Effect of the Public Sector on Economic Performance in a Spatial Framework: Evidence from Chinese Cities

Thesis submitted in accordance with the requirements of

the University of Liverpool for the degree of Doctor of Philosophy

by

Fushu Luan

Department of Economics

IBSS

XJTLU

September 2019

Abstract

This thesis studies the effects of various dimensions of the public sector on economic performance in China, including economic growth, innovation, labour mobility and the internal core–periphery pattern. It adopts mixed theoretical perspectives and empirics and uses prefecture city–level panel datasets. The aim is to contribute to empirical analysis of regional development experiences in prefecture-level cities.

Chapter 1 provides an introduction of the research objectives and questions, and discusses which indicators of economic performance form our main interest and how these are influenced by government policy. Against the backdrop of China's transition from rapid gross domestic product growth to sustainable development, Chapter 2 (the first empirical study) explores the features that are unique to China's innovative performance, yet are missing from the literature. The study analyses the role of government institutions–particularly meritocracy–in shaping innovative development.

Following this, given that transportation development led by the government is an important driver of urban economic performance, Chapter 3 explores the effects of various modes of transportation infrastructure on economic growth in prefecture cities. The results indicate that both inter-city infrastructure (highways and railways) and intra-city public transit play significantly positive roles in the economic growth of these cities. The western region benefits mostly from improvement in transport infrastructures, while the effects of transportation construction on economic growth are least pronounced in the central China. As a result of the confirmed significant effect of railways in Chapter 3 and the progress of concomitant technology, this study deduces that China's development of high-speed railway (HSR) continuously reshapes the city landscape and generates significant effects on the distribution of economic activities.

Chapter 4 first provides a detailed overview of the development of China's HSR system in the period 2008 to 2014 regarding connections, frequency and travel time.

This chapter then analyses the effect of China's HSR system on economic activities. The results indicate that regional market access is a crucial determinant to explain the observed wage differentials between prefecture cities in China. Moreover, the counterfactual simulation indicates that the expansion of HSR networks would strengthen core–periphery patterns for China.

Finally, this thesis concludes with Chapter 5. Main findings, contributions, policy implications and further research are summarized in this chapter. Our first major contribution comes from the estimation of local leader's roles in promoting innovation using manually collected patent information and profiles of city party secretaries. The results provide fresh evidence showing heterogeneous impacts of the cadre governance features on city innovative performance and have rich implications in regard to official appointment and selection mechanism in leading innovative development. The second main contribution lies on the use of spatial models to understand the economic performances which are not neutral across space, wherein we look into different types of transport infrastructure in different types of cities and simulate China's future economic activities based on different scenarios of transport cost.

Publication

Chapter 3, “Heterogeneous effects of inter- and intra-city transportation infrastructure on economic growth: Evidence from Chinese cities”, co-authored with Yang Chen, Nemish Salike and Ming He, is now published in the ***Cambridge Journal of Regions, Economy and Society***.[1]

[1] Chen et al. (2016) in the Bibliography.

Acknowledge

I must express my sincere gratitude to all those who helped and supported me during the writing of this Ph.D. thesis. My deepest gratitude goes first and foremost to Professor Charles van Marrewijk, my first primary supervisor, for his immense knowledge and tremendous support throughout my research study. He led me into the world of geographical economics. It would not have been possible to work on this thesis, especially in the part of economy geography without the help and guidance of him. I also benefit tremendously from his invitation of the short visit of the University of Utrecht in June 2018. He provided extremely useful advices during this short visit time.

Second, I am indebted to my supervisors at Xi'an Jiaotong Liverpool University: Dr. Yang Chen and Dr. Paulo Regis for their brilliant comments and critical suggestions. Dr. Yang Chen, as my second primary supervisor, has walked me through all the stages of the writing this thesis. She cares so much about my research and always gives prompt responses to my queries. Equally, Dr. Paulo Regis devotes a considerable portion of his time to helping me improve my academic research and offering me invaluable comments and suggestions. Without their consistent and illuminating guidance, this thesis cannot have reached its present form. My sincere thanks also extend to my supervisor from the University of Liverpool: Dr. Yan Li who helped and supported me a lot.

I am also using this opportunity to express my great thanks to my beloved family for their care, love and constant support throughout my academic studies. I also owe my gratitude to my friends, yinyu, leilei, xinhui, yidan and hanyu, who gave me great encouragement and considerable support in difficult times.

Contents

List of Figures and Tables

List of Abbreviations

2SLS	Two-stage Least Squares
ADF	Augmented Dicky-Fuller
CES	Constant Elasticity of Substitution
CYL	Communist Youth League
DOLS	Dynamic Ordinary Least Squares
FAI	Fixed Asset Investment
FMOLS	Fully Modified Ordinary Least Squares
GDP	Gross Domestic Product
GIS	Geographic Information System
GMM	Generalised Method of Moments
HSR	High-speed Railway
IO	Input–Output
IPC	International Patent Classification
IPS	Im-Pesaran-Shin
LM	Lagrange Multiplier
LPC	Locarno Patent Classification
NBS	National Bureau of Statistics
NEG	New Economic Geography
NLS	Non-linear Least Squares
OLS	Ordinary Least Squares
PRC	People's Republic of China
R&D	Research and Development
S-GMM	System Generalised Method of Moments
SIPO	State Intellectual Property Office
UIC	International Union of Railways
US	United States
VECM	Vector Error Correction Model

Chapter 1: Introduction

In the wake of China's remarkable industrial development since the late 1970s, the new challenge facing the country is to sustain its economic success, which has been historically built on massive investment and led by a series of economic reforms (Chow, 1993; Song et al., 2011). As a response to this new challenge, the Chinese government has adopted several measures with two main focuses: (i) to build an innovation-oriented country,[2] which highlights the role of institutions in general and government governance in particular (Freeman, 1995; Nelson, 1993), and (ii) to invest in various modes of transportation infrastructure, particularly to construct a high-speed rail network to improve economic development. In brief, this thesis studies the effects of various dimensions of the public sector on economic performance, including innovation, economic growth, labour mobility and internal economic geographical patterns in China. This question is analysed at the prefecture city level under a spatial framework.

1.1. Two perspectives of the public sector

1.1.1. Leaders' personal characteristics and qualities and the bureaucratic system

Lane (2000) discussed the concept of the public sector, which fundamentally refers to both the types of public activities undertaken by a set of public institutions and the way decisions and policies are made and implemented by these institutions. The marked economic growth in China is somehow illustrated as evidence of good national leadership (Easterly and Pennings, 2015; Shih et al., 2012). Good leadership is attributed to both leaders' personal characteristics and qualities, and the bureaucratic system. China's subnational personnel structure not only relies on the

[2] The national strategy can be found from a government report of the Eighteenth National Congress of the Communist Party of China, available at http://www.gov.cn/jrzg/2012-12/28/content_2300813.htm (in Chinese).

performance and achievement of local leaders, but also depends on the will of the superior administrative level. Thus, this study investigates the channels through which the characteristics of the city party secretary and the types of bureaucratic incentives improve economic performance, particularly regarding innovation.

1.1.2. Heterogeneous modes of transportation infrastructure

Given that China's economic development levels are unevenly distributed, transportation plays a vital role in promoting national and regional prosperity. It provides easier access to nearby regions and markets, provides more opportunities for trade, reduces the cost of production, improves labour productivity and efficiency, and accelerates urbanisation (Kustepeli et al., 2012). Thus, to improve economic performance, China has devoted much attention to infrastructure investment since its new reform process started in the 1980s.

Figure 1.1a illustrates the alterations in passenger volumes in highway, railway and public transit from 1995 to 2012 in various regions of China (vertical comparison in each figure). The figures in the bottom row with darker shades indicate the huge increase in passenger flows in 2012 compared with 1995. Although the flow increased heavily in the eastern part of China, it has also been increasing in inland areas in recent years. In particular, the passenger traffic of public transportation in 2012 was highly saturated, surpassing 550 million people in most provinces of China (China City Statistical Yearbooks, 1996&2013). Figure 1.1b also confirms the rapid development of China's transportation, yet from the perspective of length measured in kilometres. It illustrates a sharp rise in railways and highways after the 1990s, which is consistent with the volumes of passenger flows (Ministry of Transport of the PRC and National Railway Administration of the PRC, 1979-2018). In terms of high-speed trains, Figure 1.1c displays the progressive rise of China's high-speed railway (HSR) network over recent years. China constructed and put into service over 19,000 kilometres of track of HSR over the period 2008 to 2015, which represents the largest HSR network in the world (National Railway Administration of the PRC and

International Union of Railway, 2016). Thus, the effect of the various modes of transportation infrastructure is another important factor that needs to be examined.

Figure 1.1a. Changes in passenger traffic volumes by mode of transportation

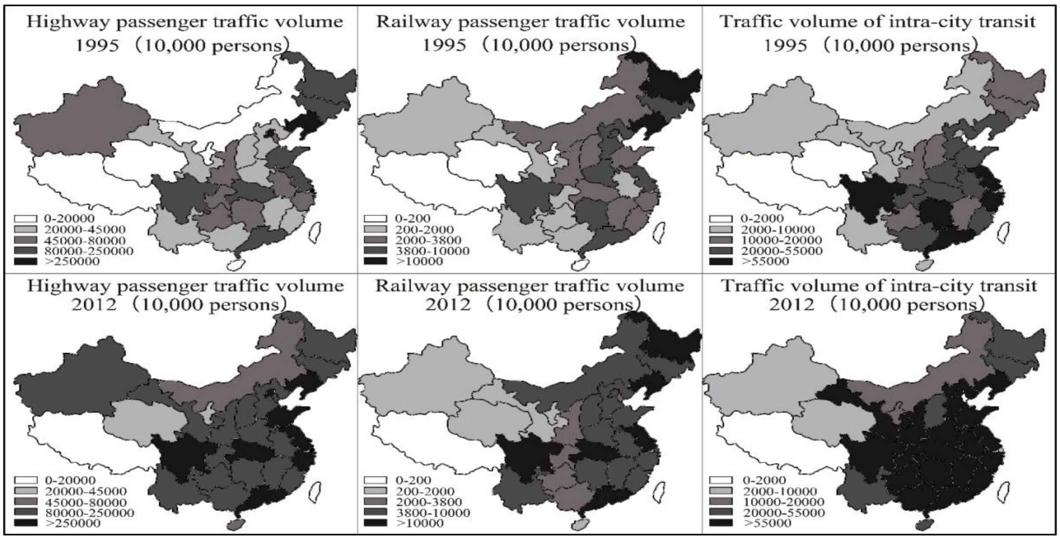


Figure 1.1b. Length of railways and highways in China

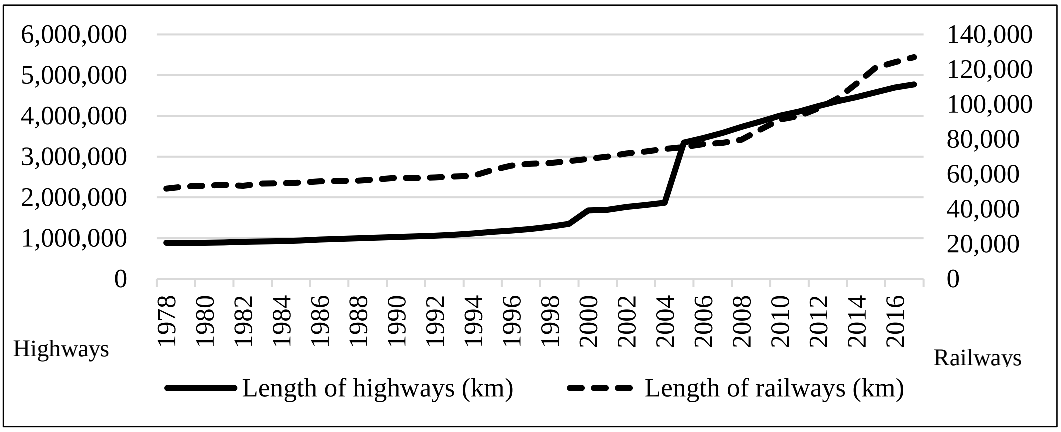
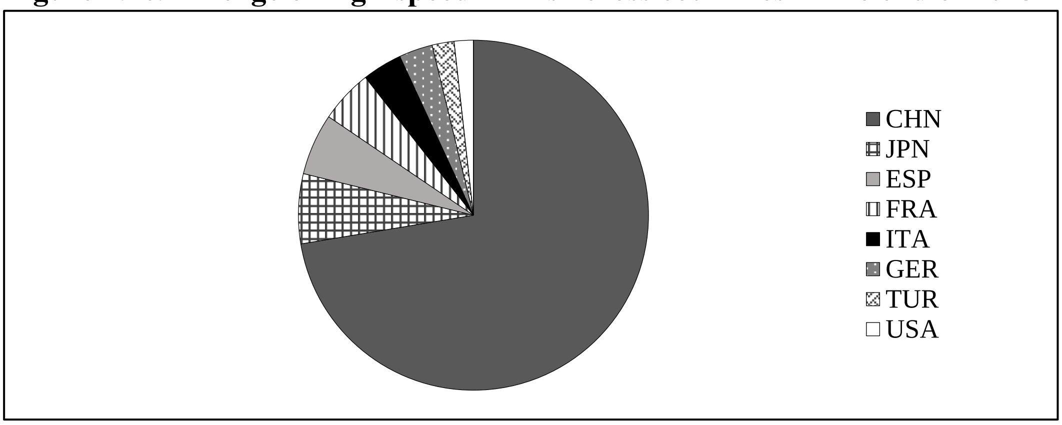


Figure 1.1c. Mileage of high-speed trains across countries at the end of 2015



Source: Data in Figure 1.1a are from China City Statistical Yearbooks (1996, 2013). Data on highways and railways in Figure 1.1b were collected from the Ministry of Transport of the People's Republic of China (1979-2018) and National Railway Administration of the People's Republic of China (1979-2018). Data on the HSR were collected from the National Railway Administration of the People's Republic of China (2016) and International Union of Railway (2016).

In brief, we concentrate on the public sector from two perspectives: bureaucracy and transportation infrastructure. In describing economic performance, the performance is briefly measured by three representative indicators—innovation, gross domestic product (GDP) growth and labour mobility—in a spatial pattern at the prefecture city level.

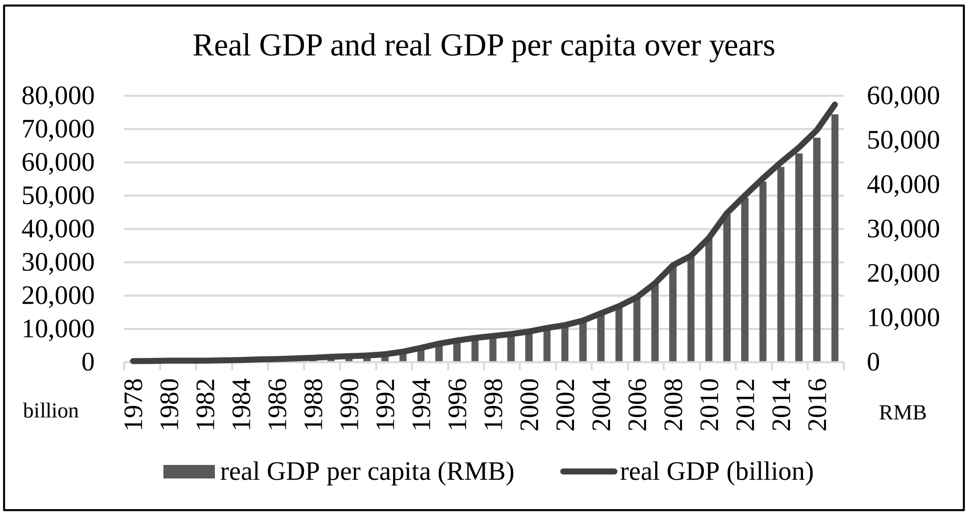
1.2. Key performance for the Chinese economy

Economic growth is an important indicator of economic performance. In addition, to pursue a path of indigenous innovation and build an innovation-oriented country, innovative output is considered a new component of economic performance. Further, China's large variation in population density and mobility of labour at regional and city levels appears to produce a highly uneven distribution of economic activities across space. This spatial distribution and internal economic geographical pattern can be predicted by using a new economic geography model.

1.2.1. Economic growth

During the last three decades, China—as one of the youngest contemporary economies—has become the second-largest economy in the world. Figure 1.2 displays the development of China's economy, proxied by real GDP and real GDP per capita, computed by their nominal values divided by a GDP deflator, since China initiated market reforms in 1978. The figure illustrates a sharp convexity in real GDP, as well as real GDP per capita, indicating rapid economic growth after roughly 2004. Interestingly, the lengths of highways and railways also ascended after 2004, as demonstrated in Figure 1.1b. This intrigued us to explore the linkages between different modes of transportation and economic development.

Figure 1.2. China's economic development



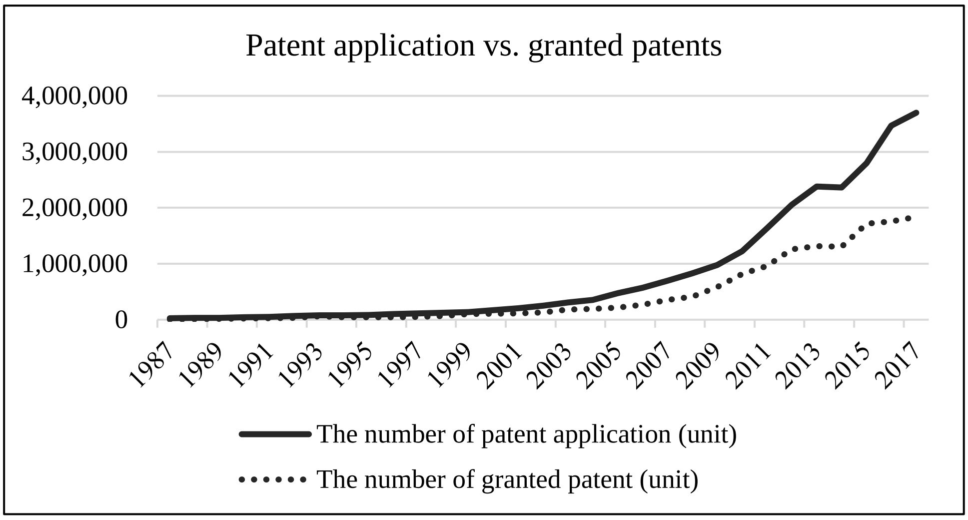
Source: National Bureau of Statistics (NBS), 1979-2018.

1.2.2. Innovative output

Innovation is the most important engine of economic growth. The growth trend of innovative output displayed in Figure 1.3 is consistent with the GDP growth in Figure 1.2, thereby to some extent confirming the contribution of innovation to economic development. Thus, it is important to consider who or what is able to expand innovative capacities to facilitate economic growth. The innovation milieu in China is attributable to several driving forces, such as investment in science and technology, foreign direct investment and industrial agglomeration (Fu and Gong, 2011; Ning et al., 2016). However, empirical evidence regarding the effect of China's unique political leadership and governance on innovation remains inconclusive. Despite its importance in shaping growth trajectories, we know little about the role of bureaucratic incentives in innovation, and the leading cadre system has rarely been captured in the production function of knowledge.

Therefore, this study first confirms the effects of innovative inputs on innovation, including domestic and foreign investment, education expenditure and labour force with their spatial lags, and agglomeration measured by diversity and specialisation. We achieve this by employing a Cobb-Douglas knowledge production function, with the empirical result used as a benchmark. Further, we examine the role of bureaucratic incentives in shaping innovative development, particularly from the perspective of city leaders' age, tenure, educational background, perceived promotion pressure, previous work experience and factional ties. Examining these specific components of government officials could provide answers regarding which characteristics of local government officials could stimulate or weaken the capacity for city innovation.

Figure 1.3. Numbers of patent applications and granted patents



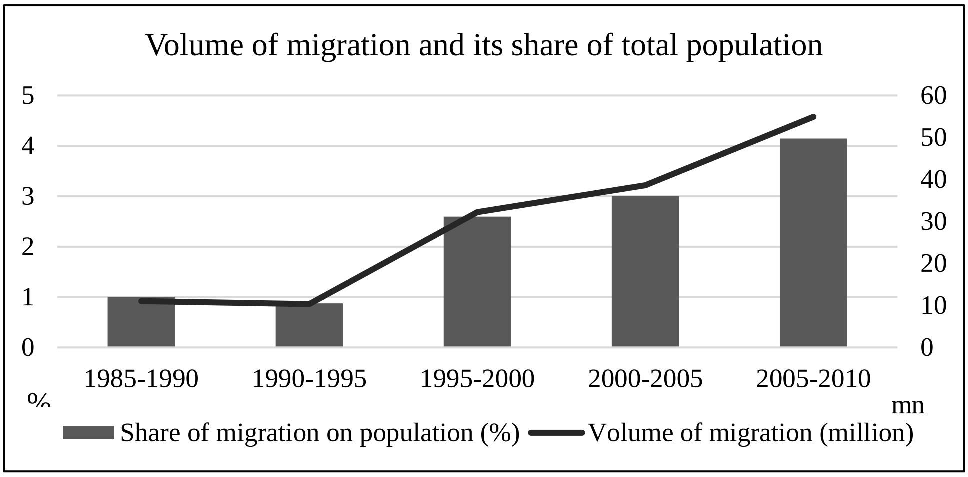
Source: National Bureau of Statistics (NBS), 1987-2018.

1.2.3. Mobility of labour

Progress in traffic and transportation technology has important consequences for urban development. China's development of high-speed trains continuously reshapes the city landscape and has significant effects on the distribution of economic activities, particularly in terms of labour mobility. The last two decades have witnessed an alarming increase in China's volume of migration, increasing nearly five times from 11.10 million (1985 to 1990) to 54.91 million (2005 to 2010), as displayed in Figure 1.4. China's internal clustering pattern will be influenced by the rising shares of migrants in the total population. A recently expanding stream of literature analyses the effects of railroad construction on a range of outcomes, addressing the consequences of establishing HSR systems in China (Wang and Lin, 2011, and Chen and Meng, 2013); however, little attention has been devoted to analysing the effect of reducing transport costs on labour distribution under the framework of a geographical economic model.

Therefore, after providing a description of the development of the HSR system in the period 2008 to 2014 in terms of connections, frequency and travel time, we then seek to determine the effect of the HSR on the spatial distribution of regional economic activities. In particular, we assess the possible consequences of China's internal economic geographical pattern based on the prediction of labour mobility.

Figure 1.4. China's migration and migrants' proportion of the total population



Source: Migration data were attained from Liu et al. (2014) and data on the total population were collected from the NBS (1986-2011). The values for shares were computed by the average value of each five-year period's total population.

1.3. Research questions

Given that we were interested in explaining the puzzle of China's economic performance, we studied three research questions, as follows:

Research Question 1 (Chapter 2): How did city leaders and their bureaucratic incentives affect city innovation across 284 prefectures during the 2001 to 2014 period?

Research Question 2 (Chapter 3): What is the effect of inter- and intra-city transport infrastructure on a city's economic development?

Research Question 3 (Chapter 4): What will happen to China's economic activities and internal economic geographical pattern when transportation is improved?

1.4. Data collection

This section provides some details on the data collected during this PhD study. A significant portion of the researcher's time, especially during the first two years, was devoted to cleaning datasets. Stata and Microsoft Excel are mainly used for data manipulation.

1.4.1. Bureaucracy

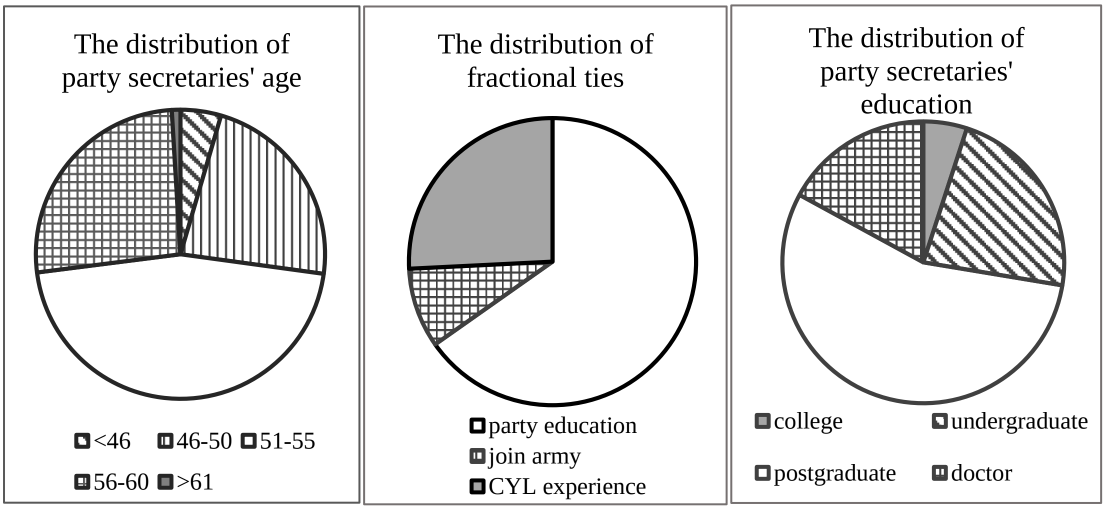
We explored the first research question across 284 prefecture cities during the period 2001 to 2014 using a manually collected annual dataset that combined patent data, prefecture city economic data and prefectural party committee secretary data. Three data sources were used to construct the city-level panel data, where the number of patent applications was manually collected from the State Intellectual Property Office (SIPO) of the People's Republic of China (PRC). The manually collected data of bureaucracy was based on the curriculum vitae of prefectural-level party secretaries, collected using Chinese Politicians Database[3], and double-checked using Baidu Baike. I am grateful to Dr Yang Chen for her splendid contribution in data collection of a bureaucrat. Finally, the economic data were collected from the China City Statistical Yearbooks (various years from 2001 to 2015).

Figure 1.5 displays various institutional variables regarding party secretaries' age, fractional ties and educational level. The dataset included 1,254 party secretaries at the prefecture city level from 2001 to 2014, with the aim of exploring their effect on city innovation. First, the distribution of each party secretary's age showed a clear age band, with most aged between 51 and 55 years, followed by a range of 56 to 60. To some extent, this indicates a preference for a certain age group in the appointment and

[3] It can be found from http://cpc.people.com.cn/gbzl/index.html.

selection of cadres. Second, according to the distribution of fractional ties, interpersonal relationships seem to be effectively maintained during the period of the Communist Youth League, followed by experience in party education. Joining the army is less important to the fraction relations of party secretaries. Finally, the high proportion of party secretaries with higher educational levels indicates that well-educated cadres will be given priority for selection and appointment.

Figure 1.5. Distributions of party secretaries' bureaucratic data



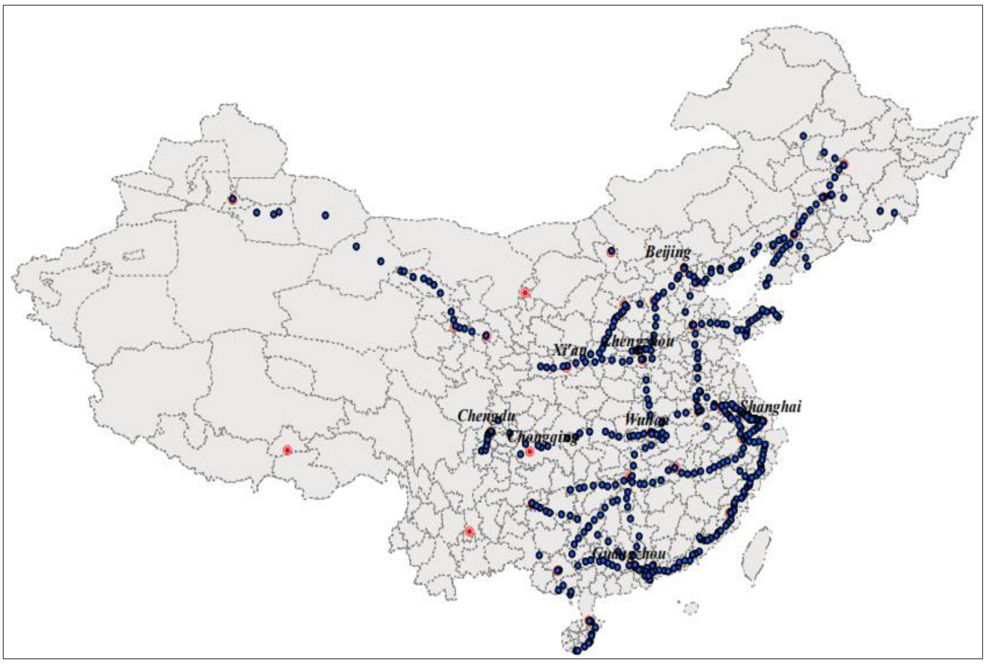
Note: Data were collected manually from the curriculum vitae of prefectural-level party secretaries using Chinese Politicians Database and Baidu Baike.

1.4.2. Transportation infrastructure

To estimate the influence of transportation infrastructure in China, panel data on prefecture cities were collected from various official data sources, including China City Statistical Yearbooks, Baidu Baike and the Railway Customer Service Centre of China (www.12306.cn). Covering information on 287 prefecture-level cities during the period of 1999 to 2014, the first data source was employed to assemble the volume of passenger traffic on railways, highways and public transit. Using the last three data sources, our study then extended from the physical measures of railways, highways and public transit to consider regimes of travel time and frequency of regular trains and HSR in China.

Figure 1.6 is particularly concerned with the status of development of China's HSR, where the red dots represent provincial capitals and blue dots represent all open HSR stations by the end of 2014. One hundred and fourteen prefecture cities have established HSR stations, with 306 stations put into service. It can be clearly seen that China's HSR construction is mainly concentrated on the east coast of China, followed by relatively densely populated areas in central China. Western areas are covered the least. In addition, provincial capitals are given priority in the siting of HSR stations. The cities marked on the map refer to the eight major HSR hub cities in China, playing a vital role in linking the east, middle and west of China.

Figure 1.6. HSR stations opened during 2008 to 2014



Note: Information on each HSR station was collected from a geographic information system (GIS), Baidu Baike and the Railway Customer Service Centre of China (www.12306.cn).

1.4.3. Stock variables of factors of production

Stock variables should be applied in the production function; however, this information is not published by the NBS. The official statistics report flow series, which represent investment figures. Therefore, we constructed the aggregate physical capital stocks using the perpetual inventory method of Kohli (1978). For example, the growth rate of real fixed asset investment in year t was defined as:

$$g_t = \frac{rINV_t}{rINV_{t-1}} - 1 \tag{1.1}$$

Thus, the average growth rate over the period of study (2001 to 2014) was computed as:

$$\bar{g} = \frac{1}{14}\sum_{2001}^{2014} g_t \tag{1.2}$$

The method assumes that *rINV* grew at the same rate prior to 2001. Thus, the initial capital stock in 2000 was estimated by:

$$K_{2000} = \frac{rINV_{2000}}{\bar{g}+\delta} \tag{1.3}$$

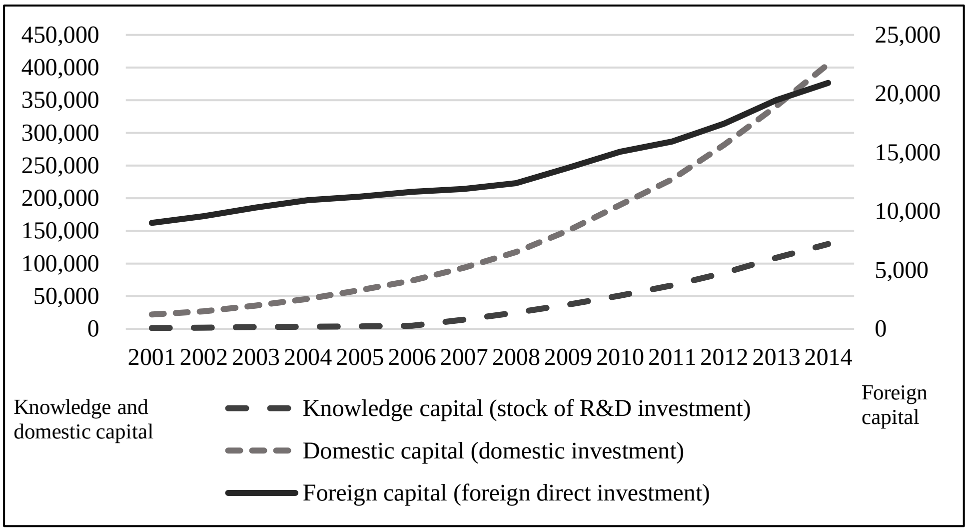
where δ (= 9.6%) is the aggregate depreciation rate. This depreciation rate is widely used in Chinese studies, as suggested by Zhang et al. (2004). Finally, the capital stock in subsequent years could be computed as:

$$K_t = (1-\delta)K_{t-1} + rINV_t \tag{1.4}$$

Similarly, the capital stock for foreign direct investment (FDI) and research and development (R&D) could also be calculated with the use of a depreciation rate of 5% based on Zhong (2019) and 15% based on Boeing et al. (2016), Hall et al. (2005) and Hu and Jefferson (2004).

Figure 1.7 displays the aggregate stock variables of real fixed asset investment per capita, R&D expenditure per capita and FDI per capita from 2001 to 2014. It reveals that all three lines illustrate an upwards trend, where the fastest increase was domestic capital, especially after 2008. The growth rates of knowledge capital and foreign capital were essentially the same.

Figure 1.7. Per capita stock of R&D, domestic and foreign investment



1.4.4. Others

For each chapter, we also collected other data from official sources, such as the China City Statistical Yearbooks (such as GDP, employment, employment composition by industry, distance of city to the nearest seaport, education, roads, population and urban population) and NBS (such as wages, population density, unemployment and housing prices).

Particularly important was the collection of patent application data from the China patent office. The raw data were available from their official website—the SIPO of the PRC. Information on all patent applications was available from the International Patent Classification (IPC) and Locarno Patent Classification (LPC). The former consists of two types of patent: invention and utility model. The latter focuses on design. Thus, we collected patent applications separately based on the IPC and LPC at the prefecture level, and aggregated them as a measure of a city's innovative performance.

1.5. Review of empirical methodology

We examined the research questions using different empirical methodologies. The endogeneity of production inputs is an important issue to address if the production function framework is adopted. In Chapter 2, reverse causality may exist that the innovative output and input variables can be simultaneously determined or an innovative city might be more able to conduct R&D and attract investment; therefore, we used the two-step system generalised method of moments (S-GMM) estimator of Blundell and Bond (1998). The panel structure of the data suggested the use of lags as instruments. The instrument was expanded with two external instruments (distance of each centre to the nearest six seaports and real average wage) to improve the performance of the instrumental variables (IV) estimator. In addition, the performance of the S-GMM was compared with ordinary least squares (OLS), fixed effects and two-stage least squares (2SLS).

To explore whether transportation infrastructure is a major propelling force of economic growth in Chapter 3, we focused on the linkage between transportation and GDP performance. Given the stationarity and cointegration relationship among the variables of interest, the level equation could be estimated using bias-correction methods, such as fully modified OLS (FMOLS) or dynamic OLS (DOLS) (Phillips and Hansen, 1990; Stock and Watson, 1993). In consideration of the short time span in our panel data, we preferred the panel FMOLS estimator based on Pedroni (2000).

Chapter 4 presents an empirical strategy to assess how improving the HSR system influences the distribution of economic activities in China. The strategy can be divided into three steps. First, the equilibrium wage equation was estimated by the nonlinear least squares (NLS) estimator introduced by Hanson (2005) because of the nonlinearity of market access. Our approach has some resemblance to the studies of Bosker et al. (2012) and Mion (2004). Second, we adopted panel linear least squares (OLS) estimation with fixed effects, according to Poncet (2006), to estimate the migration dynamics. Finally, we used the key structural parameters estimated by wage equation and migration equation, in combination with China’s current situation of manufacturing and housing, as inputs to conduct a counterfactual analysis (Bosker et al., 2010; Bosker et al., 2012). The combination of two empirical estimations and simulation provided more geographical realism to the new economic geography (NEG) model, which differs from related geographical economic studies in China (Wang and Lin, 2011; Chen and Meng, 2013).

1.6. Conclusion

Through using various theoretical models and empirical strategies, our analyses confirm that the public sector constitutes a key mechanism in the improvement of China’s economic performance. The Chinese government has invested substantial effort to facilitate economic growth and innovative output, such as expanding railway and highway networks and adjusting officials’ appointment and selection.

The remainder of this thesis is organised as follows. Chapter 2 examines the effects of agglomeration and bureaucratic incentives on city innovation using the Cobb-Douglas knowledge production function. This production function is also applied in Chapter 3 to investigate the effects of various transportation modes on cities’ economic growth. Chapter 4 presents the final study regarding China’s HSR and economic geography, while Chapter 5 concludes this thesis.

Chapter 2: Effect of bureaucratic incentives on city innovation

2.1. Introduction

It is accepted that the rapid innovation growth in China is partially attributable to the agglomeration economy, measured by specialisation and diversity (Driffield, 2004; Fu and Gong, 2011; García et al., 2013; Greunz, 2004; Sembenelli and Siotis, 2003). However, in most studies investigating influences on city innovation, cities or regions are viewed as 'floating islands in space' (Fujita and Mori, 2005), with spatial and inter-city interdependencies typically neglected. In fact, a city may receive inter-regional spillovers from its neighbours. Thus, the theory of NEG offers deeper insights into the relationship between cities, instead of treating cities independently (Krugman 1991a, 1992, 1993; Krugman and Venables, 1995). This chapter extends the previous literature to study the links between agglomeration and city innovation via combining knowledge production function with geographical consideration, through considering 284 Chinese prefectural cities for the period 2001 to 2014.

In the large quantity of literature on innovation, researchers have overwhelmingly focused on the effects of market forces, and devoted little attention to the role of bureaucratic incentives. Empirical results in capitalist countries, especially in Western democracies, provide evidence that national leaders play an active role in promoting economic growth (Glaeser et al., 2004; Acemoglu et al., 2005). Different from Western democracies, 5,000 years of Chinese history shape the unique and peculiar Chinese political culture, whereby the appointment power of officials is highly concentrated in the Chinese central government. The Chinese hierarchy of officials means that subnational leaders face a national institutional situation, whereby momentum in local economic development is highly associated with opportunities for local leaders' promotion. As the government pushes for the transformation from the traditional economic growth model based on factor accumulation to sustainable development based on innovation and productivity, whether and how leaders fulfil their mission is an open question. And as a response the leading cadres in China have called for building a national innovation system that incorporates favourable policies, innovative infrastructure and entrepreneurship culture since 2000[4]. The proposal and development of the national vision and implementation strategy by the ruling elites highlights the important role of Chinese leaders in driving innovation.

In this regard, the characteristics of subnational political leadership and patterns of local official promotion are inextricably linked to local innovative performance. China is a textbook case that offers an opportunity to analyse the way a city leader affects city innovation. Studies on the effects of local officials' actions on regional economic activities have begun to be conducted in response to an increasing trend of decentralisation of authority (Gu and Shen, 2012; Liu et al., 2012; Xu et al., 2007; Zhang, 2010). Nevertheless, the existing research focuses on the way that local leaders affect economic growth and whether subnational officials explain innovativeness provincially or regionally, yet none have the same focus as our study.

In this chapter, we study how local party secretaries affected city innovation across 284 prefectures during 2001 to 2014 by using a dataset combining patent data, prefecture city economic data and prefectural party committee secretary data. Before undertaking this, we first attempt to explore the way that agglomeration (measured by diversity and specialisation) affects innovation, and this empirical result is used as a benchmark. We achieve this by employing the Cobb-Douglas knowledge production function. More importantly, we examine how industrial agglomerative forces, such as diversity and specialization and, joint with institutional elements to determine the city innovative capacities. We consider the characteristics of party leaders in each city to explore the role of city leaders and their political incentives in promoting city innovation from the perspective of the city leaders' age, tenure, educational background, perceived promotion pressure, previous work experiences and factional ties. Examining these specific components of government officials could provide answers to the question of which characteristics of local government officials tend to

[4] The national strategy can be found in a government report in the eighteenth National Congress of Communist Party of China.

stimulate or weaken the capacity of city innovation. If we simply examined the correlation between a particular character and innovation, we would be unable to attain a complete picture of the role of the local government in affecting city innovation. Virtually no scholars have studied this topic from an empirical perspective; thus, our results will fill the gap in this field and make up for the deficiencies in the existing literature.

To overcome the potential endogeneity problem, we used the two-step system generalised method of moments (GMM) approach within a dynamic production function framework. Consistent with the previous literature, we found that R&D, investment in physical and human capital, and FDI enhanced cities' innovative outputs, while urban industrial diversity weakened cities' innovative capacity.

We also found the following outcomes. First, turnover rate negatively affects city innovation. Similarly, perceived promotion competition among city leaders, measured by turnover rate, plays a significantly negative role in enhancing innovation in the area; however, this negative effect can be moderated by industrial agglomeration. Second, a municipal secretary whose previous work is in the same province is more likely to promote innovation. Third, education background plays a positive role in promoting innovation. Fourth, an official who has experience in the Communist Youth League (CYL), army or party education is more likely to promote innovation. Finally, with increasing age, a city leader is less motivated to promote innovative activities. Our findings provide rich implications for innovation-related policy making to stimulate the innovative capacity of Chinese cities.

The rest of this chapter is structured as follows. Section 2.2 summarises the literature on the effects of city innovation from the two aspects of market mechanism and government official characteristics. Section 2.3 introduces empirical strategies, while Section 2.4 presents detailed descriptions of the data and variables. Section 2.5

presents the empirical results, while Section 2.6 presents the conclusions and suggestions for further work.

2.2. Literature review

Our study contributes to two main strands of the literature—first, to studies on the influence of agglomeration and, second, to studies considering the effect of government official characteristics and incentives joint with industrial agglomerative forces.

The first topic generally addresses the question of whether an agglomeration economy affects city innovation. The growth of cities results from a social division that allows highly specialised enterprises and professional talents to easily gather together and produce a certain degree of competitiveness. Meanwhile, the diversity of the urban population structure, culture and social structure contribute to the formation of a diverse urban environment (Jacobs, 1969; Marshall, 1890; Porter, 1990). When urban industries agglomerate, specialisation (Marshall-Arrow-Romer externalities) and diversity (Jacobs externalities) are used to reveal interactions between firms and industries, thereby influencing innovative output and productivity growth.

Although widely accepted as an important element of city innovation, industrial agglomeration still embodies inconclusive outcomes regarding which form is more significant. Paci and Usai (2000) analyse the linkages between spatial agglomeration (specialisation and diversity), innovation and production activities using a sample of 85 industrial sectors and 784 Italian local labour systems. They find that both diversity and specialisation are key factors explaining innovation significantly and positively. Greunz (2004) finds a consistent result, and indicates that specialisation and diversity spillovers significantly and positively affect innovation between 153 European regions across 16 manufacturing sectors.

In contrast, Feldman and Audretsch (1999) find that specialisation leads to an overall descending of innovation efforts, while they suggest the opposite effect if the industries are diversified. Similarly, through examining 170 United States (US) cities during 1956 to 1987, Glaeser et al. (1992) provide evidence that urban industrial diversity is positively related to regional growth, and that such effects are more effective than specialised cities. Using city-level data on South Korean manufacturing industries, Lee et al. (2005) also argue that diversity affects productivity significantly and positively, while the positive impact of Marshallian specialisation thesis does not hold. In a paper focusing on China, Mody and Wang (1997) use data of 23 industrial sectors of seven coastal regions from 1985 to 1989, and show that productivity growth benefits disproportionately more from a lower level of specialisation, especially for light industries. Despite several pieces of research providing evidence of a significant and positive effect of diversity on innovation and productivity, other empirical research presents some contradictory evidence on it. For instance, by combining a unique database with mapping software, Rosenthal and Strange (2003) contend that negative diversified externalities exist in US ZIP Code regions.

Research regarding the effect of local officials' actions on regional economic activities has begun to be conducted, with the increasing trend of decentralisation of authority. For example, a recent paper by Liu et al. (2012) analyse land finance from the perspective of local officials' promotion, using a dataset of China's 257 prefecture cities over the period 2003 to 2008. They explore a U-shaped effect of tenure of officials on land finance and also conclude that promotion of local officials contributes to city land finance, and this spillover effect is relatively larger in western China than in the east. In terms of the link between official characteristics and economic growth, some researches, such as Xu et al. (2007) and Zhang (2010), address the linkage between local officials and economic growth across Chinese provinces—from 1978 to 2005 and 1992 to 2007, respectively. However, the former focuses on the positive effects of governor transfer, while the latter emphasises the contribution of local governors' entrepreneurial background to regional economic development.

The role of local leaders in determining various economic performances has been acknowledged, but few studies attempted to illustrate empirically how cadres and bureaucracy affect local innovation. A strand of literature that shares the systematic perspective of innovation that highlights the role of institutions in general and government governance in particular (Freeman, 1995; Mitton, 2016), with empirical findings at both national and regional level (Rodríguez-Pose and Di Cataldo, 2015; Choi et al., 2011). The closest related paper to ours is by Rodríguez-Pose and Di Cataldo (2015), who assess how institutions shape innovative performance in the Europe. Institutions are measured by control of corruption, rule of law, government effectiveness and government accountability. They find that corruption and ineffectiveness of government go against innovation in the European Union. In the context of China, Gu and Shen (2012) explore city-level variation in the preferences and values of local officials using a dataset of the listed enterprises in the Small and Medium Enterprises Board in the Yangtze River Delta and Pearl River Delta during 2007 to 2009. They find that local leaders with an entrepreneurial background are favourable towards improving regional innovation.

The main indicator of China's bureaucratic incentive system is still the performance of GDP, although local competition based only on GDP probably bring serious negative consequences in many aspects (Xu, 2017). Hence, given the state's efforts in the development of innovation, this is an opportunity to provide some evidences for the reasonable improvement of the bureaucratic promotion mechanism based on the important role of officials in innovation. Virtually no scholars have studied this topic from an empirical perspective; thus, our results will fill the gap in this field.

The literature above only touches the separate linkages between agglomeration and innovation and between bureaucrat incentives and innovation; however, China’s appointment and selection mechanism may influence city innovative outputs with a focus on the industrial agglomeration. For instance, Li (2015) uses labour mobility, R&D expenditure and intermediate inputs as institutional variables to examine the impact of both specialisation and institutions as important features on regional innovation systems. He finds that the positive impact of specialization externalities is moderated by regional institutional factors by using Chinese SIC manufacturing industries at the provincial-level in 2009. This is similar to us that bridges two separate lines of research by linking agglomeration and government official incentives to affect innovation.

Previous research examining the effects of regional innovation in China does not generally consider inter-regional externalities. However, considering that correlation exists across space, a city may receive inter-regional spillovers from its neighbours. The theory of NEG offers deeper insights into the relationship between cities, instead of treating cities independently (Krugman 1991a, 1992, 1993). Based on this, Jaffe et al. (1993) create geographically localised knowledge spillovers, and find that spatial spillovers reinforce unequal regional development. Similarly, spatial clusters of regional innovation are explored via combining knowledge production function with geographical consideration by using the US innovation count database (Acs et al., 2002). The existence of spatial proximity of knowledge is also considered by Fischer and Varga (2003) and Goncalves and Almeida (2009). These studies inspire us to extend the knowledge production function to the spatial framework, as geographical dependence may occur between cities close to each other. Hence, to explain the existence of spatial interdependence, we construct spatially lagged variables of innovative inputs on the basis of the knowledge production function framework.

Overall, this study goes beyond the existing related studies by analysing the effects of agglomeration and local officials on city innovation, through the use of prefecture city data from the perspective of market mechanisms and political incentives.

2.3. Empirical strategy

2.3.1. Theoretical framework: knowledge production function

Rodríguez-Pose and Di Cataldo (2015) suggest institution as a factor in growth or knowledge production function as it matters for the regional economic trajectories (Myrdal, 1957). We adopt an extended knowledge production function with externality effects popularized by Griliches (1979) and Griliches (1992). R&D-based

knowledge capital was included and lower-case variables were expressed in per capita terms, given by:

$$pat = \mathrm{Z}\, k^{\beta} \bar{k}^{\bar{\beta}} e^{\varepsilon} \tag{2.1}$$

where *pat* stands for a city's innovative output, measured by the number of patent applications; k denotes all productive inputs, including knowledge capital (stock of R&D investment), domestic capital (domestic investment), foreign capital (FDI) and human capital (education); $\bar{k}$ represents the spatial spillovers of four inputs of production in the neighbouring cities; ε is the disturbance term; β and $\bar{\beta}$ are two vectors of elasticities of production inputs; Z is an aggregate index of all other factors affecting the patent production function, where $Z = Z_0\, e^{aI} A^{b}$; and Z_0 is the exogenous parameter associated with total factor productivity, combining city and time fixed effects that capture individual heterogeneity across cities. Of particular interest is the variable represented by I, referring to local officials' characteristics and political incentives. We also accounted for the effect of agglomeration comprising indices of specialisation and diversity, grouped in vector A.

Given that neither the China City Statistical Yearbook nor the NBS release data on capital stock, the measure of physical and knowledge capital stocks was constructed with Kohli's (1978) perpetual inventory method, using data on real R&D expenditure and the number of patents, with a 15% depreciation rate, as well as real fixed assets investment and real foreign investment, with 9.6% and 5% depreciation rates, respectively (see Section 1.4.3 for the construction of capital stocks).

Taking the logarithms on both sides of Equation (2.1) provides our estimation equation:

$$lnpat_{it} = X'_{it}B + I'_{it}a + \gamma_t + \mu_i + \varepsilon_{it} \tag{2.2}$$

where $lnpat_{it}$ is the log-linearised per capita patent applications; subscript i and t refer to city and time, respectively; vector I'_{it} denotes local officials' characteristics and political incentives; vector X'_{it} gathers all variables from k, $\bar{k}$ and A; γ_t is time fixed effects; μ_i denotes city fixed effects; and ε_{it} is the error term.

In summary, four alternative empirical models are proposed and fit a dynamic panel data model. The baseline model is as follows:

Model 1:

$$lnpat_{it} = \alpha lnpat_{i,t-1} + \beta_1 lninv_{it} + \beta_2 lnrd_{it} + \beta_3 lnhum_{it} + \beta_4 lnfdi_{it} + \beta_5 lnspe_{it} + \beta_6 lndiv_{it} + \gamma_t + \mu_i + \varepsilon_{it} \tag{2.3}$$

where $pat_{i,t-1}$ is the lagged dependent variable that fits the dynamic model; inv_{it} and fdi_{it} are the domestic physical capital per capita and foreign physical capital, respectively; rd_{it} is knowledge capital per capita; hum_{it} is human capital per capita; and agglomeration variables, spe_{it} and div_{it}, denote the indices of specialisation and diversity, respectively.

With consideration of the characteristics of city leaders and their political incentives, we have the second model:

Model 2:

$$lnpat_{it} = \alpha lnpat_{i,t-1} + \beta_1 lninv_{it} + \beta_2 lnrd_{it} + \beta_3 lnhum_{it} + \beta_4 lnfdi_{it} + \beta_5 lnspe_{it} + \beta_6 lndiv_{it} + I'_{it}a + \gamma_t + \mu_i + \varepsilon_{it} \tag{2.4}$$

where vector I'_{it} includes party secretaries' age, tenure, perceived promotion pressure, factional ties, previous working situation and educational background. With the inclusion of the spatially lagged variables, we can also derive Models 3 and 4 from Models 1 and 2, respectively:

Model 3:

$$lnpat_{it} = \alpha lnpat_{i,t-1} + \beta_1 lninv_{it} + \beta_2 lnrd_{it} + \beta_3 lnhum_{it} + \beta_4 lnfdi_{it} + \beta_5 lnspe_{it} + \beta_6 lndiv_{it} + \beta_7 Wlninv_{it} + \beta_8 Wlnrd_{it} + \beta_9 Wlnhum_{it} + \beta_{10} Wlnfdi_{it} + \gamma_t + \mu_i + \varepsilon_{it} \quad (2.5)$$

where W represents the spatial lags of productive inputs.

Model 4:

$$lnpat_{it} = \alpha lnpat_{i,t-1} + \beta_1 lninv_{it} + \beta_2 lnrd_{it} + \beta_3 lnhum_{it} + \beta_4 lnfdi_{it} + \beta_5 lnspe_{it} + \beta_6 lndiv_{it} + \beta_7 Wlninv_{it} + \beta_8 Wlnrd_{it} + \beta_9 Wlnhum_{it} + \beta_{10} Wlnfdi_{it} + I'_{it} a + \gamma_t + \mu_i + \varepsilon_{it} \quad (2.6)$$

2.3.2. Empirical methodologies

The estimation is biased and less efficient if the classical linear estimators of OLS and fixed-effects model are used, as a result of the existence of a potential endogenous problem. Therefore, we preferred fixed-effects instrumental variables estimation (2SLS) and linear GMM estimator. According to the result of the test of over-identifying restrictions,[5] weak instruments arose, leading to the bias of the 2SLS estimator. In addition, as discussed by Roodman (2009), GMM is generally more efficient than 2SLS because of the complication with its sophisticated reweighting moments. More importantly, endogeneity of the production inputs is an important issue to address since innovation output and input variables can be simultaneously determined or an innovative city might be more able to conduct R&D, and attract investment. To address such concerns as omitted variable bias and reverse causality, we use instrumental variable estimator especially designed for short dynamic panels (Blundell and Bond, 1998).

The competitive advantages of the GMM estimator make it popular for dealing with the empirical issues of panel data, as the GMM estimator is particularly designed

[5] The result rejected the null hypothesis that all instrumental variables were exogenous, as the p-value was less than 0.1.

for a linear relationship in panels with small T and large N, in which explanatory variables are not strictly exogenous and the dependent variable is dynamic and influenced by its own past realisations. Additionally, the fixed individual effects are contained and are heteroskedastic and auto-correlated within, yet not across, individuals. Then the general model is as follows:

$$y_{it} = \alpha y_{i,t-1} + V_{it}'\varphi + \varepsilon_{it} \qquad i = 1, \dots, N; \;\; t = 1, \dots, T$$
$$\varepsilon_{it} = \mu_i + v_{it} \tag{2.7}$$

where V_{it}' includes a vector of strictly exogenous covariates that depends on neither current nor past v_{it} and a vector of endogenous covariates that is potentially associated with past and present errors; $y_{i,t-1}$ is the lag of y that is potentially correlated with past errors; α and β are estimated parameters and $E(\mu_i) = E(v_{it}) = E(\mu_i v_{it}) = 0$; μ_i are unobserved individual-level effects; and v_{it} are the observed specific errors.

The Arellano–Bond estimator (Arellano and Bond, 1991) transforms all regressors by differencing and using the GMM without the two-step standard error correction. It is known as ‘difference GMM’. The Arellano–Bover/Blundell–Bond estimator, augmented by Arellano and Bover (1995) and developed by Blundell and Bond (1998), allows consideration of more instruments because of an additional assumption of no correlation between the first differences of instrument variables and the fixed effects. It establishes a system of two equations—the original one and the transformed one—thereby dramatically improving efficiency. It is called ‘system GMM’. According to evidence suggested by Windmeijer (2005), two-step GMM produces lower bias and corrected standard errors, and is superior to one-step GMM in estimating coefficients.

To summarise, the two-step S-GMM estimator is used to investigate the effects of agglomeration and bureaucratic incentives on city innovation.

2.4. Data and variable description

2.4.1. Data sources

The data used in this study were compiled from three datasets: (i) the SIPO of the PRC, (ii) China City Statistical Yearbook and (iii) Database on Prefectural Party Secretary of the PRC.

The SIPO is affiliated directly with the State Council, which is mainly engaged in patent work and coordination of foreign-related intellectual property matters. This database covers all announced and published China patent information from 10 September 1985, consisting of three basic types of patent: invention, utility model and design. The patent data were constructed at a unique city level and collected manually from SIPO for the period 2001 to 2014. The data were collected using 'advanced search' from the official website of the SIPO.[6] The time period was limited by the availability of city patent statistics and other required variables. Of the 287 prefecture cities, 284 were included in this dataset. The IPC includes two types of patent: invention and utility model. The design is part of the LPC, rather than the IPC. The total number of application patents summed by the applications of the invention, utility model and design were used as the dependent variable.

China City Statistical Yearbooks were used to collect the Chinese urban characteristics data, including cities from 22 provinces, four municipalities and four autonomous regions[7] during 2001 to 2014. This dataset included city characteristics, such as expenditure for R&D, GDP, investment in fixed assets, FDI, population density, human capital and employment of 19 industrial sectors. In particular, data on 19 industrial sectors' employment were used to calculate the industrial agglomeration.

[6] We selected each type of patent and filled in the application date and application address in the form of province and city, and then searched the website.

[7] The four municipalities were Beijing, Shanghai, Tianjin and Chongqing. The four autonomous regions were Inner Mongolia, Guangxi, Ningxia and Xinjiang. Cities in Tibet were excluded from this dataset because of insufficient statistical information. In addition, Hong Kong and Macau were not included because of the different administrative systems.

Following information on local officials' curriculum vitae, a dataset of politician profiles was manually collected from the Database on Prefectural Party Secretary of the PRC and Baidu Database, which were representative of all secretaries of municipal committees in each city from 2001 to 2014.[8] Our final profile data contained information on 1,254 city party secretaries, including their tenure; age; experience in the CYL, party or army; education background, degree of promoting competition; and working experience.

2.4.2. Variables used in the estimation

Table 2.1 illustrates some summary statistics of all variables used in this study.

Table 2.1. Description and summary of variables

Variables and descriptions	Classification	Obs.	Mean	Std dev.
Innovation: Number of patent applications in unit/total population	Dependent variable	3,946	-0.009	1.826
FDI: Actually utilized foreign capital/total population	Innovative inputs	3,844	-1.334	1.864
R&D: Expenditure for R&D in million yuan/total population		3,965	2.464	1.858
Education: Student enrolment in high schools in 10,000 person/total population		3,815	4.230	1.190
Capital investment: Investment in fixed assets in million yuan/total population		3,965	-0.707	0.495
FDI (spillover): Constructed by spatial lag of log of FDI	Spillover effects	3,780	0.414	0.980
R&D (spillover): Constructed by spatial lag of log of R&D		3,827	3.322	1.636
Education (spillover): Constructed by spatial lag of log of education		3,750	4.249	0.395
Capital (spillover): Constructed by spatial lag of log of physical capital		3,836	5.601	1.036
Distance of cities to the nearest six largest Chinese seaports in meters	External instruments	3,864	13.262	0.810
Real average wage		3,899	9.863	0.591
Specialisation index: Calculated by 19 industrial sectors' employment	Agglomeration	3,948	-0.800	0.393
Diversity index: Calculated by 19 industrial sectors using Herfindahl index		3,948	1.278	0.784
Party education = 1 if having experience in party education	Factional ties	3,842	0.571	0.495
Experience in CYL = 1 if having experience in CYL		3,867	0.254	0.435
Join army = 1 if joining army		3,897	0.084	0.277
College degree = 1 if graduated from college	Education background	3,875	0.050	0.218
Undergraduate degree = 1 if graduated with bachelor degree		3,875	0.226	0.418
Postgraduate degree = 1 if graduated with master's degree		3,875	0.553	0.497
Turnover rate = 1 if official is changed	Perceived pressure	3,971	0.268	0.443
Tenure of city leaders: Different between the first half year and second half year		3,132	2.660	1.700
Competition intensity of leaders: Calculated by turnover rate		3,976	0.380	0.435
Age: Age of secretary	Individual feature	3,918	52.151	3.945
Workplace = 1 if previous job is in same province as current job	Workplace	3,878	0.984	0.126

Dependent variable

We employed domestic patent applications per capita to measure city innovation. The reason we used patent application date, rather than publication date, was because

[8] The name lists of secretaries were collected from http://www.hotelaah.com/liren/index.html. Based on the name lists, the characteristics of secretaries were then researched and collected from the Database on Prefectural Party Secretary of the PRC and Baidu Database.

patent application considers innovative effort, which can mirror spillover effects more effectively than granted patents, and subsequently avoid underestimation of city innovative activities and capacities (Li, 2011; Ning et al., 2016; Usai, 2011).

Several previous studies argued that new product sales can be a more suitable indicator than patent data to reflect innovation activities, given that not all innovations are successfully granted as patents (Griliches, 1991). However, in the context of China, the sales of new products are often over-recorded by firms to reap more subsidies from the local government, thereby leading to an overestimation of city innovation. In contrast, the applications of a patent are based on a standardised procedure across the whole of China (Wang and Zhou, 2013). Besides, new product sales are more inclined to evaluate the technological-economic value, while patents reflect more the generation and improvement of technologies (Huang et al., 2012). Thus, we preferred a patent-based variable, which was relatively more accurate and more suitable than the use of new product sales.

Explanatory variables

From the perspective of the knowledge production function, physical, knowledge and human capital should be included first, which particularly consist of R&D expenditure per capita, human capital per capita, FDI per capita and capital investment per capita. We included inwards FDI because new technology is usually associated with new foreign capital investment (Driffield and Love, 2007; Sembenelli and Siotis, 2003). We expected that increased R&D expenditure, FDI, capital investment and an educated workforce were likely to promote local innovative capacity.

Knowledge spillovers and innovation are often embedded in industrial agglomeration to improve the efficiency of the study suggested by Griliches (1991); thus, we considered two typical industrial structures (specialisation and diversity) to examine the effect of agglomeration on urban innovation. We measured city industrial specialisation by employing 19 industrial sectors, according to the Krugman specialisation index (Krugman, 1991b; Kim, 1995), which is defined as follows:

$$spec_{it} = \sum_{j=1}^{p} \left| \frac{E_{ijt}}{\sum_{j=1}^{p} E_{ijt}} - \frac{\sum_{i=1}^{q} E_{ijt}}{\sum_{j=1}^{p} \sum_{i=1}^{q} E_{ijt}} \right| \tag{2.8}$$

where E_{ij} is employment in industry j in city i, and p and q are the total numbers of industries and cities, respectively. The higher the value of the city's specialisation, the more it is considered specialised. In addition, according to Henderson (1997), a city's diversity is constructed with the Hirschman-Herfindahl concentration index on employment, as follows, to measure the effect of Jacobs externalities:

$$div_{it} = \frac{1}{\sum_{j=1,j' \neq j}^{p} [\frac{E_{ij}}{E_i - E_{ij}}]^2} \tag{2.9}$$

where p is the total number of industries. This indicator excludes industry j to avert the relations between the diversity of an industry and the specialisation of itself.

More importantly, to estimate the effects of bureaucratic incentives on the performance of city innovation, we considered various characteristics of municipal party secretaries, listed in Table 2.1, including the party secretaries' education background, age, tenure, perceived promotion pressure, fractional ties and work experience. Notably, considering that it takes time for officials to perceive competition, we used its first lag to test the impact of competition intensity on local innovation.

Instrumental variables

A noteworthy point about possible reverse causality needs to be discussed. To conquer the potential problem of endogeneity, we adopted the S-GMM approach in a dynamic production function framework. Lags in first difference and levels are used as instruments to deal with endogeneity issues. In addition to lags, two other external instruments are included to improve the performance of the instrumental variable estimator: distances from each city center to the nearest six seaports[9] and real wages in each prefecture city. Instruments need to be selected among the determinants of the demand function of the inputs of production. Production function is estimated based on the duality approach from multiple equation structural models with input demand functions. In a structural model, average wage indices are used by Bernstein and Nadiri (1991) for the estimation of product demand functions and spillover effects. The key exogeneity assumption is that city's historical characteristics are exogenous to current shocks in performance.

Spatially lagged variables

The theory of NEG offers deeper insights into spatial interdependence, instead of treating regions independently (Krugman 1991a, 1992, 1993; Krugman and Venables, 1995). As discussed in the literature, the relationship between cities is measured by using spatially lagged variables to investigate the effects of economic activities between one city and its neighbours. In accordance with the knowledge production function framework, we constructed the spatial lags of R&D expenditures, FDI, domestic investment and human capital, followed by the spatial econometric analysis proposed by Keisuke (2017).

2.5. Empirical results

2.5.1. Main results on the way agglomeration economy affects city innovation

Table 2.2 reports the empirical results of the way that an agglomeration economy affects city innovation for a range of estimators, using the natural log of patent applications per capita as the dependent variable. In all specifications, the most innovative inputs had significant and positive effects on city innovation. The elasticities of R&D stock ranged from 2.5 to 6.8%, while those of domestic and

9 The major seaports used in this chapter are Shanghai port, Shenzhen port, Ningbo port, Qingdao port, Guangzhou port and Tianjin port.

foreign capital stocks ranged from 5.3 to 15.0% and from 1.8 to 3.9%, respectively, and those of human capital ranged from 1.2 to 6.6%. According to the estimates in the last two columns, diversity of industries is negatively related to city innovativeness. This result was similar to the work of Stiebale and Reize (2011). The specialisation produces the similar negative effect on innovation, which is consistent with Ning et al. (2016). In addition to the innovative inputs and industrial agglomeration, city innovation also highly depends on its past realisations.

Table 2.2. Results for effects of agglomeration economy on innovation

Variables	**OLS**	**FE**	**2SLS**	**S-GMM**	**S-GMM2**
Lagged dep. var.	0.894***	0.694***	0.770***	0.853***	0.855***
	(0.006)	(0.013)	(0.021)	(0.003)	(0.003)
R&D (stock)	0.040***	0.068***	0.025	0.056***	0.058***
	(0.007)	(0.014)	(0.018)	(0.002)	(0.003)
Capital (stock)	0.059***	0.150***	0.148***	0.060***	0.053***
	(0.013)	(0.030)	(0.038)	(0.006)	(0.006)
FDI (stock)	0.022***	0.018	0.029*	0.039***	0.039***
	(0.006)	(0.013)	(0.015)	(0.002)	(0.002)
Education (enrolment)	0.012*	0.030	0.066*	0.038***	0.038***
	(0.007)	(0.019)	(0.039)	(0.004)	(0.004)
Aglom. (specialisation)	-0.020	0.021	-0.007	-0.017***	-0.016***
	(0.017)	(0.033)	(0.036)	(0.003)	(0.005)
Aglom. (diversity)	-0.028***	-0.027	0.006	-0.038***	-0.038***
	(0.009)	(0.019)	(0.021)	(0.003)	(0.003)
Cons.	-0.289***	-0.902***	-1.057***	0.000	0.000
	(0.062)	(0.143)	(0.212)	(0.000)	(0.000)
Obs.	3,404	3,404	3,129	3,404	3,339
R-squared	0.910	0.923	0.921		
AR (1)				-8.349***	-8.317***
(p-value)				(0.000)	(0.000)
AR (2)				1.812	1.816
(p-value)				(0.070)	(0.069)
Hansen test of exogeneity				260.09	254.71
Hansen-in-difference test 1					-2.790
Hansen-in-difference test 2					-1.529

Note: * (**, ***): significance at the 10% (5%, 1%) level. Standard errors are reported in parentheses. Endogenous variables are lagged patent, R&D, capital, FDI and education. The S-GMM estimation considers the full set of lags available of the endogenous variables as instruments. In the last regression, two additional instruments are considered: the distance of city to its nearest seaport and real average wage. Separate statistics of Sargan test of over-identification of the two externals are reported as well. Tests for first-order and second-order serial correlation are reported in AR (1) and AR (2).

Table 2.3 displays the results of the spatial autoregressive model by OLS, FE, 2SLS and two-step S-GMM estimators. By comparing the empirical results between various specifications and estimation methodologies, different outcomes arose from the specification of the spatial weight matrix. It can be clearly seen that the magnitudes of coefficients of innovative inputs and agglomeration variables in Table

2.2 differed considerably from those estimated by the spatial econometric model. For instance, the effect of R&D stock decreased by approximately 3%, while foreign capital stock contributed more than 2% to city innovation. Besides, the contribution of human capital rose by around 1 to 2%. In terms of agglomeration, the effect of specialisation became insignificant, and the effect of diversity reduced slightly. The spatially lagged variables captured spatial spillover effects on city innovation across prefecture cities, suggesting that the city's innovation was also affected by innovative inputs in neighbouring cities. Columns 5 and 6 show the results of Model 3, in which the spatial lags of R&D spending and human capital significantly and positively affect city innovation, indicating that an increase in neighbouring knowledge capital investment led to a rise in innovation. Conversely, the negative signs of the coefficients of spatially lagged domestic and foreign investment suggest that more either domestic or foreign investment in neighbouring city crowded out the own city's innovation. In brief, surrounding cities with higher-skilled and higher-educated labour, as well as more expenditure on knowledge and technologies, have knowledge spillovers in promoting city innovation, compared with investment in public spending. Thus, spatial spillover effects need to be considered as a significant channel for research and policy implications.

Table 2.3. Results for effects of agglomeration on innovation with spatial lags

Variables	OLS	FE	2SLS	S-GMM	S-GMM2
Lagged dep. var.	0.891***	0.633***	0.692***	0.840***	0.839***
	(0.007)	(0.014)	(0.024)	(0.004)	(0.004)
R&D (stock)	0.010	0.001	-0.039**	0.027***	0.028***
	(0.009)	(0.015)	(0.019)	(0.004)	(0.005)
R&D (stock, spatial)	0.203***	1.213***	1.198***	0.317***	0.341***
	(0.070)	(0.108)	(0.133)	(0.029)	(0.032)
Capital (stock)	0.086***	0.155***	0.136***	0.083***	0.095***
	(0.017)	(0.033)	(0.042)	(0.010)	(0.008)
Capital (stock, spatial)	-0.353***	0.179	0.425	-0.429***	-0.467***
	(0.100)	(0.255)	(0.306)	(0.070)	(0.044)
FDI (stock)	0.015**	0.044***	0.057***	0.056***	0.060***
	(0.007)	(0.014)	(0.018)	(0.003)	(0.005)
FDI (stock, spatial)	0.026	-0.267***	-0.337***	-0.066***	-0.082***
	(0.031)	(0.092)	(0.100)	(0.019)	(0.013)
Education (enrolment)	0.022***	0.037**	0.082**	0.047***	0.041***
	(0.007)	(0.019)	(0.040)	(0.005)	(0.005)
Education (spatial)	0.196***	0.035	-0.109	0.182***	0.188***
	(0.073)	(0.187)	(0.216)	(0.022)	(0.026)
Aglom. (specialisation)	-0.018	0.046	0.025	-0.006	-0.003
	(0.017)	(0.033)	(0.035)	(0.006)	(0.005)
Aglom. (diversity)	-0.030***	0.009	0.042*	-0.026***	-0.023***
	(0.010)	(0.019)	(0.021)	(0.003)	(0.003)
Cons.	0.207	-3.654***	-4.697***	0.000	0.000
	(0.342)	(1.132)	(1.518)	(0.000)	(0.000)
Obs.	3,404	3,404	3,129	3,404	3,339
R-squared	0.911	0.927	0.925		
AR (1)				-8.355***	-8.313***
(p-value)				(0.000)	(0.000)
AR (2)				1.808	1.808
(p-value)				(0.071)	0.071
Hansen test of exogeneity				254.49	250.02
Hansen-in-difference test 1					0.764
Hansen-in-difference test 2					0.942

Note: * (**, ***): significance at the 10% (5%, 1%) level. Standard errors are reported in parentheses. Endogenous variables are lagged patent, R&D, capital, FDI and education. The S-GMM estimation considers the full set of lags available of the endogenous variables as instruments. In the last regression, two additional instruments are considered: the distance of city to its nearest seaport and real average wage. Separate statistics of Sargan test of over-identification of the two externals are reported as well. Tests for first-order and second-order serial correlation are reported in AR (1) and AR (2).

2.5.2. Main results of the way bureaucratic incentive affect city innovation

Table 2.4 presents the results of the tests for the effect of bureaucratic incentive on city innovative capacities, using the two-step S-GMM estimator, including six estimates of various characteristics of municipal party secretaries, including their educational background, work experiences, tenure, age, promotion competition and factional relations. The six aspects of the characteristics of officials can be classified into five categories, as shown in Table 2.1.

In terms of the variables of bureaucracy, the first result gleaned from Column (1) is that all variables regarding party secretaries' factional relations were significantly and positively associated with innovation, with army experience the major contributor at 4.8%, followed by youth party (3.0%) and party education (1.3%). These results may delineate that officials who have similar experience are more likely to be provided opportunities to maintain a relatively close relationship with other officials, even central government. They tend to follow the policies that emphasise the importance of innovation, as claimed by national leaders consciously and intuitively. Second, the level of education has a highly significant and positive relationship with city innovation, which implies that the higher educational level attained by the party secretary, the greater the probability that he or she will contribute more to city innovation. Third, the age of city leaders played a negative role in city innovation. This result indicates that young cadres have more incentives to pursue innovative city performance. Fourth, result in Column (3) indicates the effect of the workplace of the party secretary on city innovation. The evidence illustrates that, if a party secretary is transferred within the same province, this leads to a significantly positive influence on city innovation (4.5%). This result raises important implications for policymakers to design the appointment and selection of cadres in promoting city innovation.

Finally, the coefficient of the city leaders' turnover rate was negative, signifying that a high turnover rate between officials weakens the capacities of city innovation. Generally speaking, this result indicates that, although collusion between officials and local firms might be avoided by personnel shuffling from one locality to the other, this leads to a rise in local policy uncertainties and finally goes against city innovation. The interaction terms Turnover* specialisation and Turnover* diversity is negative and significant at the 5% significance level, showing the negative moderating effect of specialisation and diversity on the relationship between turnover and city innovation. This indicates industrial agglomerative forces are more limited to the impact of turnover on innovation.

High perceived competition, measured by turnover rate, also negatively affected innovation. This aligns the interests of local agents with the central principle. Notably, this negative role has a positive moderating effect illustrated in the interaction terms in Column (5). In addition, we also expected tenure's effect to be conditional on the city's agglomeration. With the introduction of the interaction variable of tenure and specialisation and diversity, we found that none of them are significant. The positive but insignificant sign revealed that a longer period of tenure promoted innovation, which indicates that local leaders staying in the same position for a long time seemed to be helpful for city innovation via the consideration of policy stability and continuity of implementation. Apart from these results, all the variables of innovative inputs had positive correlations with city innovation. In addition, both specialisation and diversity played negative roles in promoting city innovative capacities.

Table 2.5 reports the main results from Model 4, with spatially lagged variables of innovative inputs. As a whole, the magnitudes of spatial lag of R&D stock ranged from 0.29 to 0.36, while those of spatial lag of human capital were around 0.2 at the 1% significant level, and those of spatial lag of domestic and foreign capital stocks ranged from -0.42 to -0.36 and from -0.09 to -0.07, respectively. For agglomeration variables, similar results were found to those in Table 2.3. When we contrasted the estimates of the variables of bureaucracy, we found that the magnitudes of all increased slightly except age when the spatial spillovers were considered.

Table 2.4. GMM results for effects of bureaucratic incentive on innovation

Variables	(1)	(2)	(3)	(4)	(5)	(6)
Lagged dep. var.	0.848***	0.854***	0.855***	0.855***	0.852***	0.856***
	(0.005)	(0.004)	(0.004)	(0.003)	(0.003)	(0.004)
R&D (stock)	0.060***	0.057***	0.060***	0.061***	0.060***	0.064***
	(0.003)	(0.003)	(0.004)	(0.004)	(0.004)	(0.004)
Capital (stock)	0.056***	0.056***	0.044***	0.050***	0.046***	0.046***
	(0.008)	(0.008)	(0.008)	(0.006)	(0.007)	(0.008)
FDI (stock)	0.041***	0.048***	0.041***	0.043***	0.043***	0.041***
	(0.002)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Education (enrolment)	0.041***	0.031***	0.042***	0.038***	0.041***	0.039***
	(0.005)	(0.004)	(0.005)	(0.004)	(0.005)	(0.004)
Aglom. (specialisation)	-0.027**	-0.026**	-0.015**	0.003	-0.022**	-0.013*
	(0.006)	(0.005)	(0.006)	(0.006)	(0.007)	(0.007)
Aglom. (diversity)	-0.040**	-0.039**	-0.038**	-0.029**	-0.051**	-0.032**
	(0.003)	(0.003)	(0.003)	(0.003)	(0.004)	(0.005)
Party edu. (dummy)	0.013***					
	(0.003)					
Army (dummy)	0.048***					
	(0.005)					
Youth party (dummy)	0.030***					
	(0.004)					
College deg. (dummy)		-0.069**				
		(0.008)				
Underg. deg. (dummy)		0.016***				
		(0.004)				
P-grad. deg. (dummy)		0.052***				
		(0.003)				
Age			-0.003**			
			(0.000)			
Workplace (dummy)			0.045***			
			(0.016)			
Turnover (dummy)				-0.033**		
				(0.008)		
Turnover × specialisation				-0.034**		
				(0.007)		
Turnover × diversity				-0.011**		
				(0.004)		
Party competition (lag)					-0.085**	
					(0.017)	
Party comp.(lag) × specialisation					0.039***	
					(0.015)	
Party comp.(lag) × diversity					0.055***	
					(0.009)	
Tenure						0.001
						(0.002)
Tenure × specialisation						-0.000
						(0.002)
Tenure × diversity						-0.001
						(0.001)
Cons.	0.000	-0.571**	0.000	0.000	0.000	-0.531**
	(0.000)	(0.040)	(0.000)	(0.000)	(0.000)	(0.057)
Obs.	3,254	3,281	3,291	3,334	3,339	3,330
AR (1)	-8.141	-8.230	-8.266	-8.328	-8.310	-8.313
(p-value)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
AR (2)	1.828	1.782	1.903	1.822	1.832	1.859
(p-value)	0.068	0.075	0.057	0.069	0.067	0.063
Hansen test of exogeneity	251.49	246.63	251.99	252.40	249.59	248.96
Hansen-in-difference test 1	-1.449	-3.322	2.313	3.590	-1.070	-7.108
Hansen-in-difference test 2	-0.469	-4.180	-1.069	0.353	1.522	-7.217

Note: * (**, ***): significance at the 10% (5%, 1%) level. Standard errors are reported in parentheses. Endogenous variables are lagged patent, R&D, capital, FDI and education. The S-GMM estimation considers the full set of lags available of the endogenous variables as instruments. In the last regression, two additional instruments are considered: the distance of city to its nearest seaport and real average wage. Separate statistics of Sargan test of over-identification of the two externals are reported as well. Tests for first-order and second-order serial correlation are reported in AR (1) and AR (2).

Table 2.5. GMM results for effects of bureaucratic incentive with spatial lags

Variables	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Lagged dep. var.	0.840*** (0.005)	0.841*** (0.005)	0.836*** (0.006)	0.839*** (0.005)	0.839*** (0.005)	0.840*** (0.004)
R&D (stock)	0.030*** (0.006)	0.038*** (0.006)	0.025*** (0.006)	0.037*** (0.006)	0.034*** (0.005)	0.032*** (0.005)
R&D (stock, spatial)	0.308*** (0.033)	0.291*** (0.036)	0.358*** (0.041)	0.309*** (0.037)	0.316*** (0.040)	0.314*** (0.025)
Capital (stock)	0.079*** (0.011)	0.089*** (0.015)	0.079*** (0.011)	0.080*** (0.008)	0.076*** (0.008)	0.091*** (0.008)
Capital (stock, spatial)	-0.417*** (0.058)	-0.416*** (0.066)	-0.363*** (0.049)	-0.356*** (0.067)	-0.408*** (0.059)	-0.404*** (0.051)
FDI (stock)	0.058*** (0.004)	0.064*** (0.004)	0.055*** (0.004)	0.055*** (0.005)	0.058*** (0.005)	0.055*** (0.004)
FDI (stock, spatial)	-0.079*** (0.015)	-0.085*** (0.019)	-0.084*** (0.015)	-0.079*** (0.016)	-0.077*** (0.016)	-0.074*** (0.014)
Education (enrolment)	0.049*** (0.005)	0.031*** (0.007)	0.062*** (0.007)	0.050*** (0.007)	0.045*** (0.006)	0.042*** (0.007)
Education (spatial)	0.184*** (0.025)	0.180*** (0.027)	0.155*** (0.027)	0.161*** (0.027)	0.186*** (0.028)	0.181*** (0.030)
Aglom. (specialisation)	-0.009 (0.007)	-0.014** (0.007)	-0.003 (0.006)	0.005 (0.006)	-0.016** (0.008)	-0.007 (0.008)
Aglom. (diversity)	-0.030*** (0.004)	-0.022*** (0.004)	-0.029*** (0.004)	-0.023*** (0.003)	-0.039*** (0.005)	-0.023*** (0.005)
Party edu. (dummy)	0.011*** (0.003)					
Army (dummy)	0.048*** (0.007)					
Youth party (dummy)	0.022*** (0.004)					
College deg. (dummy)		-0.076*** (0.008)				
Underg. deg. (dummy)		0.011** (0.006)				
P-grad. deg. (dummy)		0.047*** (0.004)				
Age			-0.004*** (0.001)			
Workplace (dummy)			0.073*** (0.017)			
Turnover (dummy)				-0.031*** (0.008)		
Turnover × specialisation				-0.032*** (0.007)		
Turnover × diversity				-0.010** (0.004)		
Party competition (lag)					-0.076*** (0.016)	
Party comp.(lag) × specialisation					0.050*** (0.014)	
Party comp.(lag) × diversity					0.051*** (0.008)	
Tenure						0.001 (0.002)
Tenure × specialisation						-0.001 (0.002)
Tenure × diversity						-0.001 (0.001)
Cons.	0.000 (0.000)	0.000 (0.000)	-0.439 (0.298)	-0.473 (0.395)	0.000 (0.000)	-0.206 (0.312)

Obs.	3,254	3,281	3,291	3,334	3,339	3,330
AR (1)	-8.170	-8.240	-8.328	-8.336	-8.330	-8.314
(p-value)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
AR (2)	1.821	1.774	1.902	1.816	1.824	1.849
(p-value)	0.069	0.076	0.057	0.069	0.068	0.064
Hansen test of exogeneity	250.09	247.70	249.87	248.58	248.58	247.54
Hansen-in-difference test 1	-1.449	3.188	-4.022	-1.086	-0.411	2.601
Hansen-in-difference test 2	-5.056	2.695	2.819	-1.596	0.326	-0.302

Note: * (**, ***): significance at the 10% (5%, 1%) level. Standard errors are reported in parentheses. Endogenous variables are lagged patent, R&D, capital, FDI and education. The S-GMM estimation considers the full set of lags available of the endogenous variables as instruments. In the last regression, two additional instruments are considered: the distance of city to its nearest seaport and real average wage. Separate statistics of Sargan test of over-identification of the two externals are reported as well. Tests for first-order and second-order serial correlation are reported in AR (1) and AR (2).

2.5.3. Extensions and robustness checks

In this section, we directly use flow data from China City Statistical Yearbook to conduct the robustness check. The results for robustness checks are displayed in Table 2.6. Compared with the results in Table 2.4, the similarity of these results is striking, and only a few deviations are worthy of note. First, the magnitudes of innovative inputs generally decrease to some extent except R&D, leading to an underestimation as flow data are introduced. More importantly, when we switched to measures of the city leaders, the effects of most estimated coefficients turnover, competition and previous workplace—became smaller, which again confirmed the underestimation by using flow variables, while the influences of interaction term, Party comp.(lag)* specialisation, became insignificant.

Table 2.7 reports the results for when we accounted for spatial lags. In comparison with Table 2.5, the signs of diversity remained the same, and the impact of specialisation was still insignificantly. In addition, through comparing the estimates of Table 2.7 and Table 2.6, we found that highly educated cadres who transferred within the same province contributed much more to city innovation, while the positive effect of a party secretary with good factional ties decreased a bit. In addition, turnover and perceived promotion competition played a relatively more important role in city innovation.

Table 2.6. GMM results for city innovation using flow data

Variables	(1)	(2)	(3)	(4)	(5)	(6)
Lagged dep. var.	0.853***	0.856***	0.861***	0.854***	0.854***	0.859***
	(0.004)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
R&D	0.110***	0.101***	0.103***	0.101***	0.104***	0.099***
	(0.004)	(0.005)	(0.005)	(0.004)	(0.004)	(0.005)
Capital	0.022**	0.029***	0.030***	0.034***	0.032***	0.034***
	(0.010)	(0.010)	(0.009)	(0.009)	(0.010)	(0.007)
FDI	0.034***	0.043***	0.037***	0.039***	0.039***	0.035***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.002)	(0.002)
Education (enrolment)	0.030***	0.017***	0.024***	0.026***	0.022***	0.029***
	(0.005)	(0.006)	(0.005)	(0.006)	(0.006)	(0.005)
Aglom. (specialisation)	-0.028***	-0.028***	-0.018***	-0.009	-0.024***	-0.019***
	(0.007)	(0.006)	(0.005)	(0.006)	(0.007)	(0.007)
Aglom. (diversity)	-0.043***	-0.040***	-0.038***	-0.035***	-0.044***	-0.042***
	(0.004)	(0.004)	(0.003)	(0.003)	(0.004)	(0.005)
Party edu. (dummy)	0.015***					
	(0.003)					
Army (dummy)	0.050***					
	(0.006)					
Youth party (dummy)	0.029***					
	(0.004)					
College deg. (dummy)		-0.064***				
		(0.010)				
Underg. deg. (dummy)		0.013***				
		(0.005)				
P-grad. deg. (dummy)		0.054***				
		(0.004)				
Age			-0.003***			
			(0.000)			
Workplace (dummy)			0.021**			
			(0.010)			
Turnover (dummy)				-0.025***		
				(0.006)		
Turnover × specialisation				-0.026***		
				(0.007)		
Turnover × diversity				-0.008***		
				(0.003)		
Party competition (lag)					-0.076***	
					(0.014)	
Party comp.(lag) × specialisation					0.015	
					(0.013)	
Party comp.(lag) × diversity					0.024***	
					(0.007)	
Tenure						-0.002
						(0.002)
Tenure × specialisation						0.001
						(0.002)
Tenure × diversity						0.001
						(0.001)
Cons.	-0.278***	-0.119**	-0.230***	0.000	0.000	-0.278***
	(0.059)	(0.058)	(0.061)	(0.000)	(0.000)	(0.046)
Obs.	3,260	3,287	3,297	3,340	3,345	3,336
AR (1)	-8.235***	-8.314***	-8.336***	-8.388***	-8.395***	-8.400***
(p-value)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
AR (2)	2.107	2.101	2.177	2.105	2.116	2.131
(p-value)	0.035	0.036	0.0230	0.035	0.034	0.033
Hansen test of exogeneity	260.91	257.61	258.09	261.14	258.72	259.85
Hansen-in-difference test 1	0.975	-0.688	2.739	3.981	-3.473	-1.484
Hansen-in-difference test 2	2.106	1.907	-5.022	-0.265	3.743	2.716

Note: * (**, ***): significance at the 10% (5%, 1%) level. Standard errors are reported in parentheses. Endogenous variables are lagged patent, R&D, capital, FDI and education. The S-GMM estimation considers the full set of lags available of the endogenous variables as instruments. In the last regression, two additional instruments are considered: the distance of city to its nearest seaport and real average wage. Separate statistics of Sargan test of over-identification of the two externals are reported as well. Tests for first-order and second-order serial correlation are reported in AR (1) and AR (2).

Table 2.7. GMM results for city innovation using spatial lags and flow data

Variables	(1)	(2)	(3)	(4)	(5)	(6)
Lagged dep. var.	0.847***	0.853***	0.856***	0.852***	0.851***	0.855***
	(0.006)	(0.006)	(0.006)	(0.005)	(0.006)	(0.006)
R&D	0.081***	0.075***	0.070***	0.064***	0.070***	0.071***
	(0.005)	(0.005)	(0.004)	(0.006)	(0.005)	(0.005)
R&D (spatial)	0.233***	0.231***	0.227***	0.256***	0.226***	0.227***
	(0.039)	(0.038)	(0.031)	(0.039)	(0.037)	(0.031)
Capital	0.047***	0.065***	0.066***	0.084***	0.059***	0.062***
	(0.015)	(0.015)	(0.017)	(0.015)	(0.013)	(0.014)
Capital (spatial)	-0.438***	-0.447***	-0.488***	-0.471***	-0.391***	-0.363***
	(0.065)	(0.084)	(0.065)	(0.070)	(0.068)	(0.072)
FDI	0.030***	0.036***	0.029***	0.025***	0.031***	0.028***
	(0.003)	(0.003)	(0.003)	(0.004)	(0.003)	(0.003)
FDI (spatial)	0.027*	0.023	0.031*	0.032*	0.017	0.013
	(0.015)	(0.021)	(0.017)	(0.018)	(0.016)	(0.017)
Education (enrolment)	0.057***	0.039***	0.052***	0.051***	0.049***	0.058***
	(0.006)	(0.007)	(0.006)	(0.007)	(0.006)	(0.007)
Education (spatial)	0.092***	0.064*	0.112***	0.076*	0.079**	0.103***
	(0.034)	(0.034)	(0.039)	(0.041)	(0.040)	(0.034)
Aglom. (specialisation)	-0.003	-0.007	-0.001	0.011	-0.008	0.008
	(0.006)	(0.007)	(0.007)	(0.007)	(0.006)	(0.009)
Aglom. (diversity)	-0.032***	-0.032***	-0.032***	-0.030***	-0.044***	-0.030***
	(0.004)	(0.004)	(0.004)	(0.003)	(0.003)	(0.005)
Party edu. (dummy)	0.010***					
	(0.004)					
Army (dummy)	0.058***					
	(0.008)					
Youth party (dummy)	0.027***					
	(0.004)					
College deg. (dummy)		-0.070***				
		(0.009)				
Underg. deg. (dummy)		0.012**				
		(0.006)				
P-grad. deg. (dummy)		0.054***				
		(0.004)				
Age			-0.003***			
			(0.001)			
Workplace (dummy)			0.072***			
			(0.012)			
Turnover (dummy)				-0.032***		
				(0.007)		
Turnover × specialisation				-0.033***		
				(0.008)		
Turnover × diversity				-0.007**		
				(0.003)		
Party competition (lag)					-0.098***	
					(0.013)	
Party comp.(lag) × specialisation					0.013	
					(0.013)	
Party comp.(lag) × diversity					0.034***	
					(0.007)	
Tenure						-0.001
						(0.003)
Tenure × specialisation						0.000
						(0.003)
Tenure × diversity						0.000
						(0.001)
Cons.	0.932***	0.000	0.000	0.000	0.660*	0.373
	(0.358)	(0.000)	(0.000)	(0.000)	(0.380)	(0.422)

Obs.	3,235	3,262	3,272	3,315	3,320	3,311
AR (1)	-8.141	-8.237	-8.245	-8.305	-8.328	-8.296
(p-value)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
AR (2)	2.103	2.080	2.150	2.060	2.100	2.103
(p-value)	0.036	0.038	0.032	0.039	0.036	0.036
Hansen test of exogeneity	250.10	253.02	254.04	248.67	251.90	250.44
Hansen-in-difference test 1	7.016	2.779	1.598	-4.953	5.580	-2.753
Hansen-in-difference test 2	-0.126	5.144	1.121	-5.908	1.968	-1.251

Note: * (**, ***): significance at the 10% (5%, 1%) level. Standard errors are reported in parentheses. Endogenous variables are lagged patent, R&D, capital, FDI and education. The S-GMM estimation considers the full set of lags available of the endogenous variables as instruments. In the last regression, two additional instruments are considered: the distance of city to its nearest seaport and real average wage. Separate statistics of Sargan test of over-identification of the two externals are reported as well. Tests for first-order and second-order serial correlation are reported in AR (1) and AR (2).

2.6. Conclusion

This chapter has provided empirical insights into the question of how China's city innovation is affected by the agglomeration economy and bureaucratic incentives. To avoid the potential endogenous problem, we conducted a two-step S-GMM approach within a dynamic production function framework, using panel data consisting of 284 prefecture cities for the period 2001 to 2014. We examined the factors that affect China's performance of innovation from two aspects—first by diversity and specialisation, and second by different characteristics of local leaders of a city from various perspectives of age, tenure, education background, factional relations, perceived competition and working experience.

Our major contribution comes from the estimation of leader's role in promoting innovation with manually-collected patent information and profiles for city leaders. We find that promoting younger cadre with rich work experiences into leader's positions facilitates innovation. In addition, the negative influence of both high turnover and high level of competition among city leaders exist to cities. The interaction terms between turnover and industrial agglomeration are significantly negative across all models, which implies that cities may benefit less if they have either a very diverse industrial structure or a very specialised industrial structure from high turnover rate of official. In contrast, the positive signs of interaction terms between competition intensity and industrial agglomeration are significantly positive indicate that more specialised and diversified industrial structure with relatively higher perceived competition foster local innovation. Lastly, good factional relations positively affect city innovation and, officials with a lower educational level are limited in innovation. Another contribution of this study is that using spatially lagged variables, we sought to measure more realistic economic activities in China from the inter-regional perspective in response to those studies that ignored spatial spillover effects.

In regard to policy, it is advisable for policymakers and the Chinese government to observe a trade-off between local leaders and city innovation and its underlying rationale. Because of the existence of heterogeneity of local government official characteristics in affecting city innovation, the Chinese central government should be able to develop methods—such as the appointment of younger talent from nearby previous workplaces into leadership positions—to improve the capacity of innovation and productivity, rather than pursuing surface political performance.

Chapter 3: Heterogeneous effects of inter- and intra-city transportation infrastructure on economic growth: Evidence from Chinese cities

3.1. Introduction

The contribution of public infrastructure in economic development has been a topic of interest for economists for a long time. Several country-level studies with western experiences have found strong positive influence of public infrastructure on economic growth (Eisner, 1991; Munnell, 1992; Roller and Waverman, 2001; Pereira and Andraz, 2007) and on productivity (Aschauer, 1989; Munnell, 1990; Nadiri and Mamuneaus, 1994; Fernandez and Montuenga-Gomez, 2003). The experience of other non-western countries has also shown such a relationship (Hulten, 1996; Vijverberg et al., 2011; Kustepeli et al., 2012). This chapter goes beyond the present literature by analysing the effect of transportation infrastructure with the use of city-level data from the perspective of inter- and intra-city transportation and its impact on economic growth of cities.

Among other forms of infrastructure, transportation in particular plays a significant role in the prosperity of the countries and regions. It affects the economy through better connections among the entities providing increased opportunities in trade, lower cost of production, better access to markets and urbanization. It also helps in increasing labour productivity and organizational efficiency (Kustepeli et al., 2012). Agbelie (2014) finds that highway and railway infrastructure expenditures and densities have positive impact on GDP and such effect varies significantly across 40 countries studied. Fernald (1999) shows that the productivity growth of vehicle-intensive industries benefits disproportionately more from road building. Del Bo and Florio (2012) provide evidence that investment in quality and quantity of transport infrastructure along with information and communication technology improvement has a significant and positive impact on GDP. In a paper focusing on US transportation, Boarnet (1996), using data on California counties from 1969 to 1988, argues that road and highway capital is productive and that ground transportation infrastructure has partially opposing direct and indirect effects. In a comparison between US and Europe, Melo et al. (2013) show that productivity effect of transport infrastructure tends to be higher for US than for European countries.[10]

China placed much attention to infrastructure investment after the opening up of her economy starting from the 1980s. In particular, investment in transportation infrastructure gained pace since the late 1990s. The emphasis was on highway connections and railway expansion to connect the cities as well as public transportation facilities within the cities. In the early stage of reform and opening up, China's transportation infrastructure was weak and deemed insufficient. In 1978, the total mileages of highway and railway routes were only 890,000 km and 52,000 km, respectively, compared with those of 4,230,000 km and 98,000 km in 2012.[11] Transportation experienced tremendous development since 1995 and transportation infrastructure has been an essential part of China’s development policy since then. It is noteworthy that the development of railways gained much pace in the later years, especially that of high-speed railway system. From Figure 3.1a, it is evident that these investments in highways and railways have contributed positively to passenger flow, particularly after 2003. The passenger flow increases by about 95% for highways and 143% for railways from 2003 to 2012. There has also been a huge growth in intra-city movement of people during this time. Figure 3.1b illustrates the annual aggregate passenger flow of intra-city public transportation, which increased by 122% between 2002 and 2013.

[10] See Appendix 3.A for details of this literature.
[11] Data is collected from NBS in 1978 and 2012, respectively.

Figure 3.1a. Passenger traffic volumes of Highways and Railways (1978-2012)

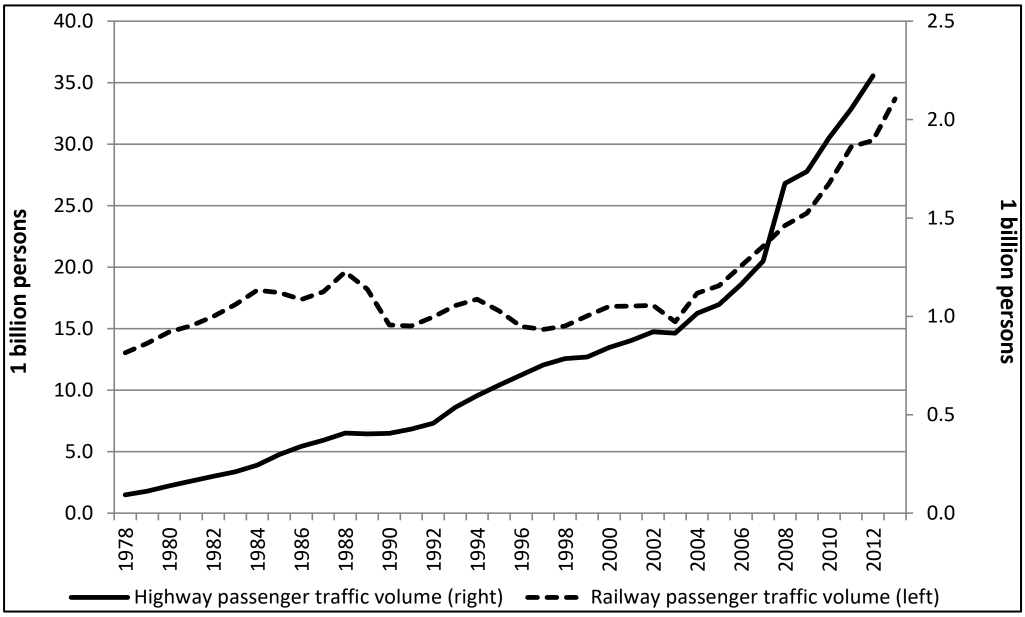
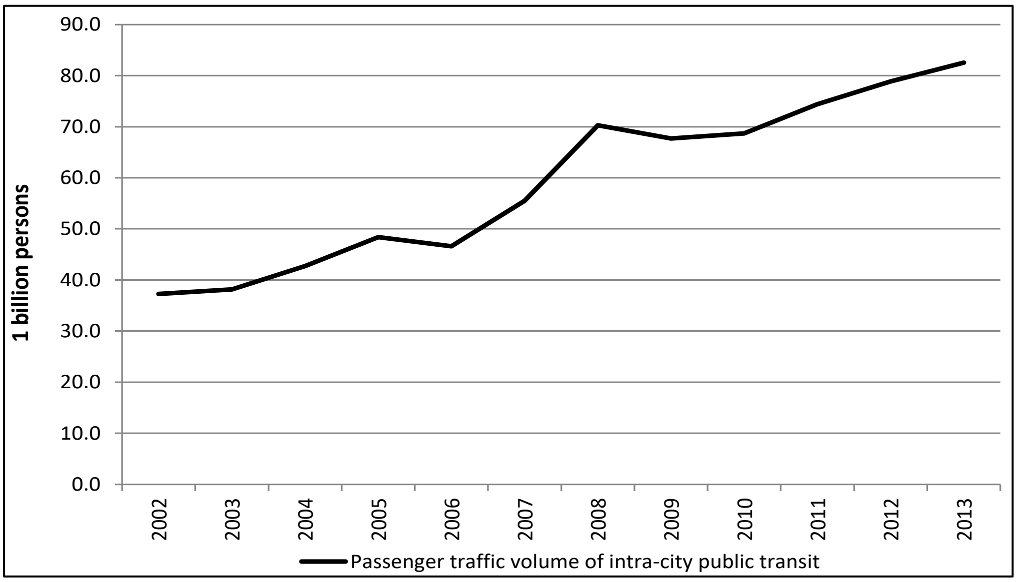


Figure 3.1b. Passenger traffic volume of intra-city public transit (2002-2013)



Note: Data is collected from NBS.

A few studies explore China's experience in infrastructure and economic growth focusing on the provincial level. Demurger (2001) analyses the linkage between infrastructure investment and economic growth using a sample of 24 Chinese provinces from 1985 to 1998. He finds that difference in transport facilities is a key factor in explaining the growth gap. Similarly, Yu et al. (2013) indicate that positive spillovers exist between provinces in each period due to the connectivity characteristic of transport infrastructure at the national level. At the regional level, transport infrastructure spillover effects vary considerably over time across China's four macro-regions[12]. These findings generally echo those of the international studies surveyed previously.

Innovations in new economic geography (NEG) theories (Krugman 1991, 1992, 1993; Krugman and Venables, 1995; Baldwin and Martin, 2004) offer deeper insights into the role of transportation costs in local economic growth. Brakman et al. (2009, pp. 65-72) emphasize that the reduction of trade costs within a certain range, facilitated by improvement in transportation facilities, strengthens the core with increased manufacturing share and economic size at the expense of the less industrialized periphery. The role played by the geographical economics in explaining the heterogeneity in city growth is confirmed by a bulk of empirical literature. For example, Black and Henderson (2003) state that variations in economic growth across US cities can be explained by differences in first-nature geography and the second-nature geography[13] due to the concentration effect (also see Mellinger et al., 2003; Nunn and Puga, 2012). Similarly, Li and Ni (2013) contend that the improvement of transport networks which lowers inter-city transport costs enables the core cities to attain faster growth by stimulating factor agglomeration. However, other empirical studies find some contradicting evidence. Using the 1995 Israeli census data, Leck et al. (2008) find out that newly introduced rail links significantly enhance the welfare of the underdeveloped cities. Lao et al. (2016) conclude that the improvement in air transportation plays an important role in accelerating the economic development of cities in central and western China rather than eastern region. It is thus interesting to explore whether and to what degree the improvement of various transportation facilities contributes to economic prosperity within the core-periphery framework.

This chapter examines the effects of transportation infrastructure on China’s economic growth from two perspectives. On the one hand, we investigate the heterogeneous roles of various transportation modes in urban economic development.

[12] See Appendix 3.A for details of this literature.

[13] The first-nature geography is also termed as the physical geography, which could be measured using the climate condition or the distance to a port or ocean. The second-nature geography is more important in explaining why cities continue to thrive because of agglomeration economies even when the initial cost advantages no longer exist. It is usually measured by an urban potential function.

On the other hand, we assess the heterogeneous effects of transportation infrastructure on different types of cities. Our contribution is threefold. First, this chapter engages more refined city-level data. The second contribution lies on the heterogeneity aspect of the analysis wherein we look into inter-city infrastructure (highways and railroads) and intra-city infrastructure (public transit) which per our knowledge lacks in present literature. Third, this study analyses the impact of transportation on different types of cities, either by administrative/economic hierarchy or by geographical location. Whereas most of the previous studies on China look at transportation in aggregate at the provincial level, the roles of different types of infrastructure need to be looked into separately. For example, highways have a specific role in linking nearby cities that allow people to work in one city but reside in another. Railroads connect distant cities in a much more efficient manner in terms of time and resources which gives rise to urban migration, in unison providing convenience for people to return to their hometowns for family reunions. Urban development also demands strong public transportation within the cities due to the increasing number of residents. Having insights on these separate contributions, policymakers would benefit by being able to prioritize projects on different types of transportation infrastructure.

Empirically we find that both inter-city and intra-city infrastructure contribute significantly to the economic growth of Chinese cities in the long run. Nationwide, the contribution of highways and railroads towards the economic growth of cities is roughly 6% each. Similarly, the contribution of intra-city transit is about 2%. Core cities are found to benefit far more than peripheral cities from both inter- and intra-city transportation infrastructure improvements, consistent with the predictions made by the NEG theory. In the short run, we find evidence of causal effect of intra-city transportation infrastructure on local economic growth (nationwide and in core cities) as well as reverse causal effects of economic growth on highways (core cities) or railroads (nationwide and in peripheral cities). In all cases, urban growth is found not to benefit immediately from the improvement of inter-city transportation facilities. On the analysis of regional impacts, we find that the contributions of all types of transportation infrastructure are highest in western China.

The rest of the chapter is organized as follows. The next section describes the empirical framework and explains the data used for the econometric analysis. In Section 3.3, we discuss our empirical strategies. Section 3.4 presents our findings and Section 3.5 concludes.

3.2. Empirical framework and data description

3.2.1. Empirical framework

We assume that the production of final output in each city is governed by a Cobb-Douglas production function with Hicks neutral technology,

$$Y_{it} = Z_{it}F(K_{it}, L_{it}) = Z(X_{it})K_{it}^{\theta_K}L_{it}^{\theta_L} \tag{3.1}$$

where subscripts i and t denote city and year, respectively. Y is city-specific real GDP; K denotes the capital stock and L represents the labour force. X is a vector of covariates that affects the total output. In the current study, they are measures of inter- and intra-city transportation infrastructures, plus additional controls. Applying the log transformation on both sides of equation (1) gives our baseline model:

$$\ln Y_{it} = \theta_k lnK_{it} + \theta_l lnL_{it} + \sum_j \theta_j lnX_{jit} + \eta_i + \varepsilon_{it} \tag{3.2}$$

where η_i is unmeasured individual idiosyncrasy and ε_{it} is the error term. The θs are elasticities of the covariates.

In this study, we consider three types of transportation infrastructure: highway, railway, and (intra-city) urban transit. Melo et al. (2013) suggest that the urbanization rate and the urban congestion rate are potential sources of omitted variable bias in similar studies. Specifically, the urbanization rate influences the elasticities of transport infrastructures because it is positively correlated with transport investment and economic growth. If the regression model fails to account for the urbanization rate, its impact on economic growth will be partially captured by transportation, resulting in upward biases. Similarly, Finn (1993) argues that failure to control for congestion may lead to a downward bias. Therefore, they are controlled for in this study. The measurements for the variables will be discussed shortly.

3.2.2. Data description

We collect the annual aggregate data for prefecture-level cities over 1999-2012 from different sources.[14] Data on nominal GDP and city population are taken from the China City Statistical Yearbook (various issues 2000-2013). Data on total fixed asset investment (FAI), provincial CPI and labour participation are taken from the Wind Database.[15]

The annual nominal GDP is converted to its real value (in billions of 1995 Yuan) using provincial-level CPI, which serves as our measure of real GDP (*rgdp*). Our measure of the labour force (l) is not perfect: it is estimated using the city total population times the annual labour participation rate at the national level. Nevertheless, this is the best and most reliable one that can be obtained from official publications.[16]

Since the National Bureau of Statistics (NBS) does not publish data on aggregate capital stock, our measure (K) is constructed by the perpetual inventory method of Kohli (1978) using data on real fixed asset investment (*rFAI*), which is FAI deflated by CPI in year t, and adopting Zhang et al.'s (2004) estimate of the depreciation rate, which is 9.6%[17](See Section 1.4.3. for the construction of aggregate capital stock).

---

[14] The definition of the labor force in the China City Statistical Yearbook has undergone a major revision in 1999. We find that the values reported by the yearbook have been reduced by roughly a magnitude following this change in definition. To keep consistency, we choose 1999 as the starting period of our study.

[15] NBS does not publish price indices for prefecture-level cities. Provincial data on CPI are the best we can find.

[16] We also construct an alternative measure of labour force by summing up unit employment, employment in privately owned enterprises, the number of self-employed, and the urban registered unemployed. This measure excludes urban migrant employees (also referred to as the floating population) and leads to inconsistency with the definition of labour force. Although this measure is not adopted here, regressions using this alternative measure do not qualitatively change our results.

[17] The estimation of capital stock at the provincial level was pioneered by Zhang et al. (2004). This depreciation rate of 9.6% is widely used in Chinese studies such as Yang and Li (2007), Wu et al. (2014). Other researchers proposed other values, such as 9.2% (Jin, 2012) and 5% (Fan et al. 2004). However, these estimates are less popular than Zhang's.

We use two different measures of the transportation infrastructure, either by physical capital (capacity) or by volume of passenger traffic. Data on traffic volumes of highway (*hp*), railroad (*rp*) and intra-city public transit (*pp*) are taken directly from the China City Statistical Yearbook (various years 2000-2013). Capital-based measures are constructed from multiple sources. We measure the highway infrastructure by the density of highway routes, i.e., the total mileage of highways in the administration divided by the area of the administration (*hwy_density*). Higher density implies greater accessibility to/from the city by road. Similarly, we measure intra-city transit infrastructure by per capita area of paved urban roads (*aprpop*). Larger value of this variable means better urban transit conditions. The only exception is railroad, for which we cannot find a capital-based measure in NBS publications. Therefore, we continue to use the traffic-based measure (*rp*). Given the facts that inter-city passenger trains operate on a fixed timetable and that the Chinese railway system is usually operating near its full capacity, the traffic volume is likely a good proxy to the physical capacity[18]. Data on the mileage of highway routes are taken from the China Urban Construction Statistical Yearbook (various years 2000-2013), and the rest of the variables are taken from the China City Statistical Yearbook (various issues 2000-2013).

Equation (3.2) studies multiple transportation modes, but they are likely to be correlated with each other[19]. Multicollinearity may be a more serious problem for the traffic-based measures, since more economic activity (*rgdp*) entails more economic interactions, both exterior and interior, thus more traffic. Therefore, we check pairwise correlations between the transportation variables as shown in Table 3.1.

[18] On the contrary, traffic volumes by highway or intra-city transit modes may vary substantially from their designed capacity, depending on the rate of usage.

[19] Conceptually, all types of transportation infrastructure are funded by public spending. As the local economy grows, different types of facilities are likely to be improved in a synchronous way. Therefore, we expect positive correlation among the transportation variables.

Table 3.1. Pairwise correlations for different measures of transport infrastructure

	lnhwy_density	*lnrp*	*lnaprpop*		*lnhp*	*lnrp*	*lnpp*
lnhwy_density	1	¾	¾	lnhp	1	¾	¾
lnrp	0.14	1	¾	lnrp	0.45	1	¾
lnaprpop	0.24	0.22	1	lnpp	0.50	0.63	1

It is clear from the table that all traffic-based measures are highly correlated, justifying our worries. The capital-based measures, however, only exhibit mild correlations. Evidently, the capital-based measures are superior to the traffic-based ones, both conceptually and empirically.

Lastly, the urbanization rate (ur) is defined as the ratio of the non-agricultural population to the total population of each city. The congestion rate is defined as the number of rental and public vehicles divided by the area of urban paved roads. These variables are taken from the China City Statistical Yearbook (various years 2000-2013). The summary statistics is presented below.

Table 3.2. Summary statistics of variables

Variable	**unit**	**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
Real GDP (*rgdp*)	billion Yuan	3044	80.19	121.22	1.54	1355.58
Capital stock (*k*)	billion Yuan	3066	157.89	267.74	0.037	2753.22
Labor force (*l*)	10,000 persons	3066	260.81	184.11	3.27	1949.64
Real Fixed asset investment (*FAI*)	billion Yuan	3066	42.29	66.06	0.04	693.19
Highway density (*hwy_density*)	km^{-1}	3048	0.71	0.46	0.02	3.83
Highway passenger traffic (*hp*)	10,000 persons	3066	7605.84	11779.1	82	179369
Railway passenger traffic (*rp*)	10,000 persons	3066	620.61	1145.37	1.00	14271
Urban road area per person (*aprpop*)	m^2/person	3046	2.98	3.62	0.02	64.00
Passenger traffic of intra-city transit (*pp*)	10,000 persons	3066	19926.44	46398.31	33.00	525607.4
Urbanization rate (*ur*)	percent	3066	0.36	0.18	0.01	1.00
Congestion rate (*conr*)	vehicle/km^2	3066	4.33	3.16	0.27	26.47

In summary, we propose the following baseline model:

Model 1:

$$\ln Y_{it} = \theta_k lnK_{it} + \theta_l lnL_{it} + \theta_h lnhwy\_density_{it} + \theta_r lnrp_{it} + \theta_p lnaprpop_{it} + \eta_i + \varepsilon_{it} \quad (3.3)$$

With other controls, we also have

Model 2:

$$\ln Y_{it} = \theta_k lnK_{it} + \theta_l lnL_{it} + \theta_h lnhwy\_density_{it} + \theta_r lnrp_{it} + \theta_p lnaprpop_{it} + \theta_u lnur_{it} + \eta_i + \varepsilon_{it} \quad (3.4)$$

and

Model 3:

$$\ln Y_{it} = \theta_k lnK_{it} + \theta_l lnL_{it} + \theta_h lnhwy\_density_{it} + \theta_r lnrp_{it} + \theta_p lnaprpop_{it} + \theta_u lnur_{it} + \theta_c lnconr_{it} + \eta_i + \varepsilon_{it} \quad (3.5)$$

These specifications use capital-based measures of transportation infrastructure. If we switch to traffic-based measures, *hwy_density* and *aprpop* are replaced by *hp* and *pp*, respectively.

3.3. Empirical methodology

3.3.1. Testing for panel unit root and cointegration

Least squares estimates are bound to be spurious if the covariates contain unit roots (Engle and Granger, 1987). Our first step is to identify the order of integration in our data using panel unit root tests. These tests are usually based on individual unit root tests (e.g., ADF or Phillips-Perron) in each cross section. By pooling information from all cross sections, the resulting test statistic has a conventional distribution, and the test has more power than the individual tests. We use Im et al.'s (2003) IPS test and Maddala and Wu's (1999) Fisher test because both tests allow heterogeneity in the cross sections by assuming different autoregressive parameters. Consequently, these tests are less restrictive than other panel unit tests which assume homogeneous autoregressive structures (Levin et al., 2002; Breitung, 2000).

Specifically, the IPS test and the ADF-based Fisher test perform the following ADF regression for each cross-section:

$$\Delta y_{it} = \eta_i + \rho_i y_{it-1} + \sum \beta_{ij} \Delta y_{it-j} + \nu_{it} \tag{3.6}$$

where y_{it} is the variable under study; η_i is the individual intercept; ρ_i is the number of lags for cross section i; and ν_{it} is the error term that is assumed to be serially uncorrelated and mutually independent.

The null hypothesis assumes unit root in all cross sections, i.e.

$$H_0: \rho_1 = \cdots = \rho_N = 0 \tag{3.7}$$

The alternative hypothesis specifies that some series in the panel are stationary:

$$H_1: \rho_1 < 0, \cdots, \rho_{N_0} < 0, N_0 \leq N \tag{3.8}$$

Table 3.3 summarizes the results of the IPS and Fisher panel unit root tests on the variables of interests in both levels and first differences.

Table 3.3. Panel unit root tests

	level				first difference			
	IPS test		Fisher test		IPS test		Fisher test	
	W-t-bar	p-value	Z-statistic	p-value	W-t-bar	p-value	Z-statistic	p-value
lnrgdp	25.24	1.00	24.93	1.00	-20.68**	0.00	-18.99**	0.00
lnk	16.18	1.00	15.39	1.00	-9.74**	0.00	-8.64**	0.00
lnl	-0.90	0.18	-0.49	0.31	-34.66**	0.00	-26.07**	0.00
lnhwy_density	4.06	1.00	5.42	1.00	-38.27**	0.00	-31.02**	0.00
lnhp	9.84	1.00	10.54	1.00	-36.81**	0.00	-30.57**	0.00
lnrp	-1.52*	0.06	1.44	0.93	-39.96**	0.00	-31.06**	0.00
lnaprpop	-0.63	0.26	0.53	0.70	-40.37**	0.00	-29.59**	0.00
lnpp	-0.54	0.29	1.17	0.88	-40.22**	0.00	-33.05**	0.00
ur	-0.13	0.45	2.78	0.99	-36.35**	0.00	-26.30**	0.00
lnconr	-4.03**	0.00	-2.87**	0.00	-37.42**	0.00	-31.26**	0.00

Note: * (**, ***): significance at the 10% (5%, 1%) level.

According to both tests, all variables are stationary at the 5% significance level in first difference. It is also clear that most variables contain a unit root in levels. Even though the IPS test rejects the null of unit root for *lnrp* at the 10% significance level, the p-value of the Fisher test remains large. However, both the IPS and Fisher tests strongly suggest stationarity for *lnconr*. Thus, we conclude that all variables are integrated of order one except for *lnconr*.

We proceed to test the existence of cointegration relationships. To this end, we test cointegration among two sets of variables, which are (*lnrgdp*, *lnk*, *lnl*, *lnhwy_density*, *lnrp*, *lnaprpop*, *ur*) and (*lnrgdp*, *lnk*, *lnl*, *lnhp*, *lnrp*, *lnpp*, *ur*)[20]. We use Kao's (1999) and Pedroni's (1999) residual-based tests. The Kao test assumes homogeneous cointegration vectors except for individual intercepts. The null hypothesis is no cointegration (e.g., the residuals from the first-step spurious regression contain a unit root). The Pedroni test is more flexible in assuming heterogeneous cointegration vectors in the cross section. Here we report p-values against the heterogeneous alternative since it allows individual AR coefficients in the residuals. The test results as summarized in Table 3.4 clearly reject the null hypothesis of no cointegration. Therefore, we conclude that the variables in model 1 and 2 have a long-run relationship.

Table 3.4. Panel cointegration tests

	Kao test		Pedroni test	
	ADF-statistic	p-value	Group ADF-statistic	p-value
capital based measure	-17.06**	0.00	-10.22**	0.00
traffic based measure	-13.97**	0.00	-9.67**	0.00

Note: * (**, ***): significance at the 10% (5%, 1%) level.

3.3.2. Long-run relationship and short-run causality

Given the cointegration relationship identified above, equation (3.2) no longer reflects the conventional causal effect of the covariates on *lnrgdp*. Instead, it should be interpreted as a linear long-run relationship among these variables. In this sense, the covariates in equation (3.2) are endogenous, because innovations in the dependent variable will be transmitted to the covariates through the common trend. Although the OLS estimator is superconsistent, it has a second order bias that results from endogeneity. Besides, the t-statistic does not have the conventional asymptotic distribution so that inference becomes difficult. Phillips and Hansen's (1990) Fully

[20] lnconr has been identified as being stationary, thus not included.

modified OLS (FMOLS) and Saikkonen's (1991) dynamic OLS (DOLS) estimators are designed to address these issues. FMOLS is a non/semi-parametric estimation accounting for endogeneity and serial correlation as well as high degrees of heterogeneity in the cointegrated panel (Pedroni, 2000; Witt et al., 2003; De Bois et al., 2007). In comparison, DOLS is a parametric estimation that controls for endogeneity by including lags and leads of the first differenced terms. Although Kao and Chiang (2000) suggest that DOLS is superior to FMOLS with a smaller bias, using DOLS may lead to severe loss in degrees of freedom as it involves adding leads and lags of the independent variables. In our sample with a short time span, the FMOLS estimator is thus preferred (Liddle, 2012) to examine the long-run relationship in models 1 and 2.

Once the cointegration vector has been identified, we proceed to investigate the short-run dynamics of the system by using conventional vector error correction model (VECM)[21]. Denote the parameter estimates by $\widehat{\boldsymbol{\theta}}$, the error correction term is the residual from the FMOLS regression, or

$$e_{it} = \ln Y_{it} - \hat{\theta}_k lnK_{it} - \hat{\theta}_l lnL_{it} - \sum_j \hat{\theta}_j lnX_{jit} - \hat{\eta}_i \tag{3.9}$$

The pooled error correction model for variables of interest (lnY, and lnX_j) is given by

$$\begin{aligned}
\Delta \ln Y_{it} &= c_Y + \lambda_Y e_{it-1} + \gamma_{YY}\Delta \ln Y_{it-1} + \gamma_{YK}\Delta \ln K_{it-1} + \gamma_{YL}\Delta \ln L_{it-1} + \sum_j \gamma_{Yj}\Delta \ln X_{jit-1} + u_{Yit} \\
\Delta \ln X_{jit} &= c_j + \lambda_j e_{it-1} + \gamma_{jY}\Delta \ln Y_{it-1} + \gamma_{jK}\Delta \ln K_{it-1} + \gamma_{jL}\Delta \ln L_{it-1} + \sum_{m\neq j} \gamma_{jm}\Delta \ln X_{mit-1} + u_{jit}.
\end{aligned} \tag{3.10}$$

[21] Recently, a few statistical methodologies have been developed to test causal effects in panel data. These include Dumitrescu and Hurlin's (2012) panel causality test, Canning and Pedroni's (2008) long-run causality test, and Kónya's (2006) bootstrap causality test. All these tests are robust to cross-sectional dependence and structural heterogeneity. Unfortunately, none of them fits our empirical problem. The Dumitresch-Hurlin test is designed for pairwise causality between stationary variables, while Kónya's test is designed for stationary panels. Therefore, they do not apply to our multivariate cointegrated system. The Canning-Pedroni test is designed for cointegrated systems, but it allows only two variables. In their context, the test based on the parameter of the error correction term is plausible, but inference will be difficult to make if there are more than two variables.

As usual, the short-run Granger-causality can be identified through a t-test on the corresponding γ parameter.[22] For instance, the causal effect of transportation mode X_j on Y can be tested by the t-test on γ_{Yj}, the reverse causal effect of Y on X_j can be tested similarly by the t-test on γ_{jY}.[23]

3.4. Empirical results and inferences

3.4.1. Main results with panel FMOLS analysis

Table 3.5 reports the main results from our baseline model and models with additional controls based on Pedroni's (2000) panel FMOLS estimator. We contrast the two sets of estimates based on different measures of transportation infrastructure.

Table 3.5. Panel FMOLS long-run estimates

	Capital-based measure			Traffic-based measure		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
lnk	0.502**	0.501**	0.501**	0.504**	0.502**	0.497**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
lnl	0.211**	0.212**	0.210**	0.194**	0.196**	0.193**
	(0.004)	(0.004)	(0.003)	(0.009)	(0.006)	(0.005)
lnhwy_density	0.063**	0.062**	0.061**	—	—	—
	(0.002)	(0.002)	(0.001)			
lnhp	—	—	—	0.066**	0.064**	0.064**
				(0.002)	(0.001)	(0.001)
lnrp	0.066**	0.064**	0.064**	0.060**	0.059**	0.060**
	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)
lnaprpop	0.022**	0.018**	0.018**	—	—	—
	(0.002)	(0.002)	(0.002)			
lnpp	—	—	—	0.038**	0.037**	0.037**
				(0.001)	(0.001)	(0.001)
ur	—	0.122**	0.121**	—	0.117**	0.114**
		(0.005)	(0.004)		(0.005)	(0.004)
lnconr	—	—	-0.0001*	—	—	-0.017**
			(0.002)			(0.001)
fixed effects	yes	yes	yes	yes	yes	yes
cities	218	218	217	219	219	219
years	2000-2012	2000-2012	2000-2012	2000-2012	2000-2012	2000-2012
N	2800	2800	2794	2843	2843	2843

Notes: * (**, ***): significance at the 10% (5%, 1%) level. Standard errors are reported in parentheses. Dependent variable is *lnrgdp*. The estimation assumes heterogeneous cointegration relationship in the first-stage regression and heterogeneous long-run covariance matrices in the cross section.

According to the estimates in columns 1-3, when transportation infrastructures are measured by physical capital, the output share of capital is 50%, and that of labour is 21%. In all specifications, both inter-city and intra-city transportations have

[22] Here we lag the first differences by only one period because our data have a very short time span.
[23] Similarly, one can test Granger-causality between any pair of variables, but they are not our major interests.

significant impacts on economic growth. The elasticities of highway network ranges from 6.1% to 6.3%, that of railroad range from 6.4% to 6.6%, and that of intra-city transit range from 1.8% to 2.2%. The urbanization rate contributes positively to economic growth, and our measure of urban congestion is found to be negatively related to economic growth, both consistent with findings in the previous literature. However, *lnconr* is significant only at the 10% level in model 3 and the estimated coefficient is virtually zero. Note that *lnconr* is stationary in level, rigorously speaking, it should not be a component of the cointegrated system. It is thus not surprising to find the coefficient to be insignificant and small in size. When these control variables are added to the regression model, the elasticities of capital, labour, and transportation variables are generally reduced, but the changes are negligible.

When we switch to traffic-based measures of transportation infrastructure in columns 4-6, the overall result is similar to the previous ones. Remarkably, the estimated coefficients on *lnpp* are twice the size of those on *lnaprpop*. The coefficient on *lnconr* continues to be negative, but becomes highly significant and much larger in size.

Our previous discussions show that the capital-based measures are superior to traffic-based ones because the former is not only conceptually better but also less affected by multicollinearity. The unit root tests and empirical estimates both suggest that *lnconr* should not be included in the regression model. Based on these concerns, our future analysis will be based on the model in column 2.

3.4.2. The short-run Granger causality

It is clear from the FMOLS estimates that transportation infrastructure contributes positively to economic growth in Chinese cities, while how they interact in the short run remains unclear. We are motivated to show whether improvements in transportation infrastructure have any immediate effect on local economic growth which has strong policy implications, as China has been recently criticized for building too many highways and railroads without yielding expected social return

(Bai and Qian, 2010). If the infrastructure is found to have no immediate impact on local economic growth, then such policy is indeed questionable, and governments should divert resources to other needs. Notably, China's economic growth has been identified as being investment driven, a large fraction of which was on infrastructure, especially transportation facilities (Demurger, 2001; Baum-Snow et al., 2017). It is thus intriguing to explore whether city growth has reverse causal effects on transportation infrastructure. Both tasks can be accomplished with the VECM model described in section 3.3.2. Here we focus on the causation between economic growth and individual transportation modes. Table 3.6 reports the estimates based on model 2.

Table 3.6. VECM estimates

	$\Delta lnrgdp_t$	Δlnk_t	Δlnl_t	$\Delta lnhwy\_density_t$	$\Delta lnrp_t$	$\Delta lnaprpop_t$	Δur_t
$\Delta lnrgdp_{t-1}$	0.191**	0.036**	0.120**	0.053	0.301**	-0.093	-0.015
	(0.018)	(0.018)	(0.037)	(0.077)	(0.100)	(0.070)	(0.029)
Δlnk_{t-1}	0.180**	0.709**	-0.029	0.179**	0.061	0.082	-0.054**
	(0.013)	(0.013)	(0.027)	(0.056)	(0.072)	(0.050)	(0.021)
Δlnl_{t-1}	0.000	-0.009	-0.470**	-0.008	0.002	0.008	-0.009
	(0.008)	(0.008)	(0.017)	(0.036)	(0.046)	(0.032)	(0.013)
$\Delta lnhwy\_density_{t-1}$	0.004	-0.008**	-0.005	-0.212**	0.013	-0.018	-0.004
	(0.004)	(0.004)	(0.008)	(0.018)	(0.023)	(0.016)	(0.007)
$\Delta lnrp_{t-1}$	-0.003	-0.001	-0.006	-0.009	-0.176**	-0.007	0.001
	(0.003)	(0.003)	(0.007)	(0.014)	(0.018)	(0.013)	(0.005)
$\Delta lnaprpop_{t-1}$	0.011**	0.017**	-0.010	0.006	-0.006	-0.198**	-0.471**
	(0.005)	(0.005)	(0.010)	(0.021)	(0.028)	(0.019)	(0.020)
Δur_{t-1}	0.004	0.012	0.025	0.004	-0.033	-0.020	-0.471**
	(0.012)	(0.013)	(0.026)	(0.054)	(0.070)	(0.049)	(0.020)
ec_{t-1}	0.053**	0.008	-0.135**	-0.180**	-0.215**	-0.097**	-0.059**
	(0.009)	(0.010)	(0.020)	(0.041)	(0.053)	(0.037)	(0.015)

Notes: * (**, ***): significance at the 10% (5%, 1%) level. Standard errors are reported in parentheses. ec_t is computed as in equation (3.9), using the parameter estimates in column 2 of Table 3.5.

The estimates in column 1 indicate short-run causal effect of other variables on real GDP. Highways and railroads are found to have no short-run effect on real GDP at all, but that of intra-city transit has a significant impact on real GDP. Intuitively, it takes time for inter-city transport infrastructure to generate the desired effect on economic growth. In contrast, there is immediate benefit from intra-city facilities. Investment in highways ($lnhwy\_density_t$) exhibits negative serial correlation. This is also true for other types of transportation infrastructure. The estimates also suggest a positive and significant feedback from real GDP to railroads, but the reverse causal effects on other transportation infrastructures are insignificant.

3.4.3. The core and the periphery

The NEG theories (Krugman 1991, 1992, 1993; Krugman and Venables, 1995; Baldwin and Martin, 2004) suggest that improvement on inter-city transportation infrastructure affects the core and the periphery in different ways. Our next step is to investigate this hypothesis within the current analytical framework.

We define the core cities as tier-one and tier-two cities in the subdivision of Chinese cities. The classification, which divides all Chinese cities into four groups, is based on the following criteria: administrative power, economic size, population, and regional influence[24]. There are five tier-one cities[25] which are either political or economic centers of the nation and thirty-five tier-two cities which are either provincial capitals or regional economic hubs. These criteria closely match the definition of the core in the NEG theories. For this reason, we divide our sample into a subsample of 39 core cities (tier-one and tier-two) and the other of 179 peripheral cities (tier-three and tier-four), and rerun model 2 using both the capital- and traffic-based measures. The results are reported in Table 3.7.

[24] The definition of tier 1-4 cities used in this article was developed by the Institute of Finance and Trade Economics of the Chinese Academy of Social Sciences. Other institutions have their own classifications, but the definitions are conceptually similar.

[25] Beijing, Tianjin, Shanghai, Guangzhou, and Shenzhen.

Table 3.7. Panel FMOLS estimates in the core and the periphery

	Capital-based measure			Traffic-based measure		
	Full sample	Core	Periphery	Full sample	Core	Periphery
lnk	0.501**	0.468**	0.502**	0.502**	0.475**	0.505**
	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)
lnl	0.212**	0.362**	0.105**	0.196**	0.260**	0.123**
	(0.004)	(0.006)	(0.006)	(0.006)	(0.006)	(0.010)
lnhwy_density	0.062**	0.122**	0.059**	—	—	—
	(0.002)	(0.003)	(0.002)			
lnhp	—	—	—	0.064**	0.080**	0.050**
				(0.001)	(0.002)	(0.001)
lnrp	0.064**	0.164**	0.047**	0.059**	0.137**	0.046**
	(0.001)	(0.002)	(0.001)	(0.001)	(0.002)	(0.002)
lnaprpop	0.018**	0.028**	0.011**	—	—	—
	(0.002)	(0.004)	(0.002)			
lnpp	—	—	—	0.037**	0.119**	0.030**
				(0.001)	(0.002)	(0.001)
ur	0.122**	-0.023**	0.273**	0.117**	-0.027**	0.282**
	(0.005)	(0.006)	(0.008)	(0.005)	(0.006)	(0.009)
fixed effects	yes	yes	yes	yes	yes	yes
cities	218	39	179	219	39	180
years	2000-2012	2000-2012	2000-2012	2000-2012	2000-2012	2000-2012
N	2800	503	2297	2843	505	2338

Notes: * (**, ***): significance at the 10% (5%, 1%) level. Standard errors are reported in parentheses. Dependent variable is *lnrgdp*. Column 1 and 4 are taken from table 3.5 (columns 2 and 5).

Clearly, there are remarkable differences between the two sets of estimates. The estimated coefficients on transportation modes are 2-4 times larger in core cities than in peripheral ones, which shows strong evidence that the core cities benefit a lot more from improved transportation than the periphery, consistent with the theory. We also find much larger output share for labour in core cities, indicative of better human capital. The effect of urbanization rate is very different: it has a small and negative impact on economic growth in the core, but a large and positive effect in the periphery. Overall, the estimates from the subsample of peripheral cities are similar in size to those of the full sample.

We also present the short-run dynamics of model 2 for the core and peripheral cities in Tables 3.8 and 3.9, respectively.

Table 3.8. VECM estimates for core cities

	$\Delta lnrgdp_t$	Δlnk_t	Δlnl_t	$\Delta lnhwy\_density_t$	$\Delta lnrp_t$	$\Delta lnaprpop_t$	Δur_t
$\Delta lnrgdp_{t-1}$	0.308**	0.003	0.253*	0.368**	0.329	-0.330*	-0.398**
	(0.047)	(0.055)	(0.149)	(0.169)	(0.275)	(0.193)	(0.166)
Δlnk_{t-1}	0.106**	0.782**	-0.076	0.181**	0.021	0.152	-0.035
	(0.025)	(0.029)	(0.078)	(0.089)	(0.145)	(0.102)	(0.088)
Δlnl_{t-1}	-0.010	-0.010	-0.470**	-0.010	0.023	-0.020	-0.008
	(0.013)	(0.015)	(0.041)	(0.046)	(0.075)	(0.053)	(0.045)
$\Delta lnhwy\_density_{t-1}$	-0.005	-0.056**	-0.037	-0.229**	-0.037	-0.086	0.002
	(0.011)	(0.013)	(0.036)	(0.041)	(0.066)	(0.046)	(0.040)
$\Delta lnrp_{t-1}$	-0.014*	-0.012	-0.010	-0.030	-0.412**	-0.022	0.026
	(0.007)	(0.008)	(0.023)	(0.026)	(0.042)	(0.029)	(0.025)
$\Delta lnaprpop_{t-1}$	0.026**	0.040**	-0.037	0.045	-0.059	-0.190**	0.053
	(0.011)	(0.013)	(0.036)	(0.041)	(0.066)	(0.046)	(0.040)
Δur_{t-1}	0.008	0.021	0.033	0.020	-0.087	-0.060	-0.502**
	(0.014)	(0.016)	(0.043)	(0.049)	(0.079)	(0.056)	(0.048)
ec_{t-1}	-0.001	0.033	-0.279**	-0.113*	-0.411**	-0.300**	-0.025
	(0.017)	(0.020)	(0.054)	(0.061)	(0.099)	(0.069)	(0.060)

Notes: * (**, ***): significance at the 10% (5%, 1%) level. Standard errors are reported in parentheses. ec_t is computed by equation (3.9), using the parameter estimates in column 2 of Table 3.7.

Table 3.9. VECM estimates for peripheral cities

	$\Delta lnrgdp_t$	Δlnk_t	Δlnl_t	$\Delta lnhwy\_density_t$	$\Delta lnrp_t$	$\Delta lnaprpop_t$	Δur_t
$\Delta lnrgdp_{t-1}$	0.158**	0.047**	0.073**	0.038	0.274**	-0.096	0.025
	(0.019)	(0.019)	(0.036)	(0.087)	(0.108)	(0.076)	(0.019)
Δlnk_{t-1}	0.207**	0.688**	-0.000	0.163**	0.097	0.086	-0.045**
	(0.015)	(0.015)	(0.028)	(0.066)	(0.082)	(0.058)	(0.014)
Δlnl_{t-1}	0.004	-0.007	-0.472**	-0.009	-0.008	0.027	-0.005
	(0.010)	(0.010)	(0.019)	(0.046)	(0.057)	(0.040)	(0.010)
$\Delta lnhwy\_density_{t-1}$	0.005	-0.003	-0.001	-0.211**	0.015	-0.010	-0.003
	(0.004)	(0.004)	(0.008)	(0.019)	(0.024)	(0.017)	(0.004)
$\Delta lnrp_{t-1}$	-0.001	-0.000	-0.004	-0.005	-0.129**	-0.004	-0.003
	(0.003)	(0.004)	(0.007)	(0.016)	(0.020)	(0.014)	(0.003)
$\Delta lnaprpop_{t-1}$	0.007	0.014**	-0.006	0.003	0.007	-0.202**	0.002
	(0.005)	(0.005)	(0.010)	(0.025)	(0.030)	(0.021)	(0.005)
Δur_{t-1}	-0.012	-0.000	-0.000	-0.029	0.108	0.072	-0.408**
	(0.023)	(0.023)	(0.043)	(0.103)	(0.128)	(0.090)	(0.022)
ec_{t-1}	0.082**	0.000	-0.066**	-0.219**	-0.187**	-0.013	-0.052**
	(0.011)	(0.011)	(0.021)	(0.051)	(0.063)	(0.045)	(0.011)

Notes: * (**, ***): significance at the 10% (5%, 1%) level. Standard errors are reported in parentheses. ec_t is computed by equation (3), using the parameter estimates in column 3 of Table 3.7.

The two subsamples exhibit very different short-run dynamics. At the 5% significance level, we are able to identify a causal effect from intra-city transportation (*lnaprpop*) to economic growth (*lnrgdp*) among the core cities, consistent with our findings from the full sample. We also find a reverse causal effect from real GDP to highways (*lnhwy_density*), but that on railroads (*lnrp*) is insignificant. In the subsample of peripheral cities, the causal effects of all transportation modes on real GDP are found to be insignificant, but the feedback from real GDP to railroads is positive and significant. These results are summarized in Table 3.10 below.

Table 3.10. Summary of Granger-causality tests

causality	Full sample	core	periphery
highway → rGDP	no	no	No
railroad → rGDP	no	no	No
Intra-city transit → rGDP	yes	yes	No
rGDP → highway	no	Yes	No
rGDP → railroad	yes	no	Yes
rGDP → intra-city transit	no	no	No

Note: All tests are based on the 5% significance level.

In all cases, GDP does not benefit from inter-city transportation infrastructures in the short run. This finding casts doubt on China's current investment strategy. Intra-city transit facilities have a limited causal effect on GDP, at least in the core cities. The reverse causal effect is found to be significant for highways (core cities) or railroads (full sample and peripheral cities), but never for intra-city transit. Overall, we find evidence of asymmetric bidirectional causal effects between transportation and economic growth in the short run.

3.4.4. Regional differences in the long-run effects of transportation

Next, we extend the framework to subsamples of three macro-economic regions of the nation (the east, west, and central China) and present the estimates in Table 3.11 based on model 2.[26]

[26] The division of the country into three regions is based on definitions provided by the NBS. East China includes Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong and Hainan. Central China consists of Heilongjiang, Jilin, Shanxi, Anhui, Jiangxi, Henan, Hubei and Hunan. West China comprises Inner Mongolia, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Tibet, Shan'xi, Gansu, Qinghai, Ningxia and Xinjiang.

Table 3.11. long-run relationship by region—the east, center and west

	sample			
	Full sample	east	center	west
lnk	0.501**	0.504**	0.508**	0.463**
	(0.001)	(0.002)	(0.002)	(0.002)
lnl	0.212**	0.440**	0.407**	0.126**
	(0.004)	(0.008)	(0.014)	(0.005)
lnhwy_density	0.062**	0.043**	0.033**	0.160**
	(0.002)	(0.003)	(0.003)	(0.004)
lnrp	0.064**	0.064**	0.028**	0.128**
	(0.001)	(0.002)	(0.002)	(0.003)
lnaprpop	0.018**	0.014**	-0.029**	0.096**
	(0.002)	(0.002)	(0.003)	(0.003)
ur	0.122**	0.121**	0.296**	0.011
	(0.005)	(0.007)	(0.010)	(0.008)
fixed effects	yes	yes	yes	yes
cities	218	81	92	45
years	2000-2012	2000-2012	2000-2012	2000-2012
N	2800	1044	1184	572

Notes: * (**, ***): significance at the 10% (5%, 1%) level. Standard errors are reported in parentheses. Dependent variable is *lnrgdp*. Column 1 is taken from table 3.5 (columns 2).

Table 3.11 shows that in the eastern region, the economic impact of railroad investment is the largest (6.4%), followed by highways (4.3%), and intra-city transit (1.4%). The ranking of the three transport modes is different in the western region where the contribution of highways is the highest (16%) followed by railroads (12.8%) and intra-city transit (9.6%). In central China, the contribution of highways tops (3.3%) followed by railroads (2.8%). Surprisingly, intra-city transit is found to be negatively correlated to real GDP. Across the nation, the impacts of transportation on economic growth are found to be highest in the west, where the parameter estimates are 2-6 times higher than in the rest of the nation. This observation may indicate insufficient transportation infrastructure in the west. Even though cities in eastern China on average have better transportation infrastructures than those in central China[27], the contributions of transportation are still higher in the east. This phenomenon may be explained by the fact that proportionally more of the core cities are found in the east[28], which benefits more from inter-city transportation infrastructure than the peripheral ones.

[27] Summary statistics show that the sample average of highway density (*hwy_density*) is 0.81 km^{-1} in the east and 0.70 km^{-1} in central China. Similarly, the average passenger traffic volume by railroads (*rp*) is 7.65 million persons in the east and 5.31 million persons in central China, while those of intra-city public transit (*aprpop*) are 3.89 m^2 per person (east) and 2.21 m^2 per person (central), respectively.

[28] Out of the 39 core cities identified in the full sample, 23 are located in the east, 10 in central China, and 6 in the west.

3.5. Concluding remarks

Transportation infrastructure affects the economic growth in several ways. Researchers find evidence that it has positive impact on economic growth, productivity and leads to efficiency and urbanization. In this chapter, we analyse the role of transportation infrastructure in China's economic growth at the city level, using a panel dataset comprising 219 cities for the period 1999-2012. We look into two types of heterogeneity, one by different types of infrastructure, the other by different types of cities.

We consider three types of transportation infrastructure: highway density and passenger traffic volume by railroad are used to measure inter-city infrastructure while per capita area of urban paved roads is used to represent intra-city infrastructure. The panel unit root tests and panel cointegration tests suggest a long-run relationship among the variables of interest. To entangle the causal relationships in the cointegrated system, we conduct the analyses within different timeframes. The long-run relationship is identified by FMOLS regression that accounts for simultaneity and cross-sectional heterogeneity. We use the VEC model to study the short-run causal effects between transportation and economic growth. In the long-run, we find that both inter- and intra-city infrastructure have significant positive effects on the growth of cities which is aligned to our expectations. Different types of infrastructure, however, contribute to economic growth in different ways. Nationwide, the estimated contribution rates for highways and railroads are roughly 6% compared with intra-city transit at 2%.

We also look into the effects of transportation on GDP among the core cities and the peripheral cities. The estimates clearly show that in the long run, the former benefit far more from the infrastructure than the latter from all transportation modes. The evidence thus supports the NEG hypothesis that the core-periphery disparity exacerbates as inter-regional transportation costs decrease.

Although all types of transportation infrastructure contribute to economic growth significantly in the long term, our short-run analysis with the error correction model yields mixed results. Nationwide, only intra-city transit Granger-causes GDP in the short run. The same is true for the core cities. We find reverse causal effects from GDP to railroads or highways, depending on the sample being used.

Finally, we look into the regional differences in the relationship between transportation and economic growth. The impact of transport infrastructure on economic growth is most pronounced in the west but less in central China. This suggests that coordinated investment in transportation infrastructure led by the government provides a partial solution to the economic prosperity of the most backward region in China, an argument made by Rosenstain-Rodan (1943). In comparison, with a higher level of agglomeration, eastern China benefits strongly from concentration of economic activities and infrastructure investments even though such infrastructure is abundant.

From the policy aspect, it may be advisable for the Chinese government to reconsider her investment strategy on transportation infrastructure. Cities seem to benefit from intra-city transit in the short run, but most of the long-term benefits are brought by inter-city transportation facilities. The government may prioritize different infrastructure depending on the timeframe of targets. Another tradeoff between the long run and the short run is in the western region, where transportation infrastructure is most productive in the long run but barely so in the short run. Finally, infrastructural investments are most productive in core cities at the expenses of peripheral cities. This raises the challenge for the government to strike a balance between regional inequality and efficiency.

3.6. Appendix

Table 3.A. Literature related to transportation infrastructure

Study subject	Methodology and data	Conclusion
Agbelie (2014). Investigated relationship between transportation infrastructure expenditure and its effect on GDP. Cross country (40 countries across the world).	Random-parameters model. Dependent variable: GDP Variable of interest: Highway expenditures; Rail expenditures; highway density, railway density Other control variables: Employment, FDI, Industry in GDP, Service in GDP	Highway and railway infrastructure expenditures and densities have positive impact on GDP. The magnitude, influence and resulting impact on GDP varies significantly across countries. Highway infrastructure expenditures have higher impact on GDP relative to railway infrastructure expenditure.
Del Bo and Florio (2012). Examines the return to infrastructure in EU regions in a spatial framework. Data from 262 European NUTS2 regions in 2007.	Log-linear with fixed effects. Dependent variable: GDP in purchasing power Variables of interest: Infrastructure endowment Other control variables: Physical capital, labour force and human capital	Investment in information and communication technology, overall accessibility, quality and quantity of transport infrastructure has a significant and positive impact on GDP.
Boarnet (1996). Examines how road and highway investments redistribute economic activity by dividing the economic impacts of transportation infrastrucure into a direct and an indirect effect. Data on California counties from 1969 to 1988.	Fixed effects. Dependent variable: log (country output) Variables of interest: Street and highway capital stock in the county, street and highway capital stock in other counties Other control variables: Country employment, private capital stock in the county	Street and highway capital is productive for counties. Results also show that ground transportation has partially opposing direct and indirect effects.
Demurger (2001). Links between infrastructure investment and economic growth. Sample of 24 Chinese provinces (excluding municpalities) from 1985 to 1998.	Random effects, fixed effects and two-stage least-squares (2SLS). Dependent variable: Average annual growth rate of real GDP per capita Variables of interest: Geographical constraints and infrastructure endowments Other control variables: Level of real GDP per capita, matrix of variables to account for differences in reform implementation and economic structure, province and time-specific parameters	Transport facilities are a key differentiating factor in explaining the growth gap and point to the role of telecommunication in reducing the burden of isolation.
Fernald (1999). Correlation between public capital and productivity by focusing on roads, the largest component of public capital. Data on inputs and outputs for 29 sectors of the U.S economy for the years 1953- 1989.	Seemingly unrelated regressions (SUR). Dependent variable: Value-added productivity growth Variables of interest: Sectorial vehicle intensity, growth in roads Other control variables: Gross output, capital, labour, materials	Finds that when growth in roads (largest component of infrastructure) changes, productivity growth changes disproportionately in U.S. industries with more vehicles. Industry data from 1953 to 1989 strongly support the view that vehicle-intensive industries benefitted disproportionately from road-building.
Melo et al. (2013). Meta-analysis of existing empirical evidence on the output elasticity of transport infrastructure.	Pooled OLS and a maximum-likelihood random-effects estimator. Dependent variable: Output elasticity of transport	Results indicate that the existing estimates of the productivity effect of transport infrastructure can vary across main industry groups, tend to be higher for the US economy than for European countries and are

Sample of 563 estimates (of output elasticity of transport infrastructure) obtained from 33 studies.		higher for roads compared to other modes of transport.
Yu et al. (2013). Examines the possibility of spatial spillover effects of transport infrastructure in Chinese regions. Data from a panel of 29 Chinese provinces for the period 1978 - 2009 for which data is available on real GDP, private sector investment, employed population (labour input), transport infrastructure investment and public investment.	Spatial Durbin Model. Dependent variable: Real GDP Variables of interest: Transport infrastructure capital stock. Other control variables: Labour input, private sector capital stock, public capital stock (except for transport capital stock)	Results indicate that positive spillovers exist in each period due to the connectivity characteristic of transport infrastructure at the national level. At regional level, transport infrastructure spillover effects vary considerably over time among China's four macro-regions.

Chapter 4: High-speed rail and the new economic geography—Evidence from Chinese cities

4.1. Introduction

Progress in traffic and transportation technology has important consequences for urban development. A recently growing body of literature has analysed the effects of railroad construction on a range of outcomes, addressing the consequences of establishing HSR systems for a number of Western and advanced economies. Research analysing aspects of population growth, employment, housing price convergence and related industries has usually found evidence of large gains from reducing transport costs and increasing mobility because of HSR network expansion (Haynes, 1997; Pol, 2003; Preston and Wall, 2008; Willigers and Wee, 2011).

The outstanding performance of China's HSR after 2008 has led numerous studies to analyse the HSR's effect on China's economy and society (Wang and Lin, 2011, Chen and Meng, 2013). However, these were predominantly descriptive discussions, were based on expectations regarding other countries' experience in HSR development, or were case studies from a microscopic view. There has been a lack of macro-quantitative research. In recent years, some empirical studies analysing the Chinese HSR have begun to appear. For instance, Zheng and Kahn (2013) used city-level data during the period 2006 to 2010 to document that bullet trains help stimulate the growth of second- and third-tier cities. Through facilitating market integration, they found that high-speed trains were associated with increasing real estate prices in the nearby secondary cities. However, few studies have analysed the effect of HSR on distributing economic activities under the framework of the geographical economic model. Further, little attention has been devoted to the policy implications that arise from geographical economics, particularly in China.

This chapter first provides a detailed overview of the development of China's HSR system in the period 2008 to 2014, and then sheds light on the effect of HSR on the spatial distribution of regional economic activity in China. In particular, it assesses the possible consequences for China's internal economic geography to offer some useful and valuable policy implications to central planners. The analysis is firmly based on the NEG model, as it stresses the relationship between cities, rather than treating cities independently (Fujita and Mori, 2005). Three sectors—agriculture, manufacturing and housing—are considered in the NEG model, in accordance with Puga (1999) and Bosker et al. (2012). This study follows the work of Bosker et al. (2012) in considering the use of the NEG theoretical model to predict inter-regional labour mobility. Additionally, it closely aligns with Roberts et al. (2012) to evaluate the expansion of China's transportation infrastructure to economic agglomeration by adopting a counterfactual approach.

The full NEG model can be simulated by allowing a relaxation of China's Hukou system, making us predict the consequences of improving transportation condition. To simulate the consequences of reducing transport cost to migration dynamics, the key structural NEG model parameters should be estimated first. To do this, we estimate wage equation followed by Au and Henderson (2006), Bosker et al. (2010, 2012), Hering and Poncet (2010a, 2010b), Moreno-Monroy (2011) and Roberts et al. (2012) as well as migration equation followed by Poncet (2006) and Bosker et al. (2012).

The empirical strategy consisted of three steps. The first step estimated the equilibrium wage equation, which is central to the NEG model. By using a dataset of 234 prefecture cities from 2004 to 2014 in China, we found that transport cost was negatively associated with wages, while the increase of market access simulated the rise in wages. The second step estimated the migration dynamics using 2010 population census data. The regression results indicated that the higher wages and lower migration costs stimulated labour mobility. In the third step, the estimated key parameters from the wage and migration equations, together with additional information in other key parameters, were used to carry forwards some counterfactual simulations.

This final step differentiates our study from other related geographical economic studies for China. In this step, we aimed to answer one significant question: what will happen to China's economic activities and internal economic geography when transportation is improved? We dealt with this question based on two specific questions: (i) What would have happened if there was no HSR? (ii) What happens if all HSR will be active? By combining the estimates of these key structural parameters in Steps 1 and 2, we simulated the consequences of improving transportation.

We found that most of China's economic activities tend to occur in the eastern regions of China, especially the relatively developed regions. Additionally, with consideration of the housing sector, the four highest-population cities—Shanghai, Hangzhou, Suzhou and Chongqing—demonstrate a trend of agglomeration. Following the introduction of the HSR, the degree of labour mobility significantly increased; thus, the inflow of labour mobility also increased, which illustrates an enhancement of the core–periphery pattern in China.

The remainder of this chapter is structured as follows. Section 4.2 discusses the concept of China's HSR, the background of the HSR network expansion, and related studies on transportation and NEG model consisting of both western and eastern. The theoretical model is introduced in Section 4.3, while Section 4.4 describes the data and variables used for the empirical analysis. The estimated parameters of the wage equation are demonstrated in Section 4.5, while Section 4.6 estimates the migration equation. The estimates from Sections 4.5 and 4.6 are used in Section 4.7 to predict the real wages and generate the counterfactual simulations. Finally, Section 4.8 concludes this chapter.

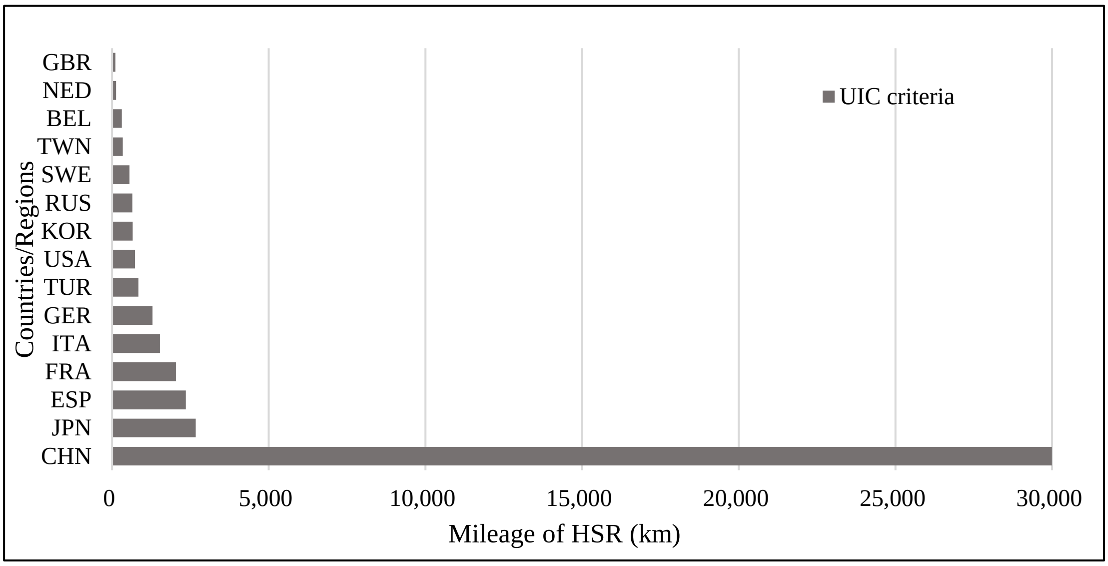
4.2. Chinese HSR and related studies

4.2.1. HSR development in China

HSR in China refers to all high-speed trains in China built for passenger-dedicated lines with commercial use at a speed of 250 km/h (160 mph) or higher. The network is built to Chinese HSR standards, and trains on the route are capable of running up to 350 km/h (217 mph) (National Railway Administration of the People's Republic of China, 2008). China's high-speed network has increased progressively over recent years. The first Chinese HSR was inaugurated in 2008 between Beijing and Tianjin. Afterwards, China planned to expand its HSR system into a network of eight east–west and eight north–south corridors to provide better transport services for 1.3 billion Chinese people and support the receding economy. Five hundred and thirty-seven HSR stations had been opened and operated by October 2016, which extended to 28 of China's 31 provinces. The nationwide HSR grid is already the world's largest, with 19,000 kilometres of track at the end of 2015, and a service exceeding 961 million passengers, seeing a sharp increase by 36.6% that accounted for 37.9% of the total passengers. In the years ahead, the envisioned HSR grid consisting of 16 corridors will be completed by 2030, as stated by Zhirong Fei, who is the head of the infrastructure department at the National Development and Reform Commission. When it is completed, the total operational mileage will accumulate to 45,000 kilometres and will connect all provincial capitals and cities with over 500,000 HSR services, which will represent more than double the current network (National Railway Administration of the People's Republic of China, 2016).

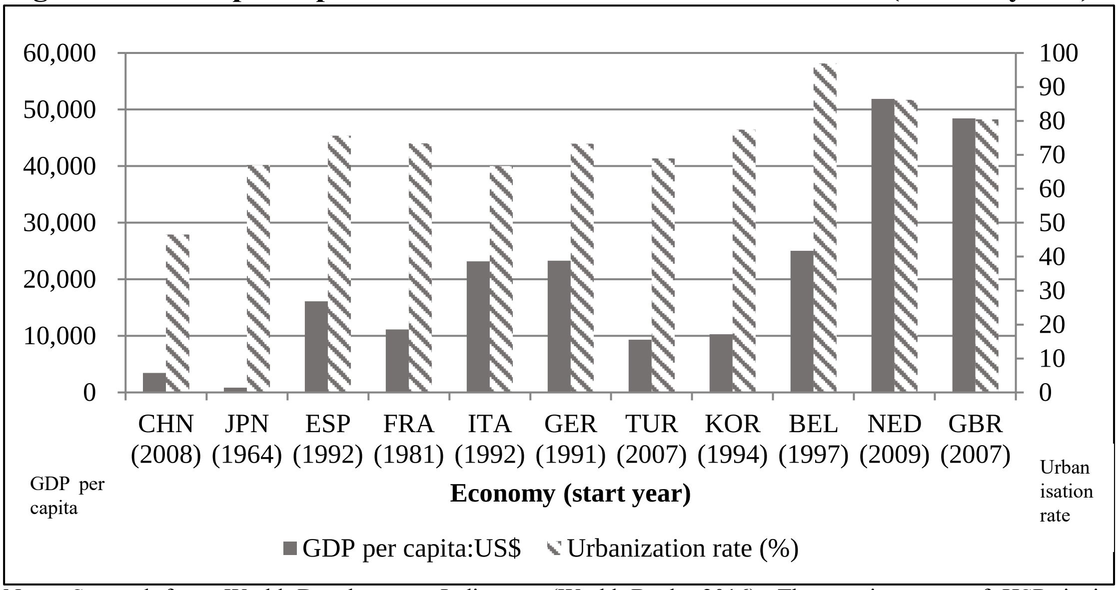
Fifteen countries and regions throughout the world had opened a HSR at the end of 2015, yet the operating length and background of HSR development in China has significant distinctions relative to the rest of the world. According to the international standards (on the basis of International Union of Railways [UIC]), the length of HSRs across 15 countries and regions at the end of 2015 is illustrated in Figure 4.1. China's HSR boom is like what John Scales said, who is the World Bank Beijing senior transport specialist. He described China's efforts to expand rail networks as unprecedented around the world: 'Historically, this is the only country that has ever attempted such an increase' (Railway technology, 2012).

Figure 4.1. Mileage of HSR across 15 countries/regions at the end of 2015



Note: The 15 countries presented in the figure from top to bottom are the United Kingdom, the Netherlands, Belgium, Taiwan, Sweden, Russia, Korea, the US, Turkey, Germany, Italy, France, Spain, Japan and China. Sourced from the National Railway Administration of the People's Republic of China and International Union of Railways (2016).[29]

Figure 4.2. GDP per capita and urbanisation rate in 11 countries (various years)



Note: Sourced from World Development Indicators (World Bank, 2016). The starting year of HSR is in parentheses. Left axis is per capita GDP, while the right axis is the urbanisation rate.

[29] (1). After 2013, China has no HSR statistics of international standards, yet they can be calculated according to the following. First, under the framework of conformity between China's standard and the UIC standard in 2011, China's HSR mileage is 9,790 km, as announced by the UIC, yet it reduced to only 5,133 km after the implementation of China's new revised standards, followed by 'Twelve-Five'. Second, after 2012, China implemented a batch of new southeast lines into operation, such as Chang Fu, Han Yi, Yu-Li and Heng Liu, with designed speeds of up to 250 km/h. These encompass more than 4,000 km, but are used for passenger and freight trains to share, which does not align with China's new standard (National Railway Administration of the People's Republic of China, 2016).

(2). The total mileage of HSR across the world is 17,166 km, with the unified standards by the end of 2011 in which is 9,790 km, constituting about 57% of the total mileage. With the rapid expansion of China's HSR, the proportion of China's HSR in the world's total is further improved. According to UIC standards, at the end of 2015, China had moved up to 67.85% of the world's total HSR mileage (National Railway Administration of the People's Republic of China, 2016).

Figure 4.2 describes GDP per capita and the rate of urbanisation for a sample of 11 countries when the first HSR line opened. This figure clearly illustrates that China's HSR was constructed during a period of rapid economic growth, yet has remained at a fairly low level, compared with the other 10 countries. For instance, the 2008 GDP per capita in China was only US$3,441.22, which remains a sizeable gap (three to seven times) with other countries in the 1990s, let alone compared with that of other countries (Netherlands and United Kingdom) around the same period.[30] This implies great potential for China's HSR passenger volume growth in the future, and demonstrates the important role of HSR in China's future economic activities. Additionally, the rate of urbanisation in China stood at 46.54% in 2008, lagging far behind the levels of other countries in the range of 66.74 to 96.92%. Thus, Chinese cities are not only faced with the rapid development of external space, but also with the conformity of internal space (World Bank, 2016).

In addition, regarding the speed of HSR construction and build-up time of its HSR network, there is a significant difference between China and the other countries. For instance, Japan, France and Germany started their second line construction after seven to eight years of operating their first line. In contrast, China started large-scale HSR construction in the fifth year after completing the first line. Therefore, this may lead to different processes and mechanisms of urban development (National Railway Administration of the People's Republic of China, 2016; International Union of Railways, 2016).

4.2.2. Related studies

The contributions of transportation infrastructure have long been theorised by economists. Several pieces of research with Western contexts have found a strong positive effect of transport construction on economic growth and productivity at the aggregate level (Boarnet, 1996; Del Bo and Florio, 2012; Melo et al., 2013; Agbelie,

[30] The HSR construction in Japan was too early, so it was not included in the comparison.

2014). The experience of other non-Western nations has also illustrated such a relationship (Kustepeli et al., 2012; Yu et al., 2013; Hornung, 2015).

High-speed trains, as one of the most important technological innovations in transportation improvements, have been discussed both theoretically and practically in recent years. For instance, Desmaris and Bouf (2015) used OLS to estimate the possible effect of HSR on French regions with regard to spatial equity. Their results illustrated a positive correlation with GDP per capita and demographic growth. Beyond that, they found that high-speed lines resulted in a peculiar and singularly unfair pricing system on the basis of intermodal competition and yield management. In addition, Albalate and Bel (2012) highlighted valuable lessons from five cases (Japan, France, Germany, Spain and Italy) that must be considered by policymakers, planners and transportation managers when building and operating HSR networks to solve traffic congestion and improve the environment. They concluded that economic activities might drain away and suffer a negative effect because of limited gains for the largest cities in the network, although this is not the case for intermediate-sized cities. Focusing on the effects of HSR on land cover change in large urban areas, Yu et al. (2014) examined Madrid's Atocha railway station influence area and proposed an accessibility-based spatial mixed logit model, with panel data from 1990 to 2006. The estimation results revealed that the improvement of regional accessibility positively affected the urbanisation of land cover changes in the Atocha station area.

In the context of China, Wang and Lin (2011) analysed the characteristics of HSR and summarised that HSR affects regional development from the perspective of spaces, cities and stations, and this effect is highly associated with the regional urbanisation level, as well as the characteristics and maturity of urban external passenger transport. Additionally, Chen and Meng (2013) reviewed both Chinese research and research from other countries by tracking the effect of HSR based on initial studies of its effect on the passenger transport market, and then examined the effect on the regional spatial structure and regional economic development.

The growing body of literature on the evaluation of HSR has thus far devoted much attention to the role of spatial effect, yet the majority of the studies were either descriptive papers or case studies. The existing empirical evidence on market access, core–periphery patterns, agglomeration and the diffusion of economic activity is still limited. Thus, the main contribution to the literature of this chapter is to use the NEG model and counterfactual simulations to examine the influence of improving transportation infrastructure and to understand the economic effects of government policy, which are not neutral across space.

The emerging geographical economics theories (Krugman 1991a, 1992, 1993; Krugman and Venables, 1995; Fujita and Mori, 2005; Behrens and Thisse, 2007) provide deeper insights into the role of transport costs in affecting local economic activities. Puga (1999) emphasised that declining transport costs alter the strength of dispersion and agglomeration forces of economic activities within the NEG model. In other words, regional disparities are initially enhanced, and an agglomeration of activity increases before the final convergence is induced. Further, dispersion of activity arises if congestion costs exceed transport cost savings. The heterogeneity of cities explained by the geographical economics was also confirmed by Brakman et al. (2009), who contended that the improvement of transport facilities and the reduction of transport costs within a certain range enable the core cities to increase economic size and manufacturing share, at the expense of the less industrialised periphery.

However, some contradictory evidence has been found in other empirical research. For example, Leck et al. (2008) used data extracted from the 1995 Israel census and concluded that the newly introduced rail links played an important role in enhancing the welfare of underdeveloped cities. Further, a new database of county-level transport costs was used to capture the changes in counties' market access in the American economy (Donaldson and Hornbeck, 2016). Donaldson and Hornbeck (2016) studied the effect of railroad network expansion in the agricultural sector from 1870 to 1890, and found that the values of county agricultural land were positively associated with county market access, thereby stimulating population levels and consumer welfares.

Research on the spatial patterns of transportation infrastructure and the existence and magnitude of regional interdependencies in the context of China is relatively rare and still produces mixed results. Li and Ni (2013) found that reduced transport costs significantly stimulated the faster growth of core cities by factor agglomeration. However, a few counter-arguments states that the presence of transportation infrastructure offers advantages to less-developed areas and periphery cities. For instance, Lao et al. (2016) found that improvement of air transportation enabled central and western China to attain faster economic growth, rather than the eastern region.

Studies that use counterfactual simulations to investigate the effect of improving transportation were suggested by Donaldson and Hornbeck (2016) and Roberts et al. (2012). The former evaluated how railroads affect the American economy using data from 1870 and 1890. Through calculation of market access if railroads were eliminated or replaced with waterways, they found that railroads played a vital role in increasing market access and market integration to promote economic development. Counterfactual scenarios were also adopted by Roberts et al. (2012), who simulated the effect of the construction of China's expressway network, using 2007 as the benchmark year. By analysing the pattern of regional inequality, they found that the expansion of the expressway was conducive to China's economic development, as reflected by a rise in real income. However, the extension of the expressway grid seemingly enhanced the spatial inequality across prefectures.

4.3. The geographical economics model and its policy implications

4.3.1. The NEG model

A flexible New Economic Geography model is used to investigate the equilibrium spatial distribution of both people and economic activity under different inter-regional labor mobility regimes. Different from most other research (Bosker and Garretsen, 2010, Krugman, 1991a; Krugman and Venables, 1995; Puga, 1999), which only included the two sectors of agriculture and manufacturing, the sharp increase in China's living costs—mainly driven by the house prices of the top cities—led us to consider housing as an additional spreading force in our theoretical model (Hanson, 2005; Bosker et al., 2012). Given that the prediction of models with only two sectors (agriculture and manufacturing) can more easily lead to an unrealistic scenario of full agglomeration with perfect inter-regional labour mobility, we included the housing sector to be closer to reality.

The model assumes that the economy consists of R ($i = 1, \ldots, R$) regions and that each region has three sectors: agriculture (A), manufacturing (M) and housing (H). L_i workers populate region i, and each region is endowed with K_i units of arable land and a stock of non-tradable housing, H_i. Arable land is used only by agriculture and is immobile between regions. Labour is used both by agricultural and manufacturing sectors, with perfect mobility between these two sectors within each region and between regions. Farmers produce a homogeneous agricultural good using arable land under constant returns to scale and perfect competition. It is described by a Cobb-Douglas production function, where θ denotes the share of labour in agricultural function. The assumption of a free trade-off of agricultural goods between regions implies that there is no transport cost for agricultural goods. Thus, the price of agricultural goods is the same in each region and is set as the numeraire. In this sense, any mobility of labourers from agriculture to manufacturing indicates obtainment of a higher wage. The fixed stock of land, K_i, together with the fixed housing stock, H_i, are regarded as the spreading forces to capture the congestion costs related to larger agglomerations.

Manufacturing firms produce differentiated products—that is, each industry produces a unique variety of manufacturers, which implies that the firms are characterised by internal economies of scale and have monopolistic power. Shipments of the manufactural variety to all regions, including to foreign markets, are where 'iceberg' transport costs (τ) occur. Iceberg transport costs in geographical economics imply that a fraction of the units does not arrive at the destination when goods are shipped between regions. That is, to ensure that one unit from region i will be delivered to region j, at least τ_{ij} (> 1) units need to be shipped. One notable point here is that transport costs can be interpreted as many measures consisting of not only distance costs, time costs and freight costs, but also tariff barriers, information costs and legal and regulatory costs (Bosker and Garretsen, 2010; Puga, 1999). In our case, the measurement of transport costs was associated with HSR, which made time the best way to represent it. According to Venables (1996) and Puga (1999), the producer demand for manufacturing is a Cobb-Douglas composite of labour and an intermediate aggregate with $0 \ll \mu \ll 1$ the share of intermediates, followed by a constant elasticity of substitution (CES) across varieties (i.e., $\sigma > 1$). As in Bosker et al. (2012), relative higher wages offered by some regions is a result of the differential of production efficiency (c_i) across different regions, and these differences arise from factors such as economic structures and human capital. Meanwhile, a similar production efficiency of industries is assumed within the same region.

Turning to the demand side, Cobb-Douglas preferences are owned by consumers over agricultural goods, housing and a CES aggregate of manufacturing goods with the Cobb-Douglas share of each good (where $0 < \gamma_z < 1$; $z = A, H, M; \gamma_A + \gamma_H + \gamma_M = 1$). For simplicity, it is assumed that all varieties enter both consumers' utility and production with the same CES (σ). Maximisation of profit and utility combined with equilibrium prices and equilibrium demand gives the equilibrium wage of the composite factor of immobile production. The wage differential is the motivation of the mobility of firms and people, and firms' and people's corresponding equilibrium distributions depend on the assumption of no labour mobility between regions (Puga, 1999). Based on Bosker et al. (2012), four equilibrium conditions are given in each region, i, if there is no inter-regional labour mobility—namely, Equation (4.1) for the manufacturing price index, q_i; Equation (4.2) for nominal wages, w_i; Equation (4.3) for total manufacturers' expenditures, e_i; and Equation (4.4) for housing price, p_{Hi}:

$$q_i = (\frac{1}{1-\mu}\sum_j(\xi_j L_j q_j^{-\mu\sigma} c_j^{-\sigma} w_j^{1-\sigma(1-\mu)} \tau_{ij}^{1-\sigma}))^{1/(1-\sigma)} \tag{4.1}$$

$$w_i = q_i^{\mu/(\mu-1)} c_i^{1/(\mu-1)} \left(\sum_j e_j q_j^{\sigma-1} \tau_{ij}^{1-\sigma}\right)^{1/(\sigma(1-\mu))} \tag{4.2}$$

$$e_i = \gamma_M(w_i L_i + K_i r(w_i)) + \mu/(1-\mu) w_i \xi_i L_i \tag{4.3}$$

$$H_i P_{Hi} = \gamma_H Y_i \qquad (4.4)$$

The equilibrium price index of the manufacturing varieties in city i (q_i) is given by Equation (4.1), where μ is the share of Chinese intermediate inputs in Chinese manufacturing production; σ is the elasticity of substitution between manufacturing varieties; ξ_i denotes the share of manufactural labour force in city i, illustrating that the lower transport costs, the smaller the price index of industrial goods; L_j is the labour force in city j; q_j is city j's manufacturing price index; c_j is city j's production efficiency; w_j is the nominal wages in city j; and τ_{ij} is the transport costs from city i to j. The nominal wage in Equation (4.2) is derived from the market equilibrium conditions of the equivalence of supply and demand (markets clear), where e_j is city j's income. Intuitively, firms located close to large markets can offer higher wages and perceive less competition. If we let e_i in Equation (4.3) denote expenditure on manufacturers in region i, this implies that expenditures mainly depend on wage income and landowner rents, where $r(w_i)$ represents the rent earned per unit of land in region i. Equation (4.4) gives the equilibrium condition on the non-tradable services sector, signifying that the rise in house prices results in more income $\gamma_H Y_i$ spent on houses, given fixed housing stock (H_i). Note that the effect of housing price on labourers' location decisions arises only if labourers are allowed to move freely between regions. Thus, if perfect inter-regional labour mobility is allowed, equilibrium conditions should consider real wage, since mobile workers can react to differences in the real wage between regions. Therefore, the equilibrium considering real wage equalisation is given by:

$$\omega_i = q_i^{-\gamma_M} p_{Hi}^{-\gamma_H} w_i = \omega \qquad (4.5)$$

Equation (4.5) indicates that real wages (ω_i) depend on both the price index of manufacturers, q_i, and housing prices, P_{Hi}. With a fixed supply of non-tradable housing, housing prices are relatively higher in large agglomerations because of the larger demand for housing. In turn, regions with higher housing prices become less attractive to people, making them seek higher real wages elsewhere. This explains why the housing sector serves as a spreading force. Given that labourers can move between regions, they will move towards regions with higher real wages. The results of this type of movement are unclear, and we need to confirm whether spreading or agglomeration depends on some crucial model parameters, such as transport costs; the shares of agriculture, manufacturing and housing; and the initial allocation of region-specific land, labour and housing stock.

The construction and development of China's HSR system make labour mobility easier and seem to positively influence the region's market access, since the transport costs reduce with the expansion of the railroad network. However, it is not exactly clear whether an improved transportation network contributes to either the agglomeration effect or spreading effect. The rest of the study will concentrate on some counterfactual simulation exercises through estimating key relevant parameters in wage equation and migration equation to explore the effect of China's HSR system on economic activities.

4.3.2. Effect of rail connections in geographical economics—pancake economy

The construction of the HSR system across cities is like building a bridge over the sea, which can easily alter the spatial distribution of economic activities via distance and time reduction, as well as improved market access. It can be demonstrated as the racetrack economy proposed by Fujita et al. (1999), which refers to many locations in neutral space.[31] Suppose that the circle of the racetrack economy is adapted with 12 cities, which is flattened to the 'pancake' shape demonstrated in Figure 4.3. The farmers and manufacturing workers are uniformly distributed between the 12 cities as assumed. This symmetric structure implies that the initial distribution

[31] Neutrality of space means that the locations are evenly distributed in a circle in which transportation moves only along the rim of that circle—that is, 'neither location is preferred by construction over the other location, because the distances between the two locations are the same, and hence so are the transport costs' (Brakman, et al., 2009).

indicates a long-term 'flat earth' equilibrium and each city can host and produce one-twelfth of the economy's total.

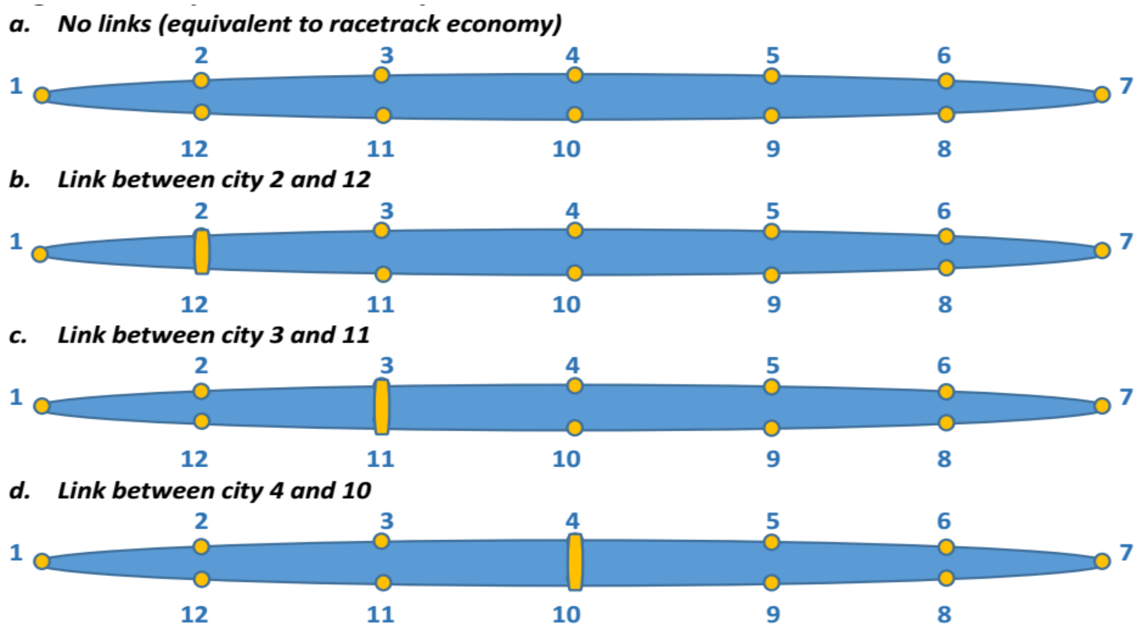
When an active policy intervention is introduced, such as a change of infrastructure and transport costs, the consequences of this flat earth equilibrium distribution might be changed, which implies that the spatial allocation of economic activity might be altered or the agglomeration might be affected. Brakman et al. (2009) provided a simple policy experiment dubbed 'building a bridge' in the multi-region congestion model. As the name suggests, 'building a bridge' can be interpreted as a direct connection between two cities, reducing the distance between them. This indicates that the space in the pancake economy is no longer neutral, which is in contrast to the racetrack economy.

When it comes to discussing the possible situations of building a vertical bridge, three cases are analysed as follows:

1) a bridge between Cities 2 and 12 (analytically equivalent to a bridge between Cities 6 and 8), as illustrated in Figure 4.3b
2) a bridge between Cities 3 and 11 (analytically equivalent to a bridge between Cities 5 and 9), as illustrated in Figure 4.3c
3) a bridge between Cities 4 and 10, as illustrated in Figure 4.3d.

The distance between the linked cities is assumed to reduce one unit in all cases.

Figure 4.3. The pancake economy



Note: based on Brakman, Garretsen and Marrewijk (2009).

The infrastructure project means that cities not directly linked by the bridge may benefit in terms of reducing their distance to other cities, which improves market access, expands labour markets and reinforces spatial agglomeration. As documented in Figure 4.3, Cities 1 and 7 never benefit from any of the possible vertical bridges, while the others do benefit from the bridge building, either directly or indirectly. An example in Panel b is the distance reduction not only between Cities 2 and 12 themselves (which falls from 2→1→12 to 2→12), but also between Cities 2 and 12 and some other cities (e.g., distance between Cities 2 and 11, which falls from 2→1→12→11 to 2→12→11). As is intuitively evident, in comparison with bridge building in Panels b and c, the bridge between Cities 4 and 10 and the linked cities themselves leads to a larger reduction in average distance.

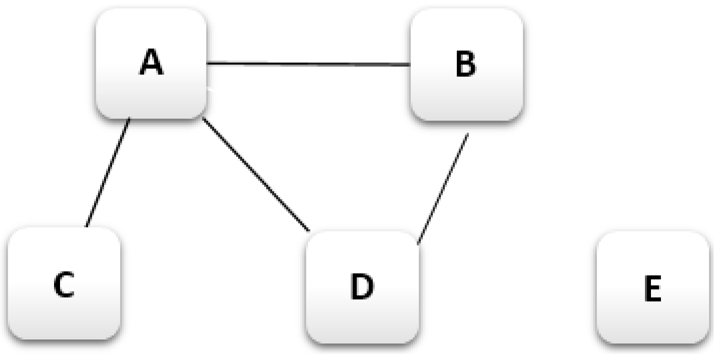
Therefore, building bridges largely affects the distribution of manufacturing activity in a pancake economy, and leads to alteration of the equilibrium spatial distribution and considerable agglomeration of economic activity. Starting from the absence of a bridge illustrated in Panel a, the flat earth equilibrium is stable for the base scenario parameter setting, which is against economic agglomeration. However, once the bridge has been introduced, its effect is remarkably high, and the rationale behind this is straightforward. It is assumed that manufacturing activity is evenly distributed. Given that the workers in the two cities at each end of the bridge are able to pay lower transport costs, this contributes to the highest real wage and thus attracts other manufacturing workers into the linked cities and expands the share of manufacturing production. It is important to note that the reduction of transport costs that results from building a bridge enhances the process of migration, yet also leads to more congestion and increases the attraction of demand in the more remote markets. These forces are balanced in the long-term equilibrium.

4.3.3. HSR network and transport costs in the NEG model

'Building bridges' in the pancake model, reflected in China's city transportation construction, is one of the most important aspects relevant to the development of HSR, as shown in Figure 4.4. Suppose that A, B, C, D and E are five cities and a black line implies a direct connection between two cities through HSR. We first analyse three possible situations of HSR connections:

1) direct HSR connection between two cities (A and B, A and C, A and D, and B and D)
2) indirect HSR connection between two cities (B and C via A, and C and D via A[32])
3) no HSR connection between two cities (E and any of A, B, C and D).

Figure 4.4. Example of HSR connections among cities



[32] C to D through A and B were not considered in our case because this would not occur in reality if C to D is available through A.

Based on this situation, particularly that of the third case (i.e., City E in Figure 4.4 has no HSR station, so it cannot connect with Cities A to D by HSR), we used the benchmark rail network (see Case A in Table 4.1) to estimate parameters on transport costs and market access, and then to conduct a counterfactual analysis for simulation. Specifically, **Case A** computed transport costs between Cities I and J starting from direct HSR connections. For those cities without direct HSR, information on the direct K-train was used to compute transport costs. We then considered indirect HSR connections and updated transport costs for cities without direct HSR if it was lower than that of the direct K-train. Finally, the rest of the cities that owned neither HSR (direct or indirect) nor direct K-trains were treated as indirect K-train and computed based on travel information of the direct K-train.

Case B (counterfactual) focused on the effect of the railway's network in the labour market, where all trains were K-type. Different from Case A, in Case B, all direct HSR connections were 'transformed' into direct K-trains. If there was no direct K-train connection, then indirect K-trains were taken into account. Finally, **Case C** (counterfactual) actually focused on the effect of developing a HSR system between two locations. For that reason, again, we began with direct HSR connections. For inter-cities without direct HSR, we first considered whether a new direct HSR would be built to replace the system of the direct K-train, and what kind of effect this would have. We then focused on indirect HSR—that is, if the inter-city could not be connected via indirect HSR, similarly, what consequences it could have once new connections were established to replace the indirect K-train connections. We first focused on Case A to predict real wages, and then moved onto the simulations that compared Cases B and C.

Table 4.1. Three cases of rail network for counterfactual analysis

Case A Benchmark network	**Case B—counterfactual** If all connections with K-trains	**Case C—counterfactual** If all connections with HSR trains
1. Direct HSR connections 2. Direct K-connections 3. Indirect HSR if transport cost lower than direct K-connections 4. Indirect K-connections	Assume direct HSR becomes direct K-trains (i.e., increase direct connections and frequencies accordingly)	Assume all direct K-trains become direct HSR (i.e., reduce travel time accordingly)

Note: Case A was used to estimate the wage equation to obtain parameters for simulation. Cases B and C aimed to conduct simulations based on the obtained parameters from Case A.

The measurement of transport costs is vital to perform counterfactual simulation exercises and investigate the effect of China's HSR system on economic development within the framework of a geographical economics model. Given the inability to directly measure transport costs, in contrast to most existing empirical NEG studies that only used distance or travel time to proxy trade costs (see Breinlich, 2006; Hanson, 2005; Hering and Poncet, 2010a, 2010b; Mion, 2004; Redding and Venables, 2004), we simultaneously applied the travel time and frequency of China's HSR and K-trains to represent transport costs in this study.

Two related questions arise with regard to the measurement of transport costs: Why should frequency be considered? Why is travel time preferred, rather than travel distance or ticket prices? One simple example can be used to explain the first question. The travel times from Beijing to Shanghai and from Beijing to Xi'an are approximately the same, while the former's frequencies are almost double that of the latter. If either travel time or frequency is the only factor in designing trade costs, then it probably includes bias. This gives strong evidence that it is necessary to consider the frequency of trains.

The reason that distance and ticket prices fail to measure transport costs is because of the different criteria for HSR and regular trains in China. Table 4.2 displays some rules and features to identify the different types of trains. It can be seen that ticket prices and distance, as transport costs, are not significant anymore when calculated in Case A. The distance is similar via comparing HSR with the K-train, and the monetary cost of the K-train is even smaller than that of HSR because of the relatively lower price of the K-train per kilometre. This again highlights the advantages of using travel time and frequency as trade costs.

Table 4.2. Criteria of HSR and K-train

Standard	Ticket price	Distance	Travel time
HSR	0.46 RMB/km	Similar to regular train	Speed of around 300 km/h
K-train	0.05861 RMB/km	Similar to HSR	Speed of around 120 km/h

Note: Price standard is based on economy class.

Specifically, we proxied transport costs by a simple power transport cost function, which was given by:

$$\tau_{ij} = \left(T_{ij} + 24/F_{ij}\right)^{\delta} \tag{4.6}$$

where T_{ij} represents the travel time from city i to city j; F_{ij} denotes frequencies between two cities (i.e., the number of trains per day from city i to city j); and δ is the decay parameter. Equation (4.6) characterises the travel conditions across regions, which indicates that the higher the cost of travel (travel time) between two cities, the lower the accessibility between them. In contrast, more frequencies imply fewer transport costs. Considering the differentials in the city's open date of HSR, the transport costs measured by HSR vary over time (s) and can be modified as follows:

$$\tau_{ij} = \left(T_{ijs} + 24/F_{ijs}\right)^{\delta} \tag{4.6a}$$

4.4. Data description

Based on China's current economic geography, China consists of four layers of regional divisions: provinces, prefecture-level cities, districts and counties, and townships. The construction of a railway system views the city as a carrier. We constructed a dataset covering 234 cities (of a total of 287 Chinese prefecture cities) in China from 2004 to 2014. The choice of number of cities was based on the status quo of China's railway construction. At the end of 2014, 234 Chinese cities had established regular trains, while HSR only existed in 153 cities. Direct regular trains between cities accounted for roughly one-third, and direct HSR accounted for a similar proportion. However, the HSR network was not fully contained by the normal speed network—12 of those 153 cities were outside the K-train network.

The prefecture city data were collected from various data sources for the estimation of wage equation. The China City Statistical Yearbook and NBS of China provide information on cities' incomes, real wages, expenditures, total employment, human capital, population density, population, and employment share in banking and finance. Baidu Baike was used to collect information on HSR stations in each prefecture city, including their opening date, to reflect changes in transport costs over time. Travel times and frequencies of HSR and regular trains between two cities were collected manually from the Railway Customer Service Centre of China (www.12306.cn).

Since China's migration flows were limited to provincial level data, we were only able to construct a migration dataset for 30 provinces to estimate migration equation. Migration flows at the provincial level were gathered from the 2010 Population Census. Provincial real average wage was computed by urban income taken from NBS. Unemployment rate at the provincial level were collected from NBS as well. GIS information of province shapefiles, latitudes and longitudes was constructed to compute the distance between provinces used in the migration estimation. In addition, dummy variables regarding whether the origin and destination regions shared a common border or were in the same province were created according to GIS information. Table 4.3 provides definitions and summary statistics of all the variables used.

Table 4.3. Description of variables

Variable name	Descriptions
Data to estimate wage equation:	
Nominal wages for city i (w_{it})	GDP per capita
City j's income (e_{it})	GDP for each city
Transport cost between city i and city j (τ_{ij})	Travel time in hours plus 24/frequency
City j's wage (W_{it})	GDP per capita
Average wage outside city j ($\overline{w}$)	GDP per capita
Share of employees in city j (λ_{it})	Level of employment in each city
Human capital for city i (X_{1it})	Student enrolment in secondary education/total population
Share of employment in banking and finance for city i (X_{2it})	Banking and finance employment/total employment
Population density for city i (X_{3it})	City population of person per km^2 (logs)
Data to estimate migration equation:	
Outflow migration from province i to j (mig_{ij})	Total number of people migrating from province i to j[33]
Province $j's$ real wage ($wage_i$)	Real average wage in destination province j
Province $j's$ unemployment rate ($unempl_ij$)	Registered unemployment rate in urban areas in province j
Distance between province i and j (d_{ij})	Distance between province i and j
Province i and j are neighbouring provinces (NB_{ij})	Dummy variable = 1 if i and j are neighbouring provinces
Province i and j are in the same province ($Intra_{ij}$)	Dummy variable = 1 if i and j are in the same province
Data in simulation (year 2010 as benchmark year):	
Number of houses in city i (H_i)	Share of urban population in city i multiplied by national housing stock
City i's income (Y_i)	GDP for each city
Labour force in city j (L_i)	Total employment of city j
Share of city j's labour force in manufacturing (ζ_i)	City j's employment in M/total labour force in M

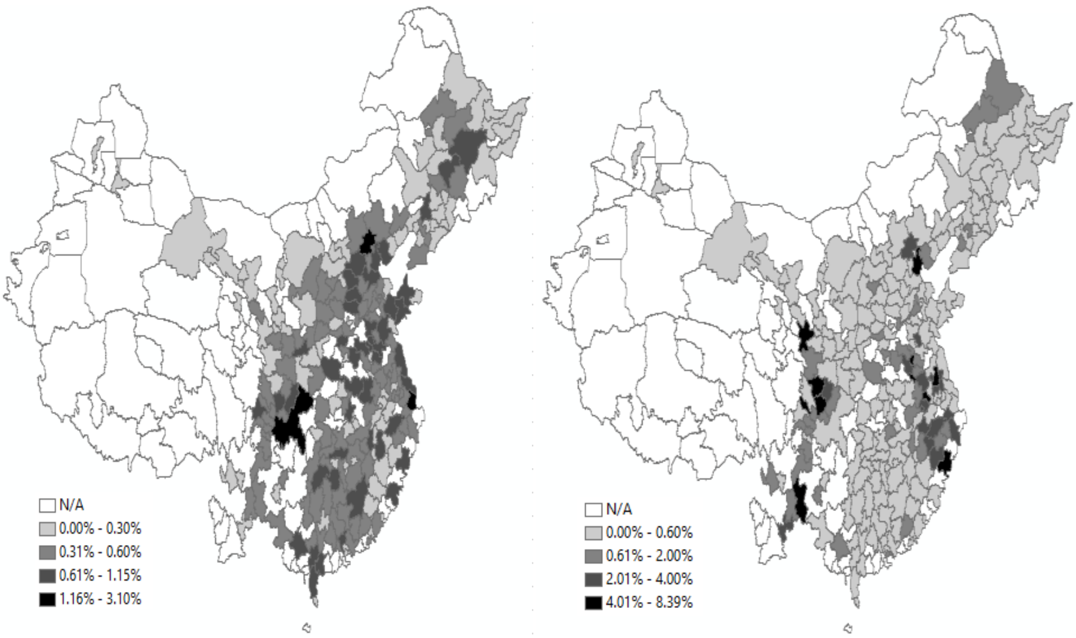
The first set of variables was used for the wage equation. The logarithm of prefecture city GDP per capita as the dependent variable was used instead of the average wage of workers or total wage of employees to measure wages to appropriately reflect wages in the private sector, following the work of Hering and Poncet (2010b). City income (GDP) was employed to proxy expenditure. The average wage was computed by all other city's per capita GDP and used to construct a price index to estimate the wage equation. A number of factors that could affect wage level were considered. We first used population density to control for the degree of interactions in the city. We argue that this density is positively related to the productivity level (Bosker et al., 2012). The population density was measured by the population number divided by city area per square kilometre. Second, we controlled for human capital through the ratio of residents in higher education divided by the total population, as a higher-educated labour force is probably more productive (Breinlich, 2006; Hering and Poncet, 2010b). Third, the possible relevance of the economic structure of the city was captured by using the share of banking and finance in total employment for each city. Finally, dummies of city and time were included to control some fixed determinants that are unobserved in a city's wage.

[33] Migration data were collected from the 2010 population census. Total numbers of people migrating were obtained from the population sampling from Long Table (9.5%), consisting of current residence, household registration and the places of household registration are other township, towns and street communities (person).

Table 4.3 also reports the variables used for migration estimation at the provincial level. The share of emigrants from province i to j were computed based on the outflow migration from i to j divided by the aggregated migration to province j. Following Poncet (2006) and Zhang and Zhao (2013), migration decisions are closely associated with expected real wages, the probability of employment in the destination and the costs of mobility. Therefore, the real income, unemployment rate, distance and dummy variables regarding whether cities were located in the same province or shared the same border were considered to explore their linkages with migration preferences. The fixed effect specific to the original province was included to increase the accuracy of the estimation.

In addition, in accordance with Equations (4.2) and (4.4) in the NEG model, several additional variables reported in the last part of Table 4.3 were used together for the simulation. These included the share of city i's urban population, national house stock, city i's income, share of city j's labour force in manufacturing and total labour force of city j.

Figure 4.5. Distribution of population and employment (2010) across cities



(a) Population share (b) Secondary industry employment shares

Source: NBS (2010) in Mainland China.

Figure 4.5 displays China's distributions of people and firms at the prefectural city level in 2010. Cities that are blank indicate missing data. The darker the cities, the higher the cities' distribution of people and firms. As indicated in Panel a, Chongqing had the largest population share, followed by two metropolises: Shanghai and Beijing. The east of China indicated the largest concentration of population. Cities in the central area of China, such as cities in Henan, Hunan and Anhui provinces, also held a large share of the population. In short, cities in the five provinces (Shandong, Henan, Hebei, Sichuan and Jiangsu) with the largest population shares accounted for around 34% of the total population, and the three largest population cities (Chongqing, Shanghai and Beijing) accounted for roughly 5.6% of the total population. This distribution was important in the long-term equilibrium analysis of simulation in Section 4.7. In contrast to the distribution in Panel a, Panel b demonstrates a more spatially concentrated pattern—specifically, cities in the five provinces with the largest secondary industry employment (Anhui, Sichuan, Zhejiang, Jiangsu and Yunnan) contained about 62.6% of the total secondary labour force, and the shares of the three largest cities (Qujing, Yangzhou and Wenzhou) of secondary industry employment were around 23.7% in total.

4.5. Estimation of wage equation

Wage equation is central in NEG model and empirical work on NEG heavily focused on the estimation of the wage equation (Hanson, 1997, 2005; Redding and Venables, 2004). In the context of China, the estimation of wage equation was followed and supported by Au and Henderson (2006), Bosker et al. (2010, 2012), Hering and Poncet (2010a, 2010b), Moreno-Monroy (2011) and Roberts et al. (2012).

We estimated the essential parameters of the NEG model first to evaluate the possible change of China's economic geography because of the HSR construction. The vital parameter σ (elasticity of substitution between manufacturing varieties) related to market access was estimated by a log-linearised version of the equilibrium wage equation, given by:

$$\ln(w_{it}) = \frac{1}{\sigma}\ln\left(\sum_{j=1}^{N} e_j \tau_{ij}^{1-\sigma} q_j^{\sigma-1}\right) + \ln(c_i) + \varepsilon_{it} \tag{4.7}$$

where the term between brackets implies market access, and c_i denotes the production efficiency of city *i*, which allows for a productivity differential across regions in our model. In addition, we assumed that the error term (ε_{it}) was uncorrelated with the included independent variables. In particular, this efficiency term took the form of Equation (4.8) in our estimation:

$$\ln(c_i) = a_i + b_t + \varphi_1 X_{1it} + \varphi_2 X_{2it} + \varphi_3 lnX_{3it} \tag{4.8}$$

where the equation includes control variables in vector *X*, and city and year fixed effects (a_i , b_t). Controls include human capital, the share of banking and finance in total employment and the population density.

Equation (4.7) is a log-linearised version of Equation (4.2) in the NEG model that has been simplified to exclude supplier access, $q_i^{\mu/(\mu-1)}$, considering that multicollinearity arises easily if market access and supplier access are included simultaneously (Redding and Venables, 2004; Hering and Poncet; 2010a; and Bosker et al., 2012). Equation (4.7) indicates that market access was associated positively with nominal wages—the better connected a region to other large regional markets (lower transport costs), the higher its market access. This indicates the crucial role of trade costs in explaining the spatial distribution of wages.

Given that cities' manufacturing price index (q_j) in Equation (4.7) could not be observed directly in the market access term, we instead measured it with wages—that is, a weighted city's own wage level and the average wage of all other cities:

$$q_j = \{\lambda_j W_j^{1-\sigma} + (1-\lambda_j)(\bar{w}\tau_{j,centre}^{\delta})^{1-\sigma}\}^{\frac{1}{1-\sigma}} \tag{4.9}$$

where λ_j is the share of employment in city j; $\bar{w}$ is the average wage level, except for city j; and $\tau_{j,centre}$ is the transport cost between city j and its nearest metropolises (Beijing, Shanghai and Guangzhou). The estimated results in Equation (4.7) were used as a benchmark to explore the effect of market access on wage levels. More importantly, the obtained parameters were used as inputs for the simulation analysis in Section 4.7.

Two basic empirical strategies for the estimation of wage equation have been provided. The first strategy stemmed from Redding and Venables (2004), and uses bilateral trade data to construct a measure of market access that is then included in the estimation of the wage equation. Studies that followed this estimation strategy include Hering and Poncet (2010a, 2010b) and Ma (2006). All these studies used data on inter-provincial trade in China. The second strategy, introduced by Hanson (2005), uses nonlinear estimation techniques to estimate the wage equation directly. This strategy was used by Bosker et al. (2012) and Mion (2004). The second strategy was preferred in our study, since we possessed wage data at the city level. Generally, use of the first strategy was not possible because bilateral trade data in China could only be accessed at the provincial level, and was unavailable at the prefecture city level to cover our sample sufficiently. A similar strategy of direct estimation regarding market access was also adopted by Amiti and Javorcik (2008), Fingleton (2006) and Au and Henderson (2006).

Using nonlinear estimation techniques, the baseline results from the estimation of Equation (4.7) are presented in Table 4.4. The results verified the sensitivity of the estimated market access coefficient with respect to the reduction of trade costs.

Table 4.4. Results for wage equation estimation across cities

Variables	Coefficients
Sigma	**3.796***** (0.34)
Delta	**0.602***** (0.04)
Ln (population density)	**0.259***** (0.02)
Human capital	**1.456***** (0.10)
Share of banking and finance in total prefecture city employment	**0.419***** (0.01)
Sample period	2004–2014
Number of observations	2,574
Fixed effects	City and year

Note: White heteroscedasticity-consistent standard errors are between brackets. All parameters and coefficients are significant at the 1% level.

Our panel NLS estimation illustrated that all parameters and coefficients were significant at the 1% significant level. The coefficient of market access was 0.263 ($= 1/\sigma = 1/3.796$), which indicated a change in the nominal wage levels of 0.263% in reaction to a change in the domestic component of market access. This confirms that market access is an important way to explain the wage differences between prefecture cities in China. This result is consistent with the work of Moreno Monroy (2011) (NLS without fixed effects, MA coefficient ≈ 0.25) and Bosker et al. (2012) (NLS with fixed effects, MA coefficient ≈ 0.17). The transport cost parameter, δ, was 0.602, which is similar to the findings of Au and Henderson (2006) (NLS without fixed effects, $\delta = 0.87$) and Bosker et al. (2012) (NLS with fixed effects, $\delta = 0.632$).

The estimates of all control variables were positive and significant at the 1% significance level. Specifically, population density was estimated to play a role in wages: a 1% increase in population density increased wages by approximately 0.26%. The relatively large coefficient of human capital (1.46) indicated that it is an important determinant of wage level. These results are similar to the suggestions of Bosker et al. (2012), Bosker and Garretsen (2010) and Hering and Poncet (2010a). Additionally, a 1% rise in the share of banking and finance in total employment contributed 0.42% to wages.

The estimated results confirmed the relationship between market access and wage level, yet did not provide any information about how China's future internal economic geography may be affected by the development of HSR and the reduction of transport costs. Therefore, after estimating the parameters, we moved onto the prediction of wages on the basis of the complete NEG model. Following this, the wage differential matrices were used to predict the migration patterns.

4.6. Estimation of migration equation

The second important equation dominated the regional migration dynamics of the model in 2010, given by Poncet (2006):

$$\ln\frac{mig_{ij}}{\sum_j mig_{ij}} = \beta_1 lnwage_j + \beta_2 lnunempl_j + \beta_3 lnd_{ij} + \beta_4 NB_{ij} + \beta_5 Intra_{ij} + \alpha_i + \epsilon_{ij} \tag{4.10}$$

where mig_{ij} is the outflow migration from province i to j, including intra-provincial migration in j; $wage_j$ is the real wage in province j; $unempl_j$ denotes the unemployment rate in province j; d_{ij} is the distance between home and host locations; NB_{ij} is a dummy variable equal to 1 if province i and j are neighbouring provinces; $Intra_{ij}$ is also a dummy variable equal to 1 if i and j are in the same province; α_i is a fixed effect specific to the original province i; and ϵ_{ij} is an error term.

We estimated Equation (4.10) using a cross-sectional dataset of migratory flows between and within 30[34] Chinese provinces, where fixed effects of originated provinces were controlled as their specific features. The results of the migration estimation are presented in Table 4.5.

Table 4.5. Results for migration equation estimation across provinces

Variables	Coefficients
Ln (real average wage)	**1.299*****(0.13)
Ln (unemployment rate)	**-0.503*****(0.13)
Ln (distance)	**-0.924*****(0.06)
Neighbouring provinces	**0.393*****(0.10)
Intra-provinces	**2.847*****(0.17)
Sample period	2010
Number of observations	795
Fixed effects	Province

Note: Standard errors between brackets. All parameters and coefficients are significant at the 1% level.

Our panel linear least squares estimation with fixed effects indicated that expected income in destination provinces was positively associated with migration dynamics—that is, a 1% rise of the expected average wage of the destination province boosted labour mobility to this province by 1.3%. The probability of finding a job also had a positive relationship with labour mobility. In terms of migration costs, our results were similar to Poncet (2006) and Zhang and Zhao (2013), thereby confirming that long distances limit workers' migration, and there is a strong intra-province preference of migration.

[34] Tibet was excluded from our dataset because of the unavailability of data.

4.7. Simulation

After estimating the wage equation and migration equation (see Tables 4.4 and 4.5), we were able to mimic the real-life distribution of economic activity in a benchmark year and start the counterfactual simulation of the effects of HSR on China's economic geography. To complete this counterfactual analysis, two scenarios were compared: the case without HSR (Case B—regular railway network in 234 prefecture cities) and the case with HSR only (Case C).

Equations (4.2) and (4.4) were first replaced in Equation (4.5), which were used for the prediction of real wages:

$$\omega_i = (\frac{\gamma_H Y_i}{H_i})^{-\gamma_H} q_i^{\frac{\mu}{\mu-1}-\gamma_M} c_i^{\frac{1}{1-\mu}} \left[\sum e_j q_j{}^{\sigma-1} \tau_{ij}{}^{1-\sigma}\right]^{\frac{1}{\sigma(1-\mu)}} \tag{4.11}$$

where Y_i is city i's income and H_i is housing stock in city i. In addition, as with q_i, q_j and τ_{ij} have been expressed in Equations (4.1), (4.9) and (4.6), respectively, and were plugged into Equation (4.11) to conduct a prediction.

Once the real wage was predicted for all 234 cities, this was then used in the dynamic equation:

$$\frac{\Delta\lambda_i}{\lambda_i} = \psi \sum m_{ij} \;;\; m_{ij} = \begin{cases} \left(|\omega_i - \omega_j|\right)^{\beta 1} D_{ij}^{\beta 2} e^{\beta 3\, NB_{ij}} \; if\ \omega_i > \omega_j \\ \left(-|\omega_i - \omega_j|\right)^{\beta 1} D_{ij}^{\beta 2} e^{\beta 3\, NB_{ij}} \; if\ \omega_i < \omega_j \end{cases} \tag{4.12}$$

where m_{ij} implies the change in the share of a city's total population resulting from immigration from another city j with a lower wage or immigration to another city j with a higher wage, and NB_{ij} is a dummy variable that indicates whether cities i and j are neighbouring cities.

One more constraint is to set a minimum for the wage differential given by Equation (4.13). This is called the wage threshold and is set to 15%:

$$\max(|\omega_i - \omega_j/\omega_j|) = x\% \quad \forall i, j \tag{4.13}$$

With the provision of main parameters in Tables 4.4 and 4.5, the real wage in 2010 could be predicted following Equation (4.11). The year 2010 was preferred as a benchmark because the newest census data in China were updated in 2010, and have the most information available on migration. More importantly, the number of HSR stations in China jumped from eight in 2008 to 77 in 2010. To some extent, the year 2010 represents the rapid development of China's HSR, and well reflects the development process of the national railway from a regular railway to a HSR.

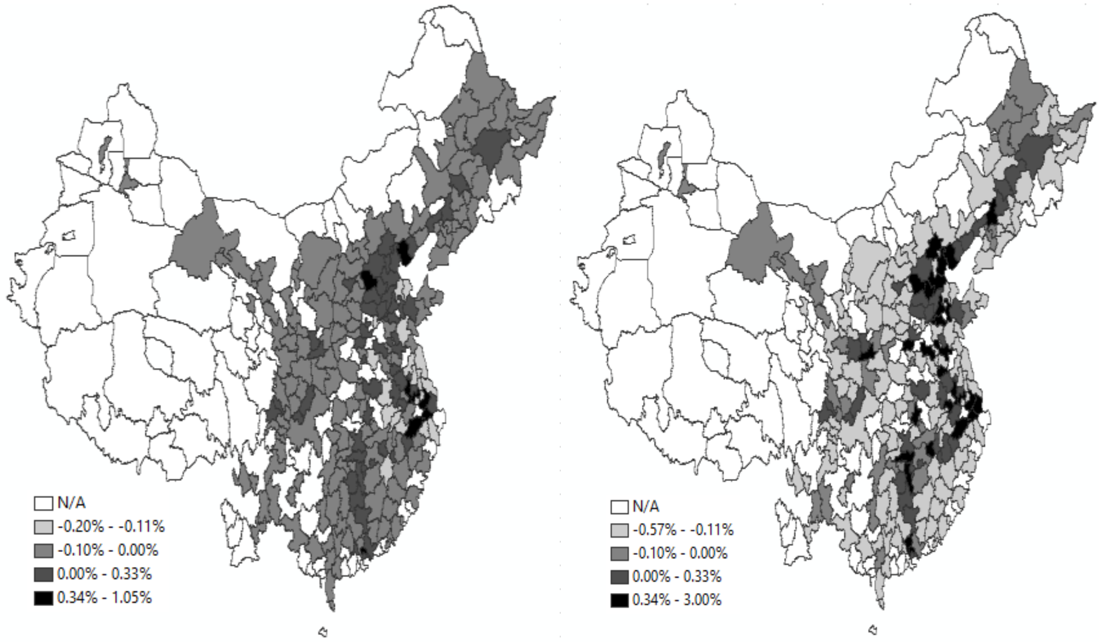
Table 4.6. Key parameter settings for the simulation

Parameters	Values	Definitions
σ	3.796	From Table 4.4
δ	0.602	From Table 4.4
μ	0.592	From input–output (IO) table: the proportion of intermediate inputs in manufacturing production
γ_M	0.331	From IO table: the proportion of income spent on manufacturing
γ_H	0.142	From NBS: the proportion of income spent on housing
β_1	1.299	From Table 4.5
β_3	-0.924	From Table 4.5
β_4	0.393	From Table 4.5

As displayed in Table 4.6, the proportion of intermediate inputs in production of manufacturing (μ) and proportion of income spent on manufacturers (γ_M) were collected and computed from a regional IO table for China in 2010. We used Chinese intermediate demand for Chinese manufacturing by Chinese manufacturing firms, as well as Chinese final demand for Chinese manufacturing as a share of the total final demand for Chinese output to calculate the values of μ (0.592) and γ_M (0.331), respectively. Additionally, the proportion of income spent on housing was calculated by sales in 2010 of commercial residential buildings, over the disposable income in that year, based on the NBS. In terms of the value of *βs*, we followed the work of Poncet (2006) and used China's 2010 census provincial migration data to analyse the magnitude of Chinese labour mobility and its effect on labour migration dynamics. The empirical results were consistent with Poncet's finding—that Chinese migration patterns depend positively on higher wages, short distances and intra-province migration.

After obtaining all important model parameters, we were in a position to generate the counterfactual simulations to see what would happen if there was no HSR (Case B) or if all high-speed trains were active (Case C). Based on Equation (4.12), we determined the directions of migration dynamics across cities, as demonstrated in Figure 4.6. Cities that appear in the two darkest colours indicate an inwards migration of labour, with the black part indicating the greatest concentration of labour. In contrast, the two light grey parts indicate the outflow of labour mobility. Compared with central China, the major labour force inwards movement occurred in the eastern regions of China, especially the more developed regions in the east. In addition, 66 prefecture cities had a positive share of work mobility in Panel b, which was slightly higher than that in Panel a (64 cities). Compared with Panel a, Panel b clearly indicates that the degree of labour mobility significantly increased with the development of transportation construction from regular trains to HSR, illustrating a trend of agglomeration towards developed cities. In particular, the number of cities with a larger share of population outflows (> 0.11% and the lightest grey) rose sharply from 19 in Case B to 127 in Case C. Similarly, regarding population inflows, the number of cities increased dramatically from eight cities in Panel a to 28 cities in Panel b if population share was greater than 0.34%. This indicated that the improvement of transportation enabled labourers easier access to nearby cities and markets. There will be an attractive agglomeration from less-developed cities to more developed cities.

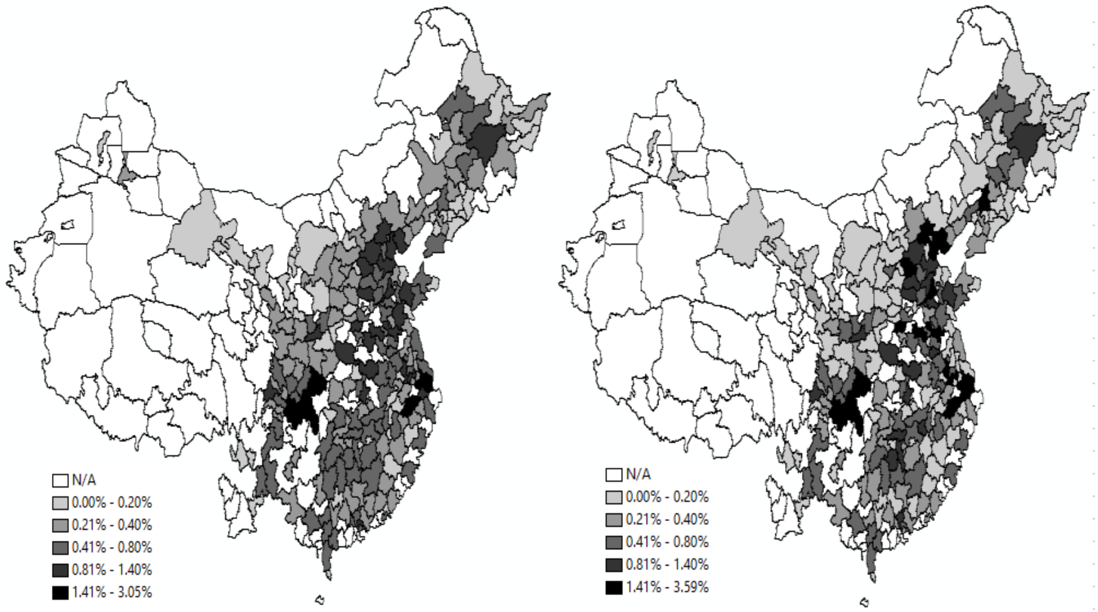
Figure 4.6. Migration dynamics if transportation is improved



(a) Migration direction: Case B (regular train only) (b) Migration direction: Case C (HSR only)

By combining the change in a city's share in the total population with the share of a city's population in the total population, we were able to simulate the population shares in Cases B and C. The results are displayed in Figure 4.7, which provides some information about how China's future economic geography may appear when considering HSR. In Panel a, there exists a clear 'two areas' shape regarding population shares of cities. One area refers to city Chongqing directly, while the other area is produced by Shanghai, Suzhou and Hangzhou. The big four cities based on population shares were Shanghai, Suzhou, Hangzhou and Chongqing (the lowest predicted population share was higher than 1.4%), which have a prime and dominant location in the centre of China's economic geography. The rise of inflow of labour mobility in these cities would obviously enhance the core–periphery pattern in China. Particularly when the transportation conditions are improved (Panel b), the city with a high proportion of the population (greater than 1.4%) surged from four cities to 16 cities, which again proved that construction of HSR strengthened the core–periphery pattern and enhanced the degree of agglomeration. Interestingly, most cities revolved around the 'two areas', followed by cities around Beijing and cities in the middle between Beijing and Shanghai (Zhengzhou and Shangqiu), such as Hangzhou, Nanjing, Suzhou, Xuzhou, Changzhou and Jiaxing, which surround Shanghai, and Shijiazhuang, Jinan, Tianjin and Tangshan, which are located near Beijing. This indicates that the improvement in transportation has led to the development of urban agglomerations centred on big cities.

Figure 4.7. Population shares (labour mobility 15%) if transportation is improved



(a) Regular train only (Case B) (b) HSR only (Case C)

4.8. Conclusions

This chapter has provided a detailed overview of the development of China's HSR system in the period 2008 to 2014, revealing the rapid development and achievements of China's HSR network in recent years. More importantly, this study analysed the effect of China's HSR system on economic activities under a geographical economics model. A wage equation and migration equation were used to estimate relevant parameters for counterfactual simulation exercises to answer questions such as: (i) What would happen if there was no HSR? (ii) What would happen if all HSR was active?

To do this, we firmly based our analysis on the NEG model. Some of the evidence on the estimation of wage equation was first reported to support the empirical relevance of the linkages between wages, market access and transport costs. The empirical results indicated that the reduction of transport costs and increase in market access led to an increase in wages. Moreover, the effects of migration costs and expected income on migration dynamics were also investigated, indicating that the higher expected wage in destination regions and the shorter distance between the originating region and destination regions promoted labour mobility. Based on the estimates of these key structural parameters, we were able to simulate the consequences of improving transportation for China's economic activities and economic geography.

The counterfactual simulation of regular trains indicated that most of China's economic activities occur in the central and eastern regions of China, especially in the more developed cities. Moreover, there clearly exist two big regions of large shares of inwards labour mobility (Shanghai, Hangzhou, Suzhou and Chongqing), showing the four largest population shares of cities. Once we introduced HSR, the degree of labour mobility significantly increased, as did the inflow of labour mobility. This illustrated a trend of agglomeration towards developed cities and an enhancement of the core–periphery pattern in China.

4.9. Appendix

Here we provide the derivation of the equations (4.1) to (4.3) for the NEG model with three sectors. The derivation follows Bosker et al. (2012) and Puga (1999).

Agriculture

Farmers produce a homogeneous agricultural good using arable land under constant returns to scale and perfect competition. The production function is given by

$$y_i = \mathrm{f}(L_i^A, K_i) \tag{A.1}$$

where L_i^A is workers in agricultural sector, K_i is the land endowment, and function f is homogeneous of degree one and is the same across regions.

To maximize profit in each region, a function of returns to land is given by

$$\mathrm{R}(p_i^A, w_i, K_i) = max\{p_i^A y_i - w_i L_i^A | y_i \leq f(L_i^A, K_i)\} \tag{A.2}$$

where w_i is wage in region i, p_i^A is the producer price of the agricultural goods. The assumption of a free trade-off of agricultural goods between regions implies that there is no transport cost for agricultural goods. Thus, the price of agricultural goods is the same in each region and is set as the numeraire ($p_i^A = 1, \forall i$). $\mathrm{R}(p_i^A, w_i, K_i)$ is homogenous of degree one in K_i because of constant returns to scale, which is given by

$$\mathrm{R}(1, w_i, K_i) = K_i r(w_i) \tag{A.3}$$

Manufacturing

Given that manufacturing firms produce differentiated products under internal economies of scale and have monopolistic power, firm's profit function in region i is given by

$$\pi_i = \sum_j^R \frac{P_{ij}(h)x_{ij}(h)}{\tau_{ij}} - {w_i^M}^{1-\mu} {q_i^\mu} c_i[\alpha + \beta \sum_j^R x_{ij}(h)] \tag{A.4}$$

where $P_{ij}(h)$ is the price of a variety in region i, $x_{ij}(h)$ is production of a quantity of a variety, τ_{ij} is transport cost from region i to region j, w_i^M is the manufacturing wage in region i, q_i is the manufacturing price index in region i, $c_i\alpha$ is fixed costs and $c_i\beta$ is the variable costs.

Preference

On the demand side, Cobb-Douglas preferences are owned by consumers over agricultural goods, housing and a CES aggregate of manufacturing goods with the Cobb-Douglas share of each good (where $0 < \gamma_z < 1$; $z = A, H, M; \gamma_A + \gamma_H + \gamma_M = 1$). It is assumed that all varieties enter both consumers' utility and production with the same CES (σ).

Equilibrium

In the agricultural sector, the equation (A.3) gives the rate of return that maximizing profit per unit of land. Its derivation with respect to w_i gives

$$r_w(w_i) \equiv \frac{\partial r(w_i)}{\partial w_i} = -\frac{L_i^A}{K_i} \tag{A.5}$$

Given a Cobb-Douglas production function, where θ $(0 \ll \theta \ll 1)$ denotes the share of labour in agricultural function, we have

$$r(w_i) \equiv (1-\theta)(\frac{w_i}{\theta})^{\theta/(\theta-1)} \tag{A.6}$$

Differentiating equation (A.6) and using equation (A.5) gives

$$L_i^A = K_i(\frac{\theta}{w_i^A})^{1/(1-\theta)} \tag{A.7}$$

The share of workers in manufacturing (ζ_i), thus, is given by

$$\zeta_i = \frac{L_i^M}{L_i} = 1 - \frac{L_i^A}{L_i} = 1 - \frac{K_i}{L_i}(\frac{\theta}{w_i^A})^{1/(1-\theta)} \tag{A.8}$$

where L_i^M is the number of labourers in manufacturing. This equation indicates that the share of labour in manufacturing in region i is endogenous determined in this model. Analogously, total demand of agricultural goods in region i (x_i^A) is determined by consumer preferences as

$$x_i^A = (1 - \gamma_M - \gamma_H)Y_i \tag{A.9}$$

In the industrial sector, the same profit maximising producer price is set by all firms producing in region i. Profit maximization by differentiating demand with respect to a firm's own price, a constant relative mark-up over marginal cost is given by

$$p_i = \frac{\sigma\beta}{\sigma-1} c_i q_i^{\mu} w_i^{M^{1-\mu}} \tag{A.10}$$

where q_i is the manufacturing price index in region i. It is defined by

$$q_i = (\int_j \tau_{ij}^{1-\sigma} n_j p_j^{1-\sigma})^{1/(1-\sigma)} \tag{A.11}$$

where n_j is the number of firms in region j and

$$w_i^M = [(1-\mu)n_i p_i(\frac{(\sigma-1)}{\sigma\beta}(\alpha+\beta x_i))](\zeta_i L_i)^{-1} \tag{A.12}$$

w_i^M is the wage in the manufacturing sector in region i.

To maximizing utility of consumers, total demand for the production of each manufacturing variety is given with the iceberg assumption

$$x_i = \int_j p_i^{-\sigma} e_j q_j^{\sigma-1} \tau_{ij}^{1-\sigma} \tag{A.13}$$

The total expenditure on manufactures in region i is

$$e_i = \underbrace{\gamma_M Y_i}_{\substack{consumer \\ expenditure}} + \underbrace{\mu n_i p_i(\frac{(\sigma-1)}{\sigma\beta}(\alpha+\beta x_i))}_{producer\ expenditure\ on\ intermediates} \tag{A.14}$$

where

$$Y_i = \underbrace{\gamma_H Y_i}_{\substack{spending \\ on\ housing}} + \underbrace{w_i^A(1-\zeta_i)L_i + w_i^M \zeta_i L_i}_{wage\ income\ of\ workers} + \underbrace{r\big(w_i^A\big)K_i}_{\substack{rents\ of \\ landowners}} + \underbrace{n_i \pi_i}_{\substack{profits \\ of\ firms}} \tag{A.15}$$

Given firms zero profits, the unique equilibrium output is

$$x_i = \alpha(\sigma-1)/\beta \tag{A.16}$$

Finally, the labour market clearing condition is given by

$$L_i = \underbrace{\Big[(1-\mu)n_i p_i(\frac{(\sigma-1)}{\sigma\beta}(\alpha+\beta x_i))\Big] w_i^{M^{-1}}}_{L_i^M} + \underbrace{K_i(\frac{\theta}{w_i^A})^{1/(1-\theta)}}_{L_i^A} \tag{A.17}$$

The number of firms in region i can be rewritten when labor demand equals labor supply

$$n_i = \frac{\zeta_i L_i}{\alpha\sigma(1-\mu) q_i^{\mu} w_i^{M-\mu}} \tag{A.18}$$

The long run equilibrium conditions shown in equations (4.1) to (4.3) in section 4.3.1. under an assumption of no labour mobility can be derived with $w_i^M = w_i^A = w_i$ in equilibrium. Equation (4.1) for the manufacturing price index can be derived by substituting (A.10) and (A.18) to (A.11). Equation (4.2) for nominal wage can be derived by substituting (A.10) and (A.16) to (A.13). Equation (4.3) for total manufactures' expenditures can be derived by substituting (A.10), (A.15), (A.16), and (A.18) into (A.14).

Chapter 5: Conclusion and further research

5.1. Empirical findings

The main goal of this thesis project was to provide a comprehensive examination of the linkages between the public sector and economic performance under a spatial framework, and to contribute to the intersecting literature on innovative performance, transportation infrastructure and economic growth. The overarching purpose was to determine the critical determinants of improving economic performance. By doing so, this thesis aimed to provide testable theoretical and empirical research, predict China's internal geography, and present targeted guidelines and policies. This final chapter of the thesis sums up the progress of these objectives and discusses some potential implications of the research findings.

Economic growth benefits from innovation, while transportation infrastructure affects economic growth in several ways. However, which factors determine innovation? How does transportation construction influence economic performance? The first study (Chapter 2) concentrated on answering the first question through exploring whether the subnational leaders and agglomeration economy jointly shape innovation, while the latter question was addressed in Chapters 3 and 4.

After controlling for the basic production inputs, our analysis unveiled a clear and significant role of meritocracy—a political philosophy that vests power in individuals based on talents, as well as merits—in sharpening the competitive advantage of city innovativeness, measured by patent applications. In the benchmark production function model, we found that R&D and both domestic and foreign capital and human capital enhance patent production. Notably, investment in neighbouring cities in domestic and foreign capital brings negative externalities to local innovation. In contrast, public spending on science, technology and education has positive spillover effects. A diversified industrial structure brings negative effect into regional knowledge and idea production.

Decomposition of bureaucrat-related variables into two main components—local party secretaries' characteristics and the cadre appointment mechanism—provided theoretical and empirical implications for the research regarding the roles of local leadership in innovation. Many of the institutional variables show a strong significant effect on innovation. Well-educated young leading cadres with army experience, CYL experience or party education are more capable and incentivised to innovate. A municipal secretary whose previous work is in the same province is more likely to promote local innovation. Regardless of the institutional environment, turnover rate negatively affects city innovation; similarly, perceived promotion competition among city leaders measured by turnover rate plays a significantly negative role in enhancing innovation in the area. However, this negative effect can be moderated by either diversified or specialised industrial structure. Our findings provide rich implications for innovation-related policy making and the cadre appointment and selection system.

In terms of the effect of transportation on economic performance, we split this study into two chapters—Chapters 3 and 4. Chapter 3 provided new evidence on the consequences of improving the different transportation forms for China's local economic growth. Two types of heterogeneity were analysed. First, we employed three different modes of transportation infrastructure—highways, railways and public transit—where the first two refer to inter-city transportation, and the latter represents intra-city transportation. We found that, in the long term, there was a positive effect on economic growth from the improvement of all types of transportation infrastructure. However, different magnitudes of coefficients indicated the heterogeneous contributions of transport infrastructure to city GDP growth. Overall, the estimated effect of highways and railways were roughly 6% on local economic growth, compared with around 2% for public transit nationwide. Second, with regard to different types of cities, city specificities were significantly distinguished by the core cities and peripheral cities. The NEG theory was confirmed by our empirical evidence that the core–periphery pattern was enhanced by the reduction of transport costs. If we examined regional disparities, western China benefited most from the development of transportation infrastructure, which suggests one viable approach by policymakers to foster the economic prosperity of this most undeveloped region.

Following the analysis of Chapter 3, Chapter 4 investigated the relationships between China's HSR system and economic activities. Based on the NEG model, the wage equation was estimated first. The estimated result indicated that the reduction of transport costs and the rise of market access led to an increase in wages. In addition, we also estimated the migration equation and found that the expected wage was positively associated with labour mobility, while labour mobility was negatively affected by the distance between regions.

Finally, key parameters estimated by the wage equation and migration equation produced the outcomes of the counterfactual simulation that let us predict what outcomes a reduction in transport cost may imply for future population distribution and economic activity across China. The simulated results on both regular trains and HSR confirmed a more pronounced core–periphery pattern. Most economic activities occurred in the central and eastern regions of China, especially in the well-developed regions of the east. The mobility of labour would significantly increase if HSR was introduced, thereby indicating that the reduction of transport costs will play a vital role in China's future economic geography. Beijing and Shanghai, with their surrounding cities, and Chongqing will further enhance their dominant position in the urban hierarchy of China. Megalopolis will drive the development of surrounding cities and probably develop into some urban agglomeration, led by megalopolis.

5.2. Contributions

The first study contributes to the economic geography literature by exploring the regional dimension of an institutional setting that depends on the local cadres' characteristics, and their effect on regional innovation. Additionally, we examined how industrial agglomerative forces—such as diversity and specialisation—join with institutional elements to determine the city's innovative capacities. The reviewed previous empirical work has presented a wide breadth of findings (He et al. 2016; He et al., 2018), yet had limited exploration of these three important urban externalities on local innovative activities in an emerging economy context against the backdrop of bureaucratic incentives. Finally, we considered that the innovation process in cities might be open, interactive and reciprocal by drawing on local and neighbouring resources for idea creation and knowledge production; thus, we add to the existing literature (Driffield, 2006; Ouyang and Fu, 2012) by exploring the spatial spillover effects of FDI, knowledge capital, physical capital and human capital. Thus, this study fills the gap in this field and makes up for the deficiencies of the literature.

The main contribution of the second study is twofold. We first made some inroads into transportation heterogeneity by testing highways, railways and public road infrastructure, which, to the best of our knowledge, has not been covered in the previous literature. For example, the relative flexibility and adaptability of highways is conducive to linking nearby cities, especially for the east and central regions of China, with dense populations and economic activities. Railroads improve transportation efficiency in areas such as the sparsely populated west, which reduces transport costs and leads to the probability of migration. Development inside the city also needs the support of good public transportation. These separate features of transportation call for prioritising projects and unambiguous plans led by the Chinese government.

In addition, contrary to most previous studies that focused on China's transportation at the provincial or aggregate level, we extended our study to the city's economic hierarchy and geographical location. We not only emphasised the effect of transportation infrastructure construction of megacities on economic growth, but also considered the different modes of transportation that may bring varied consequences to regions or economic zones with different characteristics.

The contributions of the third study derive from at least three aspects, all of which, to the best of our knowledge, have rarely been considered in the previous literature. Few studies have analysed the effect of HSR on distribution economic activities under the framework of the geographical economic model. Little attention has been devoted to the policy implications that arise from geographical economics, particularly in China. Our study used the NEG model to address the relationship between cities, rather than treating cities independently (Fujita and Mori, 2005). The results provide some useful and valuable policy implications to central planners. In addition, the updated parameters through combining the estimation of the equilibrium wage equation and migration equation enhanced the accuracy of simulation to a large extent.

Also noteworthy is that the study was extended to analyse the model-based predictions of what will happen to China's economic activities and internal economic geographical pattern when transportation is improved. The full NEG model was simulated under two different regimes of transportation (regular trains and HSR). Through gaining insights on the simulation outcomes, policymakers will benefit by being able to prioritise projects that can further improve the efficiency of public expenditure.

5.3. Political implications

The empirical results in Chapter 2 provide rich policy suggestions on the practices of cadre appointment and selection, as well as government governance. First, promoting younger people with a good educational background and rich work experience into the cadre system will help the municipal-level government to weed through the old to bring forth the new. Second, a city's innovation capacity is closely linked with a stable framework in the design and implementation of innovation-related policies. Frequent relocation of party secretaries among different positions may lead to inconsistent policy implementation, and thus impede the growth of innovation outputs. Additionally, the competition mechanism goes against innovation. This evidence signifies the importance of choosing an appropriate yardstick that inclusive of, but not restricted to, the required economic growth indicator to motivate local leaders in propelling urban innovation. The upper-level government should not only evaluate the local cadres' output of one particular aspect, such as economic growth. A balance between rotation and the cadres' perceived competition is required within the cadre appointment system to enable benefits for long-term innovation and sustainability.

From Chapters 3 and 4, some policy implications are worth discussing. Our findings in Chapter 3 suggest that, in the long term, the roles of transportation played by western China differ from those of the mid-east regions. The former may benefit more from infrastructure improvement. Hence, a choreographed policy of investment in heterogeneous transportation is required, drawing on a timeframe of objectives. In addition, infrastructure expenditure on core or peripheral cities should be balanced to improve efficiency and avoid aggravation of regional inequality. Further, the benefits of HSR development clearly outweigh those of conventional railways; however, determining where to invest and how to plan the HSR network appropriately will be a test for policymakers.

5.4. Further work

This thesis was sufficiently detailed to explore the effect of the public sector on economic performance spatially; however, several opportunities in each study can be identified as offering avenues for future research.

In Study 1, our empirical results could be robust to the inclusion of some institutional factors at a higher administrative level (i.e., provincial level), since we considered the meritocratic effect as likely to be influenced by the higher level of China's institutional quality. In recent years, with the acceleration of China's market-oriented reform process, implementation of fiscal decentralisation and strengthening of anti-corruption efforts, we probably need to devote more consideration to strategic institutional reform at the national level. Provincial institutional policies directly follow national policies, also are the weather vane of prefecture cities. Therefore, fiscal decentralisation, level of corruption and marketisation might be considered to explore how the provincial institutional quality and local cadres together affect city innovation. In addition, in China, the party secretary is the head of city leadership and takes responsibility for personnel, political duties and party affairs, while the mayor is the executive officer and is in charge of daily government operation and economic growth (Gao and Liang, 2016). We focused on the impact of party secretary, yet future research could include information about the city mayor to ensure robustness.

In Study 2, one improvement of this study might be the consideration of policy shock (Diao et al., 2012; Wong, 2011). We argue that the accelerating transportation infrastructure construction, especially in 2009 to 2010, is also attributed to the massive fiscal stimulus introduced by the Chinese government to respond to the sluggishness of the economy after the worldwide financial crisis. China introduced more than ¥4 trillion (US$586 billion) of fiscal stimulus in the fourth quarter of 2008, which was implemented throughout 2009 and 2010 by the central government (around ¥1.2 trillion), local government and non-governmental sectors (around ¥3 trillion) (Fardoust et al., 2012). This stimulus accounted for about 12.5% of China's 2008 GDP, and more than one-third of the stimulus (¥1.5 trillion) was allocated to infrastructure development and particularly to transportation infrastructure and energy.

In Study 3, we can simply conduct a sensitivity check for our simulation by using the different wage thresholds, such as 5%, 10%, 20% and 25%, to examine whether the core–periphery outcomes would be altered. More importantly, we can make a comparison to the case without the housing sector in the NEG model to explore the influence of housing in China.

In summary, this thesis provides a detailed treatment of the impact of public sector on economic performance. There is still considerable scope to develop the findings of the current results for further research.

References

Acemoglu, D., Johnson, S., and Robinson, J. A. (2005). Institutions as a fundamental cause of long-Run growth. *Handbook of Economic Growth*. Elsevier B.V.

Acs, Z. J., Anselin, L., and Varga, A. (2002). Patents and innovation counts as measures of regional production of new knowledge. *Research Policy*, 31(7), 1069-1085.

Agbelie, B. R. (2014). An empirical analysis of three econometric frameworks for evaluating economic impacts of transportation infrastructure expenditures across countries. *Transport Policy*, 35, 304-310.

Albalate, D., and Bel, G. (2012). High-Speed Rail: Lessons for policy makers from experiences abroad. *Public Administration Review*, May-June, 336-349.

Amiti, M., and Javorcik, B. S. (2008). Trade costs and location of foreign firms in China. *Journal of Development Economics*, 85(1–2), 129-149.

Arellano, M., and Bond, S. (1991). Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations. *Review of Economic Studies,* 58: 277–297.

Arellano, M., and Bover, O. (1995). Another look at the instrumental variable estimation of error-components models. *Journal of Econometrics,* 68: 29–51.

Aschauer, D. A. (1989). Is public expenditure productive? *Journal of Monetary Economics*, 23(2): 177–200.

Au, C. C., and Henderson, J. V. (2006). Are Chinese cities too small? *Review of Economic Studies*, 73(3), 549-576.

Bai, C. E., and Qian, Y. (2010). Infrastructure development in China: the cases of electricity, highways, and railways. *Journal of Comparative Economics*, 38(1), 34-51.

Baldwin, R. E., and Philippe M. (2004). Agglomeration and regional growth, in J. V. Henderson and J. F. Thisse (eds.), *Handbook of Regional and Urban Economics*, edition 1, volume 4, number 4, 2671-2712. North-Holland, Amsterdam, the Netherlands.

Baum-Snow, N., Brandt, L., Henderson, J. V., Turner, M. A., and Zhang, Q. (2017). Roads, railroads, and decentralization of Chinese cities. *Review of Economics and Statistics*, 99(3), 435-448.

Behrens, K., and Thisse, J. F. (2007). Regional economics: a new economic geography perspective. *Regional Science and Urban Economics*, 37(4), 457-465.

Bernstein, J. I., and Nadiri, M. I. (1991). Product demand, cost of production, spillovers, and the social rate of return to R&D. *NBER Working Paper No. w3625*, National Bureau of Economic Research.

Black, D., and Henderson, V. (2003). Urban evolution in the USA. *Journal of Economic Geography*, 3(4), 343-372.

Blundell, R., and Bond, S. (1998). Initial conditions and moment restrictions in dynamic panel data models. *Journal of Econometrics,* 87: 115–143.

Boarnet, M. G. (1996). The direct and indirect economic effects of transportation infrastructure. University of California. *Transportation Center Working Papers*.

Boeing, P., Mueller, E., and Sandner, P. (2016). China's R&D explosion—analyzing productivity effects across ownership types and over time. *Social Science Electronic Publishing*, 45(1), 159-176.

Bosker, E. M., and Garretsen, H. (2010). Trade costs in empirical new economic geography. *Papers in Regional Science*, 89(3), 485–511.

Bosker, E. M., Brakman, S., Garretsen, H., and Schramm, M. (2010). Adding geography to the new economic geography. *Journal of Economic Geography,* 10(6), 793-823.

Bosker, E. M., Brakman, S., Garretsen, H., and Schramm, M. (2012). Relaxing hukou: increased labor mobility and China's economic geography. *Journal of Urban Economics*, 72(2–3), 252-266.

Brakman, S., Garretsen, H., and Marrewijk, C. (2009). The new introduction to geographical economics. New York: *Cambridge University Press*.

Breinlich, H. (2006). The spatial income structure in the European Union—what role for economic geography? *Journal of Economic Geography*, volume 6(5), 593-617(25).

Breitung, J. (2000). The local power of some unit root tests for panel data. *Advances in Econometrics,* 15, 161-177.

Canning, D., and Pedroni, P. (2008). Infrastructure, long-run economic growth and causality tests for cointegrated panels. *The Manchester School*, 76(5), 504-527.

Chen, Y., and Meng, X. C. (2013). The impact of high-speed railway on passenger transport market, regional economy and spatial structure. *Urban Development Studies*, 20(4): 119-124.

Choi, S. B., Lee, S. H., and Williams, C. (2011). Ownership and firm innovation in a transition economy: Evidence from China. *Research Policy*, 40(3):441-452.

Chow, G. C. (1993). Capital formation and economic growth in China. *The Quarterly Journal of Economics*, 108(3):809-842.

De Bonis, R., Fano, D., and Sbano, T. (2007). The household aggregate financial wealth: Evidence from selected OECD countries. *Bank of Italy Working Paper*, Rome, Italy.

Del Bo, C. F., and Florio, M. (2012). Infrastructure and growth in a spatial framework: evidence from the EU regions. *European Planning Studies*, 20(8), 1393-1414.

Demurger, S., (2001), Infrastructure development and economic growth: An explanation for regional disparities in China? *Journal of Comparative Economics,* 29, 95–117.

Desmaris, C., and Bouf, D. (2015). Spatial equity and high-speed trains: the example of France. *Working Papers*.

Diao, X., Zhang, Y., and Chen, K. Z. (2012). The global recession and China's stimulus package: a general equilibrium assessment of country level impacts. *China Economic Review*, 23(1), 1-17.

Donaldson, D., and Hornbeck, R. (2016). Railroads and American economic growth: A "market access" approach. *Quarterly Journal of Economics,* 131(2), 799-858.

Driffield, N. (2004). Regional policy and spillovers from FDI in the UK. *Annals of Regional Science*, 38(4), 579-594.

Driffield, N. (2006). On the search for spillovers from foreign direct investment (FDI) with spatial dependency. *Regional Studies*, 40(1):107-119.

Driffield, N., and Love, J. H. (2007). Linking FDI motivation and host economy productivity effects: Constantual and empirical analysis. *Journal of International Business Studies,* 38(3), 460-473.

Dumitrescu, E. I., and Hurlin, C. (2012). Testing for Granger non-causality in heterogeneous panels. *Economic Modelling*, 29(4): 1450-1460.

Easterly, W., and Pennings, S. (2015). How much do leaders explain growth? An exercise in growth accounting. *Unpublished manuscript.*

Eisner, R. (1991). Infrastructure and regional economic performance. *New England Economic Review*, 5: 47–58.

Engle, R. F., and Granger, C. W. J. (1987). Cointegration and error correlation: Representation, estimation, and testing. *Econometrica*, 55, 251-76.

Fan, J. L., Bai, B. L., and Pan, Q. (2004). Progress made by the study on the contribution of infrastructure capital to economic growth: A summary of the method of production function. *Modern Economic Science*, 26(2), 87–96.

Fardoust, S., Lin, J. Y., and Luo, X. (2012). Demystifying china's fiscal stimulus. *Policy Research Working Paper*. The World Bank.

Feldman, M. P., and Audretsch, D. B. (1999). Innovation in cities: science-based diversity, specialization and localized competition. *Social Science Electronic Publishing*, 43(2), 409-429.

Fernald, J. G. (1999). Roads to prosperity? Assessing the link between public capital and productivity. *The American Economic Review*, 89(3): 619-638.

Fernández, M., and Montuenga-Gómez, V. M. (2003). The effects of public capital on the growth in Spanish productivity. *Contemporary Economic Policy*, 21(3): 383-393.

Fingleton, B. (2006). The new economic geography versus urban economics: an evaluation using local wage rates in Great Britain. *Oxford Economic Papers*, 58(3), 501-530.

Finn, M. (1993). Is all government capital productive? Economic Quarterly - *Federal Reserve Bank of Richmond*, 79(2-3), 53-80.

Fischer, M. M., and Varga, A. (2003). Spatial knowledge spillovers and university research: evidence from Austria, *Annals of Regional Science,* 37, 303–322.

Freeman, C. (1995). The 'National System of Innovation' in historical perspective. *Cambridge Journal of Economics*, 19(1):5-24.

Fu, X., and Gong, Y. (2011). Indigenous and foreign innovation efforts and drivers of technological upgrading: evidence from China. *World Development*, 39(7), 1213-1225.

Fujita, M., Krugman, P. R., and Venables, A. J. (1999). The spatial economy; cities, regions, and international trade, Cambridge, MA: MIT Press.

Fujita, M., and Mori, T. (2005). Frontiers of the new economic geography. *Papers in Regional Science*, 84(3), 377–405.

Gao, N., and Liang, P. (2016). Fresh cadres bring fresh air? Personnel turnover, institutions, and China's water pollutions. *Review of Development. Economics*, 20(1): 48–61.

García, F., Jin, B., and Salomon, R. (2013). Does inward foreign direct investment improve the innovative performance of local firms? *Research Policy*, 42(1), 231-244.

Glaeser, E. L., Kallal, H. D., Scheinkman, J. A., and Shleifer, A. (1992). Growth in cities. *Journal of Political Economy*, 100(6), 1126-1152.

Glaeser, E. L., Porta, R. L., Lopez-De-Silanes, F., and Shleifer, A. (2004). Do institutions cause growth? *Journal of Economic Growth*, 9(3), 271-303.

Goncalves, E. and Almeida, E. (2009). Innovation and spatial knowledge spillovers: evidence from Brazilian patent data. *Regional Studies*, 43(4), 513-528.

Greunz, L. (2004). Industrial structure and innovation - evidence from European regions. *Journal of Evolutionary Economics*, 14(5), 563-592.

Griliches, Z. (1979). Issues in assessing the contribution of research and development to productivity growth. *Bell Journal of Economics*, 10: 92–116.

Griliches, Z. (1991). Patent statistics as economic indicators: a survey. *Journal of Economic Literature*, 28(28), 1661-1707.

Griliches, Z. (1992). The Search for R&D Spillovers. *Scandinavian Journal of Economics,* 94(0):29-47, Supplement.

Gu, Y., and Shen, K. (2012). Innovation spirit of local officials and regional innovation—evidence from the prefecture level cities in Yangtze River Delta and Pearl River Delta. *Journal of Financial Research*, 11(389), 89-102.

Hall, B. H., Jaffe, A., and Trajtenberg, M. (2005). Market value and patent citations. *RAND Journal of Economics*, 36(1), 16-38.

Hanson, G. H. (1997). Increasing returns, trade and the regional structure of wages. *The economic journal*, 107(440), 113-133.

Hanson, G. H. (2005). Market potential, increasing returns and geographic concentration. *Journal of International Economics*, 67(1), 1-24.

Haynes, K. E. (1997). Labor markets and regional transportation improvements: the case of high-speed trains. *The Annals of Regional Science*, 31, 57-76.

He, M., Chen, Y., and Schramm, R. (2018). Technological spillovers in space and firm productivity: Evidence from China's electric apparatus industry. *Urban Studies*, 55(11), 2522-2541.

He, C., Yan, Y., and Rigby, D. (2016). Regional industrial evolution in China. *Papers in Regional Science*, 97(2), 173-198.

Henderson, V. (1997). Externalities and industrial development. *Journal of Urban Economics*, 42,449–470.

Hering, L., and Poncet, S. (2010a). Market access and individual wages: evidence from China. *Review of Economics & Statistics*, 92(1), 145-159.

Hering, L., and Poncet, S. (2010b). Income per capita inequality in China: the role of economic geography and spatial interactions. *World Economy*, 33(5), 655–679.

Hornung, E. (2015). Railroads and growth in Prussia. *Journal of the European Economic Association*, 13(4), 699-736.

Hu, A., and Jefferson, G. (2004). Returns to research and development in Chinese industry: evidence from state-owned enterprises in Beijing, *China Economic Review*, Vol. 15, pp.86–107

Huang, L. Y., Liu, X. M., and Xu, L. (2012). Regional innovation and spillover effects of foreign direct investment in China: a threshold approach. *Regional Studies*, 46(5), 583-596.

Hulten, C. R. (1996). Infrastructure capital and economic growth: How well you use it may be more important than how much you have. *NBER Working Paper Series W5847*.

Im, K. S., Pesaran, M. H., and Shin, Y. (2003). Testing for unit roots in heterogeneous panels. *Journal of Econometrics*, 115, 53-74.

Jacobs, J. (1969): The economy of cities, Random House, New York

Jaffe, A. B., Trajtenberg, M., and Henderson, R. (1993). Geographic localization of knowledge spillovers as evidenced by patent citations. *Quarterly Journal of Economics*, 108(3), 577-598.

Jin, G. (2012). The estimation of China's infrastructure capital stock. *Economic Research Journal*, 47(4): 4-14.

Kao, C. (1999). Spurious regression and residual-based tests for cointegration in panel data. *Journal of econometrics*, 90(1), 1-44.

Kao, C., and Chiang, M. H. (2000). On the estimation and inference of a cointegrated regression in panel data. In Badi H. Baltagi, Thomas B. Fomby, and R. Carter Hill (ed.) *Nonstationary Panels, Panel Cointegration, and Dynamic Panels* (Advances in Econometrics, Volume 15), 179 – 222. Emerald Group Publishing Limited, Bingley, U.K.

Keisuke, K. (2017). Introduction to spatial econometric analysis: creating spatially lagged variables in Stata. *Discussion Papers*.

Kim, S. (1995). Expansion of markets and the geographic distribution of economic activities: the trends in U.S. regional manufacturing structure, 1860-1987. *Quarterly Journal of Economics*, 110(4), 881-908.

Kohli, U. R. (1978). A gross national product function and the derived demand for imports and supply of exports, *Canadian Journal of Economics*, 11:167-182.

Kónya, L. (2006). Exports and growth: Granger causality analysis on OECD countries with a panel data approach. *Economic Modelling*, 23(6): 978-992.

Krugman, P. R. (1991a). Increasing returns and economic geography, *Journal of Political Economy*, 99: 183–199.

Krugman, P. R. (1991b). Geography and trade. MIT press, Cambridge, Mass.

Krugman, P. R. (1992). First nature, second nature, and metropolitan location, *Journal of Regional Science*, 33:129-144.

Krugman, P. R. (1993). On the number and location of cities, *European Economic Review*, 37: 293-298.

Krugman, P. R., and Venables, A. J. (1995). Globalization and the inequality of nations, *Quarterly Journal of Economics*, 110: 857-880.

Kuştepeli, Y., Gülcan, Y., and Akgüngör, S. (2012). Transportation infrastructure investment, growth and international trade in Turkey. *Applied Economics,* 44:2619–29.

Lane, J. E. (2000). The public sector: concepts, models and approaches. Sage.

Lao, X., Zhang, X., Shen, T., and Skitmore, M. (2016). Comparing China's city transportation and economic networks, *Cities*, 53: 43–50.

Leck, E., Bekhor, S., and Gat, D. (2008). Equity impacts of transportation improvements on core and peripheral cities, *Journal of Transport and Land Use*, 2: 153–182.

Lee, B. S., Sosin, K., and Hong, S. H. (2005). Sectoral manufacturing productivity growth in Korean regions. *Urban Studies*, 42(42), 1201-1219.

Levin, A., Lin, C., and Chu, C. (2002). Unit root tests in panel data: Asymptotic and finite sample properties. *Journal of Econometrics*, 108, 1-24.

Li, X. (2011). Sources of external technology, absorptive capacity, and innovation capability in Chinese state-owned high-tech enterprises. *World Development,* 39(7), 1240-1248.

Li, X. (2015). Specialization, institutions and innovation within China's regional innovation systems. *Technological Forecasting and Social Change*, 100, 130-139.

Li, Y., and Ni, P. (2013). Externalities, transport networks and the economic growth of urban clusters, *Social Sciences in China*, 34: 174–194.

Liddle, B. (2012). The importance of energy quality in energy intensive manufacturing: Evidence from panel cointegration and panel FMOLS. *Energy Economics*, 34(6), 1819-1825.

Liu, J., Wu, J. N., and Ma, L. (2012). Promotion of the local government officials and land finance: evidence from prefectural city level in China. *Journal of Public Management*, 09(2), 11-23.

Liu, Y., Stillwell, J., Shen, J., and Daras, K. (2014). Interprovincial migration, regional development and state policy in China, 1985–2010. *Applied Spatial Analysis & Policy*, 7(1), 47-70.

Ma, A. C. (2006). Geographical location of foreign direct investment and wage inequality in China. *World Economy*, 29(8), 1031–1055.

Maddala, G. S., and Wu, S.W. (1999). A comparative study of unit root tests with panel data and a new simple test. *Oxford Bulletin of Economics and statistics*, 61(S1): 631-652.

Marshall, A. (1890): Principles of economics: an introductory volume, Macmillan, London.

Mellinger, A. D., Sachs, J. D., and Gallup, J. L. (2003). Climate, coastal proximity and development, in Gordon L. Clark, Meric S. Gertler, and Maryann P. Feldman (eds.), *The Oxford Handbook of Economic Geography*, 169-194. Oxford University Press, Oxford, U.K.

Melo, P. C., Graham, D. J., and Brage-Ardao, R. (2013). The productivity of transport infrastructure investment: a meta-analysis of empirical evidence. *Regional Science and Urban Economics*, 43(5), 695-706.

Mion, G. (2004). Spatial externalities and empirical analysis: the case of Italy. *Journal of Urban Economics*, 56(1), 97-118.

Mitton, T. (2016). The wealth of subnations: Geography, institutions, and within-country development. *Journal of Development Economics*, 118, 88-111.

Mody, A., and Wang, F. Y. (1997). Explaining industrial growth in coastal China: economic reforms and what else? *World Bank Economic Review*, 11(2), 293-325.

Moreno Monroy, A. I., (2011). Market access and the heterogeneous effect of shocks on wages: evidence from Chinese cities. *Papers in Regional Science*, 90(1), 9-25.

Munnell, A. H. (1990). Why has productive growth declined? Productivity and public investment. *New England Economic Review*, 1990(1-2): 4-22.

Munnell, A. H. (1992). Policy watch: infrastructure investment and economic growth. *The Journal of Economic Perspectives*, 6(4): 189-198.

Myrdal, G. (1957) Economic theory and underdeveloped regions. London: Gerald Duckworth.

Nadiri, M. I., and Mamuneas, T. P. (1994). The effects of public infrastructure and R&D capital on the cost structure and performance of U.S. manufacturing industries. *The Review of Economics and Statistics*, 76(1): 22-37.

Nelson, R. R. (Ed.). (1993). National innovation systems: a comparative analysis. *Oxford University Press.*

Ning, L., Wang, F., and Li, J. (2016). Urban innovation, regional externalities of foreign direct investment and industrial agglomeration: evidence from Chinese cities. *Research Policy*, 45(4), 830-843.

Nunn, N., and Puga, D. (2012). Ruggedness: the blessing of bad geography in Africa. *The Review of Economics and Statistics*, 94(1): 20-36.

Ouyang, P., and Fu, S. (2012). Economic growth, local industrial development and inter-regional spillovers from foreign direct investment: Evidence from China. *China Economic Review*, 23(2):445-460.

Ozbay, K., Ozmen-Ertekin, D., and Berechman, J. (2007). Contribution of transportation investments to county output. *Transport Policy*, 14(4): 317-329.

Paci, R., and Usai, S. (2000). Externalities, knowledge spillovers and the spatial distribution of innovation. *GeoJournal*, 49(4), 381-390.

Pedroni, P. (1999). Critical values for cointegration tests in heterogeneous panels with multiple regressors. *Oxford Bulletin of Economics and statistics*, 61(s1): 653-670.

Pedroni, P. (2000). Fully modified OLS for heterogeneous cointegrated panels. *Advances in Econometrics*, 15, 93-130.

Pereira, A. M., and Andraz, J. M. (2007). Public investment in transportation infrastructure and economic performance in Portugal. *Journal of Economic Development,* Vol 32. No. 1.

Phillips, P. C. B., and Hansen, B. E. (1990). Statistical inference in instrumental variables regression with i (1) processes. *Review of Economic Studies*, 57(1), 99-125.

Pol, P. M. J. (2003). The economic impact of the high-speed train on urban regions. *General Information*, 10(1), 4-18.

Poncet, S. (2006). Provincial migration dynamics in China: borders, costs and economic motivations. *Regional Science & Urban Economics*, 36(3), 385-398.

Porter, M. E. (1990): The Competitive Advantage of Nations, Macmillan, Houndmills.

Preston, J., and Wall, G. (2008). The ex-ante and ex-post economic and social impacts of the introduction of high-speed trains in South East England. *Planning Practice and Research,* 23, 403-422.

Puga, D. (1999). The rise and fall of regional inequalities. *European Economic Review*, 43, 303-334.

Railway technology. (2012). China's high-speed rail revolution. [Online]. http://www.railway-technology. com/features/feature124824.

Redding, S., and Venables, A. J. (2004). Economic geography and international inequality. *Journal of International Economics*, 62(1), 53-82.

Roberts, M., Deichmann, U., Fingleton, B., and Shi, T. (2012). Evaluating China's road to prosperity: A new economic geography approach. *Regional Science and Urban Economics*, 42, 580–594.

Rodríguez-Pose, A., and Di Cataldo, M. (2015). Quality of government and innovative performance in the regions of Europe. *Journal of Economic Geography*, 15(4):673-706.

Roller, L. H., and Waverman, L. (2001). Telecommunications infrastructure and economic development: A simultaneous approach. *The American Economic Review*, 91(4): 909-923.

Roodman, D. M. (2009). How to do xtabond2: an introduction to "difference" and "system" GMM in Stata., 9(1), 86-136.

Rosenstein-Rodan, P. N. (1943). Problems of industrialization in eastern and south-eastern Europe, *The Economic Journal*, 53(210/211): 202-211.

Rosenthal, S. S., and Strange W. C. (2003): Geography, industrial organization, and agglomeration, *Review of Economics and Statistics*, 85, pp. 377-393.

Saikkonen, P. (1991). Asymptotically efficient estimation of cointegration regressions. *Econometric theory*, 7(01): 1-21.

Sembenelli, A., and Siotis, G. (2003). Foreign direct investment, competitive pressure and spillovers. An empirical analysis on Spanish firm level data. *Social Science Electronic Publishing.*

Shih, V., Adolph, C., and Liu, M. (2012). Getting Ahead in the Communist Party: Explaining the Advancement of Central Committee Members in China. *American Political Science Review,* 106(1), 166-187.

Song, Z., Storesletten, K., and Zilibotti, F. (2011). Growing like China. *American Economic Review*, 101(1):196-233.

Stiebale, J., and Reize, F. (2011). The impact of FDI through mergers and acquisitions on innovation in target firms. *International Journal of Industrial Organization,* 29(2), 155-167.

Stock, J. H., and Watson, M. W. (1993). A simple estimator of cointegrating vectors in higher order integrated systems. *Econometric,* 61,783-820.

Usai, S. (2011). The geography of inventive activity in OECD regions. *Regional Studies*, 45(6), 711-731.

Venables, A. J. (1996). Equilibrium locations of vertically linked industries. *International Economic Review*, 341-359.

Vijverberg, W. P., Fu, F. C., and Vijverberg, C. P. C. (2011). Public infrastructure as a determinant of productive performance in China. *Journal of Productivity Analysis*, 36(1): 91–111.

Wang, J. X., and Lin, C. H. (2011). High-speed rail and its impacts on the urban spatial dynamics in China: the background and analytical framework. *Urban Planning International*, 26(6): 16-23.

Wang, Y., and Zhou, Z. (2013). The dual role of local sites in assisting firms with developing technological capabilities: evidence from China. *International Business Review*, 22(1), 63-76.

Willigers, J., and Wee, B. V. (2011). High-speed rail and office location choices. a stated choice experiment for the Netherlands. *Journal of Transport Geography*, 19(4), 0-754.

Windmeijer, F. (2005). A finite sample correction for the variance of linear efficient two-step GMM estimators. *Journal of Econometrics,* 126: 25–51.

Witt, S. F., Song, H., and Louvieris, P. (2003). Statistical testing in forecasting model selection. *Journal of Travel Research*, 42(2): 151-158.

Wong, C. (2011). The fiscal stimulus programme and public governance issues in China, *OECD Journal on Budgeting*, 11(3), 11-11.

Wu, J. D., Ning L., and Shi, P. J. (2014). Benchmark wealth capital stock estimations across China's 344 prefectures: 1978 to 2012. *China Economic Review*, 31: 288-302.

Xu, C. G. (2017). Incentive problems in bureaucratic institutions. *China Journal of Economics*, (02), 5-17, in Chinese.

Xu, X., Wang, X., and Yuan, S. (2007). Local officials and economic growth. *Economic Research Journal*. 9, 18-31.

Yang, J., and Li, X. (2007). Education inequality, human capital and economic growth: an empirical study on China. *Journal of Quantitative and Technical Economics*, 2: 37-45.

Yu, N., Jong, M. D., Storm, S., and Mi, J. (2013). Spatial spillover effects of transport infrastructure: evidence from Chinese regions. *Journal of Transport Geography,* 28(4), 56-66.

Yu, S., João, D. A. E. S., and Luis, M. M. (2014). Assessing high-speed rail's impacts on land cover change in large urban areas based on spatial mixed logit methods: a case study of Madrid Atocha railway station from 1990 to 2006. *Journal of Transport Geography*, 184–196.

Zhang, E. (2010). Economic Growth and local governors' entrepreneurial background – evidence from the secretary of the CPC provincial committee and provincial governor. *China Industrial Economics*, 3(264), 129-138.

Zhang, J., Wu, G., and Zhang, J. (2004). The estimation of China's capital stock at province-level: 1952-2000, *Economic Research Journal*, 39: 35-44, in Chinese.

Zhang, J., and Zhao, Z. (2013). Measuring the income-distance tradeoff for rural-urban migrants in China. *Social Science Electronic Publishing*.

Zheng, S, Q., and Kahn, M, E. (2013). China's bullet trains facilitate market integration and mitigate the cost of megacity growth. *Proceedings of the National Academy of Sciences*, 110(14): E1248- E1253.

Zhong, J. (2019). Biased technical change, factor substitution, and carbon emissions efficiency in China. *Sustainability*, 11(4), 955.