanghai-Yangtze River Delta. It addresses why government and market orientations exert different impacts on the externalities of foreign expansion time-based characteristics and industrial structures in FDI spillovers from a regional context perspective. To my knowledge, this thesis is the first to provide empirical evidence on the externalities of the foreign expansion process and industrial structures within urban groups, thereby contributing to the spatial FDI spillover theoretical framework.

8.5. Limitations and Recommendations for Future Research

This PhD thesis has some limitations and shortcomings, and further studies need to be undertaken. First, the measurement of city level technological upgrading in this PhD thesis is total factor productivity (TFP), which has been widely used in prior studies (Hong and Sun, 2011, Hanel, 2000, Hu and Jefferson, 2002). However, TFP cannot fully reflect some characteristics of technological upgrading. To be specific, TFP is an indicator that measures the level of efficiency and intensity of the inputs utilised in production; it calculates the technical progression and productive evolution in regions and sectors (Boscá et al., 2004, Fu and Gong, 2011). However, it cannot explain whether the technological progression is successfully transformed to final outputs. Therefore, some other measurements have been suggested in recent studies to examine FDI spillovers in host regions. For example, some scholars have argued that patents and new product sales could be used as alternative indicators to measure technological upgrading and innovation (Wang et al., 2014, Ning et al., 2016, Sun and Du, 2010, Liu and Zou, 2008). This is because these measurements can be clearly defined based on standardised procedures and criteria, and can accurately illustrate technological upgrading outputs. Owing to data source limitations, I did not incorporate patents or new product sales to measure technological upgrading performance in this PhD thesis. It is strongly recommended that future studies examine whether the findings of this thesis can be replicated if these alternative dependent variables are adopted. Using different measurements of technological upgrading could provide more convincing evidence to explain FDI spillovers in Chinese cities.

Second, although the empirical results in this PhD thesis confirm that foreign presence is a key engine of regional technological upgrading both within and across Chinese cities, its heterogeneity is not fully discussed. In other words, I have not considered the impacts of FDI composition in technology transfers and disseminations. For example, FDI expansions in high-tech industries are more likely to generate knowledge spillovers that will facilitate technological upgrading in host regions (Rosenzweig and Nohria, 1994, Xia and Walker, 2015). The origins of international expansions also matter in regard to the extent of FDI spillovers in host cities. Buckley et al. (2007a) have shown that FDI activities adopted by MNEs from western economies, e.g. the USA, can more effectively result in the dissemination of new knowledge than those adopted by firms from Hong Kong, Macau and Taiwan (HMT), owing to technological gaps. However, the existing Chinese city level database cannot provide detailed statistics on FDI types and origins, so it would be reasonable to expand future research to the industrial and firm-levels, by differentiating FDI in terms of home regional origins and investment fields.

Third, Chapter 6 employs the entropy measurement to indicate related and unrelated variety in Chinese cities, which has been widely used in previous literature (Castaldi et al., 2015, Brachert et al., 2011). Several other alternative indicators (e.g. the product proximity index or geographic distributions of interindustry employment) could also be used to measure the level of industrial relatedness on a regional level (Hidalgo et al., 2007). I did not incorporate these measurements in this PhD thesis as the existing Chinese city level database does not indicate statistical information regarding employment distributions across different sectors, can cannot support distinctions about the product proximity index or geographic distributions of interindustry employment. It is strongly recommended that future studies aggregate the industrial level datasets to a given city, in order to examine whether the externalities of related and unrelated variety using different measurements are the same in host city FDI spillovers.

Fourth, this PhD thesis does not incorporate the idea of both “forward and backward linkages” to investigate FDI spillovers affected by interindustry connections to upstream and downstream sectors. FDI can generate different vertical and horizontal linkage effects on firms’ productivity (Liu et al., 2009a). I could not consider both forward and backward linkages in industrial structures, because the existing Chinese city level database does not provide input-output (I-O) table information to indicate the relevance between two sectors. In other words, it is difficult to specify knowledge transfers and sharing through interindustry trade. Hence, it is strongly recommended that the industrial level dataset is linked to the aggregate city level, and that further steps are taken to investigate the externalities of interindustry relatedness in FDI spillovers by considering forward and backward linkages.

Fifth, although the research findings confirm the externalities of the foreign expansion process and industrial structures in FDI spillovers based on evidence from Chinese cities, this PhD thesis does not consider the internal capabilities of domestic firms. The minimum threshold of local innovation capabilities is required to help FDI generate positive knowledge spillovers (Huang et al., 2012). It is necessary to move beyond the view that specific threshold effects exist in regard to the externalities of the foreign expansion process or industrial structures in FDI spillovers. Namely, it is recommended that future studies classify host city capabilities such as absorptive capacity and innovation ability into several intervals, and find out whether the linear relationship between FDI spillovers and its determinant factors (e.g. foreign expansion process or industrial structures) still exist.

Sixth, although I investigate the differences in the externalities of the foreign expansion process and industrial structures in FDI spillovers between the Beijing-Tianjin-Hebei and Shanghai-Yangtze River Delta urban groups, this PhD thesis does not incorporate measurements to indicate government and market orientations. Because the Chinese Statistical Yearbooks do not include key information e.g. state-led R&D expenditure, I could not specifically explain how governments affect local technological upgrading in cities. It is highly recommended that future studies aggregate other statistical data sources of science and technology investments at the Chinese city level, in order to contribute to a better understanding of governmental roles in FDI spillovers and technological innovation. Moreover, this PhD thesis only selected the Beijing-Tianjin-Hebei and Shanghai-Yangtze River Delta urban groups as examples to investigate market and government orientations. Future studies should replicate this analysis with other urban groups in China, in order to verify the conclusions based on evidence from a larger geographic region.

Last but not least, the evidence in this PhD is based on Chinese cities, and there is still doubt about whether the externalities of the foreign expansion process and industrial structures in FDI spillovers exist in other developing and developed economies. China, as the largest emerging country, has several unique characteristics that differ from developed economies e.g. the US and the UK, in terms of its political system, knowledge stocks, organisational structures, and institutional settings. The industrial structure in Chinese cities is also quite different, as investment- and labour-intensive manufacturing industries often capture the largest proportion of city level industrial systems. By contrast, developed economies' industrial structures are dominated by knowledge-intensive tertiary industries. Because of data source deficiency, this PhD thesis does not make a comparison between developed countries and China in terms of the externalities of the foreign expansion process and industrial structures in FDI spillovers. Therefore, it is highly recommended that this study is replicated in a cross-country analysis, in order to obtain greater generalisability.

Appendix 1 Geographic Distribution of Chinese Cities

Appendix 2 Provincial Administrative Regions in China

Provincial administrative regions	***Descriptions***	***Provincial administrative regions list***
Municipalities	Provincial Level Super City under Administrated by Central Government	Beijing, Shanghai, Tianjin, Chongqing
Provinces	Provincial Level Region consisting of several sub-provincial and prefectural cities	Heilongjiang, Jilin, Liaoning, Hebei, Shanxi, Henan, Hubei, Hunan, Guangdong, Hainan, Shandong, Jiangsu, Anhui, Zhejiang, Jiangxi, Fujian, Sichuan, Yunnan, Guizhou, Qinghai, Gansu, Shaanxi, Taiwan
Autonomous regions	Provincial Level Region consists of several sub-provincial and prefectural cities. In Autonomous Administrative regions, the majority of population are national minority	Inner Mongolia, Xinjiang, Guangxi, Ningxia, Tibet
Special Administrative Regions	Provincial Level and Independent Region under administrated by central government. Besides, they have special autonomous rights in economic and trade fields	Hong Kong, Macau

Sources: Chinese Urban Statistical Yearbook (2003-2012)

Appendix 3 Chinese Cities in Province and Autonomous Regions

Provincial administrative regions	*Provincial administrative regions classifications*	*No. of cities*	*Location*	*List of cities*
Hebei	Province	11	N	Shijiazhuang, Tangshan, Qinhuangdao, Handan, Xingtai, Baoding, Zhangjiakou, Chengde, Cangzhou, Langfang, Hengshui
Shanxi	Province	11	N	Taiyuan, Datong, Yangquan, Changzhi, Jincheng, Shuozhou, Jinzhong, Xinzhou, Linfen, Yuncheng, Lvliang
Inner Mongolia	Autonomous Region	9	N	Hohhot, Baotou, Wuhai, Chifeng, Tongliao, Hulun Buir, Erdos, Ulan Qab, Bayannur
Liaoning	Province	14	NE	Shenyang (sub-provincial), Dalian (sub-provincial), Anshan, Fushun, Benxi, Dandong, Jinzhou, Yingkou, Fuxin, Liaoyang, Panjin, Tielin, Chaoyang, Huludao
Jilin	Province	8	NE	Changchun (sub-provincial), Jilin, Siping, Tongliao, Tonghua, Baishan, Baicheng, Songyuan
Heilongjiang	Province	12	NE	Harbin (sub-provincial), Qiqihar, Jixi, Hegang, Shuangyashan, Daqing, Yichun, Jiamusi, Qitaihe, Mudanjiang, Heihe, Suihua
Jiangsu	Province	13	E	Nanjing (sub-provincial), Wuxi, Xuzhou, Changzhou, Suzhou, Nantong, Lianyungang, Huai’an, Yancheng, Yangzhou, Zhenjiang, Taizhou, Suqian
Zhejiang	Province	11	E	Hangzhou (sub-provincial), Ningbo (sub-provincial), Wenzhou, Jiaxing, Huzhou, Shaoxing, Jinhua, Quzhou, Zhoushan, Taizhou, Lishui
Anhui	Province	16	E	Hefei, Wuhu, Bengbu, Huainan, Ma’anshan, Huaibei, Tongling, Anqing, Huangshan, Fuyang, Bozhou, Suzhou, Chuzhou, Lu’an, Chizhou, Xuancheng
Fujian	Province	9	E	Fuzhou, Xiamen (sub-provincial), Putian, Sanming, Quanzhou, Zhangzhou, Nanping, Longyan, Ningde
Jiangxi	Province	11	E	Nanchang, Jingdezhen, Pingxiang, Jiujiang, Xinyu, Yingtan, Ganzhou, Shangrao, Fuzhou, Ji’an, Yichun

Continued Table

Shandong	Province	17	E	Jinan (sub-provincial), Qingdao (sub-provincial), Zibo, Zaozhuang, Dongying, Yantai, Weifang, Jining, Taian, Dezhou, Weihai, Liaocheng, Linyi, Laiwu, Rizhao, Heze, Binzhou
Henan	Province	17	C	Zhengzhou, Kaifeng, Luoyang, Pingdingshan, Anyang, Hebi, Xinxiang, Jiaozuo, Puyang, Xuchang, Luohe, Sanmenxia, Shangqiu, Nanyang, Xinyang, Zhoukou, Zhumadian
Hubei	Province	12	C	Wuhan (sub-provincial), Huangshi, Shiyan, Jingzhou, Yichang, Xiangyang, E'zhou, Jingmen, Xiaogan, Huanggang, Xianning, Suizhou
Hunan	Province	13	C	Changsha, Zhuzhou, Xiangtan, Hengyang, Shaoyang, Yueyang, Yiyang, Changde, Chenzhou, Yongzhou, Huaihua, Zhangjiajie, Loudi
Guangdong	Province	21	S	Guangzhou (sub-provincial), Shaoguan, Shenzhen (sub-provincial), Zhuhai, Shantou, Foshan, Jiangmen, Ganjiang, Huizhou, Maoming, Zhaoqing, Chaozhou, Meizhou, Zhongshan, Dongguan, Shanwei, Heyuan, Yangjiang, Qingyuan, Jieyang, Yunfu
Guangxi	Autonomous Region	14	S	Nanning, Liuzhou, Guilin, Wuzhou, Beihai, Fangchenggang, Qinzhou, Yulin, Guigang, Baise, Laibin, Chongzuo, Hezhou, Hechi
Hainan	Province	2	S	Haikou, Sanya
Sichuan	Province	18	SW	Chengdu (sub-provincial), Zigong, Panzhihua, Luzhou, Deyang, Mianyang, Guangyuan, Suining, Neijiang, Ziyang, Leshan, Yibin, Nanchong, Dazhou, Guangan, Ya'an, Meishan, Bazhong
Guizhou	Province	4	SW	Guiyang, Liupanshui, Zunyi, Anshun
Yunnan	Province	8	SW	Kunming, Yuxi, Qujing, Shaotong, Lijiang, Baoshan, Pu'er, Lincang
Tibet	Autonomous Region	1	SW	Lhasa
Shaanxi	Province	10	NW	Xi'an (sub-provincial), Tongchuan, Baoji, Xianyang, Yan'an, Hanzhong, Weinan, Yulin, Shangluo, Ankang
Gansu	Province	12	NW	Lanzhou, Jiayuguan, Jinchang, Baiyin, Tianshui, Wuwei, Zhangye, Pingliang, Jiuquan, Qingyang, Dingxi, Longnan
Qinghai	Province	1	NW	Xining

Continued Table

Ningxia	Autonomous Region	5	NW	Yinchuan, Shizuishan, Wuzhong, Guyuan, Zhongwei
Xinjiang	Autonomous Region	2	NW	Urumqi, Karamay
Taiwan	Province	9	S	Taipei, New Taipei, Taoyuan, Taichung, Tainan, Kaohsiung, Keelung, Hsinchu, Chiayi

Sources: Chinese Urban Statistical Yearbook (2003-2012)

Note: location is classified by the geographic distribution of provinces in China: E: Eastern China (Shandong, Jiangsu, Shanghai, Zhejiang, Anhui, Fujian and Jiangxi); S: Southern China (Guangdong, Guangxi, Taiwan and Hainan); C: Central China (Hunan, Hubei and Henan); N: Northern China (Beijing, Tianjin, Hebei, Shanxi and Inner Mongolia); NW: Northwest China (Ningxia, Qinghai, Shaanxi, Gansu and Xinjiang); SW: Southwestern China (Sichuan, Guizhou, Yunnan, Chongqing and Tibet); NE: Northeastern China (Liaoning, Jilin and Heilongjiang)

Appendix 4 Industrial Classifications in the Annual Industrial Survey Database

Main industry SIC code	*Main Industries*	*Industrial Branch No.*	*Industrial Branch SIC code Lists*
06	Coal mining and washing	3	0610, 0620, 0690
07	Petrol and natural gas mining	2	0710, 0790
08	Ferrous metal mining	2	0810, 0890
09	Non-ferrous metal mining	15	0911, 0912, 0913, 0914, 0915, 0916, 0917, 0919, 0921, 0922, 0929, 0931, 0932, 0933, 0939
10	Non-metal mining	10	1011,1012, 1013, 1019, 1020, 1030, 1091, 1092, 1093, 1099
11	Other mining	1	1100
13	Agricultural & food processing	17	1310, 1320, 1331, 1332, 1340, 1351, 1352, 1361, 1362, 1363, 1364, 1369, 1370, 1391, 1392, 1393, 1399
14	Food manufacturing	20	1411, 1419, 1421, 1422, 1431, 1432, 1439, 1440, 1451, 1452, 1453, 1459, 1461, 1462, 1469, 1491, 1492, 1493, 1494, 1499
15	Beverage manufacturing	13	1510, 1521, 1522, 1523, 1524, 1529, 1531, 1532, 1533, 1534, 1535, 1539, 1540
16	Tobacco products	3	1610, 1620, 1690
17	Textile	21	1711, 1712, 1721, 1722, 1723, 1730, 1741, 1742, 1743, 1751, 1752, 1753, 1754, 1755, 1756, 1757, 1759, 1761, 1762, 1763, 1769
18	Clothing	3	1810, 1820, 1830
19	Leather, fur and feather	11	1910, 1921, 1922, 1923, 1924, 1929, 1931, 1932, 1939, 1941, 1942
20	Wood industry	10	2011, 2012, 2021, 2022, 2023, 2029, 2031, 2032, 2039, 2040
21	Furniture manufacturing	5	2110, 2120, 2130, 2140, 2190
22	Paper industry	6	2210, 2221, 2222, 2223, 2231, 2239
23	Printing and record industry	5	2311, 2312, 2319, 2320, 2330

Continued Table

24	Cultural, education and sports	17	2411, 2412, 2413, 2414, 2419, 2421, 2422, 2423, 2424, 2429, 2431, 2432, 2433, 2439, 2440, 2451, 2452
25	Oil refinery, coking and nuclear fuel	4	2511, 2512, 2520, 2530,
26	Chemical martials and products	35	2611, 2612, 2613, 2614, 2619, 2621, 2622, 2623, 2624, 2625, 2629, 2631, 2632, 2641, 2642, 2643, 2644, 2645, 2651, 2652, 2653, 2659, 2661, 2662, 2663, 2664, 2665, 2666, 2667, 2669, 2671, 2672, 2673, 2674, 2679
27	Medicine manufacturing	7	2710, 2720, 2730, 2740, 2750, 2760, 2770
28	Chemical fiber manufacturing	7	2811, 2812, 2821, 2822, 2823, 2824, 2829
29	Rubber manufacturing and products	9	2911, 2912, 2913, 2920, 2930, 2940, 2950, 2960, 2990
30	Plastic manufacturing and products	10	3010, 3020, 3030, 3040, 3050, 3060, 3070, 3081, 3082, 3090
31	Non-metallic mineral products	31	3111, 3112, 3121, 3122, 3123, 3124, 3129, 3131, 3132, 3133, 3134, 3135, 3139, 3141, 3142, 3143, 3144, 3145, 3146, 3147, 3148, 3149, 3151, 3152, 3153, 3159, 3161, 3162, 3169, 3191, 3199
32	Ferrous metal forge	4	3210, 3220, 3230, 3240
33	Non-ferrous metal forge	18	3311, 3312, 3313, 3314, 3315, 3316, 3317, 3319, 3321, 3322, 3329, 3331, 3332, 3339, 3340, 3351, 3352, 3353
34	Metal products	24	3411, 3412, 3421, 3422, 3423, 3424, 3429, 3431, 3432, 3433, 3440, 3451, 3452, 3453, 3459, 3460, 3471, 3472, 3479, 3481, 3482, 3489, 3491, 3499
35	General equipment manufacturing	33	3511, 3512, 3513, 3514, 3519, 3521, 3522, 3523, 3524, 3525, 3529, 3530, 3541, 3542, 3543, 3544, 3551, 3552, 3560, 3571, 3572, 3573, 3574, 3575, 3576, 3577, 3579, 3581, 3582, 3583, 3589, 3591, 3592
36	Special equipment manufacturing	51	3611, 3612, 3613, 3614, 3615, 3621, 3622, 3623, 3624, 3625, 3629, 3631, 3632, 3633, 3641, 3642, 3643, 3644, 3645, 3646, 3649, 3651, 3652, 3653, 3659, 3661, 3662, 3663, 3669, 3671, 3672, 3673, 3674, 3675, 3676, 3679, 3681, 3682, 3683, 3684, 3685, 3686, 3689, 3691, 3692, 3693, 3694, 3695, 3696, 3697, 3699

Continued Table

37	Transportation equipment manufacturing	27	3711, 3712, 3713, 3714, 3719, 3721, 3722, 3723, 3724, 3725, 3726, 3731, 3732, 3741, 3742, 3751, 3752, 3753, 3754, 3755, 3759, 3761, 3762, 3769, 3791, 3792, 3799
39	Electric apparatus manufacturing	28	3911, 3912, 3919, 3921, 3922, 3923, 3924, 3929, 3931, 3932, 3933, 3939, 3940, 3951, 3952, 3953, 3954, 3955, 3956, 3957, 3959, 3961, 3969, 3971, 3972, 3979, 3991, 3999
40	Communication, computer, and electronic equipment manufacturing	21	4011, 4012, 4013, 4014, 4019, 4020, 4031, 4032, 4039, 4041, 4042, 4043, 4051, 4052, 4053, 4059, 4061, 4062, 4071, 4072, 4090
41	Instrument and meter, office machine manufacturing	25	4111, 4112, 4113, 4114, 4115, 4119, 4121, 4122, 4123, 4124, 4125, 4126, 4127, 4128, 4129, 4130, 4141, 4142, 4151, 4152, 4153, 4154, 4155, 4159, 4190
42	Art ware and other manufacturing	15	4211, 4212, 4213, 4214, 4215, 4216, 4217, 4218, 4219, 4221, 4222, 4229, 4230, 4240, 4290
43	Waste and scrap recycling	2	4310, 4320,
44	Electric, heating manufacturing and supply	6	4411, 4412, 4413, 4419, 4420, 44300
45	Gas production and supply	1	4500
46	Water production and supply	3	4610, 4620, 4690

Source: The Annual Industrial Survey Database

Appendix 5 Chinese National Level Urban Groups

Urban Group	*Location*	*Provincial Level Compositions*	*Cities No.*	*List of cities*
Shanghai-Yangtze River Delta	SE	Shanghai, Jiangsu, Zhejiang and Anhui	26	Shanghai*, Nanjing*, Wuxi, Changzhou, Suzhou, Nantong, Yancheng, Yangzhou, Zhenjiang, Taizhou, Hangzhou*, Ningbo, Jiaxing, Huzhou, Shaoxing, Jinhua, Zhoushan, Taizhou, Hefei, Wuhu, Ma'anshan, Tongling, Anqing, Chuzhou, Chizhou, Xuancheng
Beijing-Tianjin-Hebei	N	Beijing, Tianjin and Hebei	13	Beijing*, Tianjin*, Baoding, Langfang, Tangshan, Zhangjiakou, Chengde, Qinhuangdao, Cangzhou, Hengshui, Xingtai, Handan, Shijiazhuang
Guangzhou-Pearl River Delta	E	Guangdong, Hong Kong and Macau	16	Guangzhou*, Hong Kong, Macau, Shenzhen*, Foshan, Dongguan, Zhongshan, Zhuhai, Jiangmen, Zhaoqing, Huizhou, Qingyuan, Yunfu, Yangjiang, Heyuan, Shanwei
Central Plains	C	Henan	9	Zhengzhou, Luoyang, Kaifeng, Xinxiang, Jiaozuo, Xuchang, Pingdingshan, Luohe, Jiyuan
Yangtze River Midstream	C	Hubei, Hunan and Jiangxi	13	Wuhan*, Huangshi, Huanggang, E'zhou, Xiaogan, Xianning, Changsha, Zhuzhou, Xiangtan, Nanchang, Jiujiang, Jingdezhen, Yingtan
Chongqing-Chengdu	SW	Chongqing and Sichuan	15	Chongqing*, Chengdu*, Zigong, Luzhou, Deyang, Mianyang, Suining, Neijiang, Leshan, Nanchong, Meishan, Yibin, Guang'an, Ya'an, Ziyang
Central-Southern of Liaoning	NE	Liaoning	9	Shenyang*, Dalian*, Anshan, Fushun, Benxi, Dandong, Liaoyang, Yingkou, Panjin
Shandong Peninsula	E	Shandong	8	Jinan*, Qingdao*, Yantai, Zibo, Weifang, Dongying, Weihai, Rizhao
West Coast of the Taiwan Straits	E	Fujian, Zhejiang, Jiangxi and Guangdong	20	Fuzhou, Xiamen*, Quanzhou, Putian, Zhangzhou, Sanming, Nanping, Ningde, Longyan, Wenzhou, Lishui, Quzhou, Shangrao, Yingtan, Fuzhou, Ganzhou, Shantou, Chaozhou, Jieyang, Meizhou
Central Shaanxi Plain	NW	Shaanxi	10	Xi'an*, Xianyang, Baoji, Weinan, Tongchuan, Shangluo, Yangling, Tianshui, Hancheng, New West Ham

**The municipalities directly under administration of Chinese central government or Sub-Provincial Cities*

Source: National Bureau of Statistics of the People's Republic of China

Note: location is classified by the geographic distribution of provinces in China: E: Eastern China (Shandong, Jiangsu, Shanghai, Zhejiang, Anhui, Fujian and Jiangxi); S: Southern China (Guangdong, Guangxi, Taiwan and Hainan); C: Central China (Hunan, Hubei and Henan); N: Northern China (Beijing, Tianjin, Hebei, Shanxi and Inner Mongolia); NW: Northwest China (Ningxia, Qinghai, Shaanxi, Gansu and Xinjiang); SW: Southwestern China (Sichuan, Guizhou, Yunnan, Chongqing and Tibet); NE: Northeastern China (Liaoning, Jilin and Heilongjiang)

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