Economic Policies, Regional Inequality, and Growth：

Evidence from China

（経済政策、地域間格差と経済成長：中国のケース）

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2013.5

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Abstract

This dissertation empirically examines the impact of economic policies on regional inequalities and growth in China from three aspects, focusing on the trade-off between spatial equality and spatial efficiency.

The first aspect of this dissertation concerns spatial equality in terms of the geographic distribution of industries across regions in China. A dynamic panel data model is estimated to examine the impacts of economic policies on industrial specialization and regional concentration of China's high-tech industries from 1996 to 2005. It is found that the implementation of high-technology-oriented export policy and subsidy for science and high-technology activities encourage specialization and concentration, whereas local governments' protection for local high-tech enterprises results in convergence in regional industrial structure and obstructs regional concentration of high-tech industries.

The second aspect of this dissertation concerns spatial equality in terms of the geographic distribution of workers and their wages across regions in China. Using micro-data from the Chinese Household Income Projects (2002), a wage compensating differential model is estimated to examine the impact of urban infrastructure on wages and rents in Chinese cities in 2002. It is found that wages are relatively higher in cities with better urban infrastructure. The productivity effect generated by an improvement on urban infrastructure is greater than the amenity effect, so that urban infrastructure plays a more important role in influencing the demand side of urban labor market. It is also found that urban infrastructure policy unevenly affect the structure of wages. Returns to education are relatively higher, whereas returns to experience are relatively lower in cities with better infrastructure.

The third aspect of this dissertation concerns the trade-off between spatial equality and spatial efficiency in terms of industrial location, income distribution, and economic growth. Using a simultaneous equations approach, this dissertation empirically investigates the impact of two types of public infrastructure, transportation infrastructure and knowledge infrastructure, on industrial geography, regional income disparities and growth across 286 cities in China. It is found that an improvement in transportation infrastructure that reduces trade costs on goods increases growth and decreases income gap at the expense of increasing industrial agglomeration between cities. Therefore, this paper confirms the existence of a trade-off between spatial equity (more even spatial distribution of economic activities) and spatial efficiency (higher growth rate). However, for knowledge infrastructure that reduces trade costs on ideas, it is found that it increases growth but also decreases income gap and industrial agglomeration simultaneously. Moreover, the impact of knowledge infrastructure is found to be larger in the case of high labor mobility.

Acknowledgement

I wish to express my sincere appreciation to my supervisor, Professor Tatsuaki Kuroda, for his patient and conscientious guidance in the past three and half years. I would also like to thank the other members of my dissertation committee, Professor Jiro Nemoto, Professor Makoto Takahashi, and Associate Professor Nakano Makiko, for their helpful comments and suggestions on my dissertation.

I gratefully acknowledge financial support China Scholarship Council (CSC) via a scholarship under the State Scholarship Fund. I also wish to thank the *Annals of Regional Science* and *The Developing Economies* for their permission to reprint my papers which have been published on these two journals, as the third and fifth chapter of this dissertation.

I also wish to thank many other professors and classmates who offer helpful comments and warm supports on my study and life in the past three and half years: Professor Masahisa Fujita, Professor Daozhi Zeng, Professor Xiaoping Zheng, Professor Minjun Shi, Ms. Dongni Peng, Mr. Anrong Gao, and Mr. Qingmin Huang.

Finally, I would like to thank my family and friends for their constant support and encouragement throughout the happiest years we have had together.

To my supervisor, family and friends

Chapter 1 Introduction

From the spatial point of view, the geographic distribution of population and economic activities are significantly uneven across cities, regions, and countries. There are many factors influencing the distribution of economic activities. At a high abstraction level, spatial imbalances have two possible explanations (Ottaviano and Thisse, 2002). First, the uneven distribution of production activities is the outcome of the uneven distribution of natural resources (e.g., mines), or the physical landscape (e.g., access to sea). These factors are summed up as the first nature, which are closely related to location's natural or geographical endowments. With the presence of first nature, it is easily to understand the high level of specialization of resource-dependent industries in resource-abundant regions (e.g., the geographical concentration of oil industry in Mid-east countries). However, it is difficult to use the first nature to explain the emergence of high-tech industrial clusters, such as Silicon Valley in U.S., or the high concentration of joint-ventures in eastern coastal China during the period of reform and opening up. These factors that determine industrial locations are summed up as second nature, which are often related to human actions and economic incentives (e.g., scale economies or knowledge spillovers). The aim of this dissertation is to examine the impact of exogenous economic policies on the second nature, and thereby on regional economic geography, after controlling for the first nature.

With its vast territory and significant spatial variations in natural resources, geographic conditions, as well as institutional setting, China offers a valuable case for study on economic geography. China has been a socialist country since 1949, from which point the government has played a predominant role in the economy. Worden *et al.* (1987) summarizes the role of government in China as follows:

> "Under China's socialist political and economic system, the government was explicitly responsible for planning and managing the national economy. The State Constitution of 1982 specifies that the state is to guide the country's economic development and that the State Council is to direct its subordinate bodies in drawing up and carrying out the national economic plan and the state budget. A major portion of the governmental apparatus was devoted to managing the economy; all but a few of the more than 100 ministries, commissions, administrations, bureaus, academies, and corporations under the State Council were concerned with economic matters."

The central, communist structure allows China's government to implement economic policy much easier and faster than other large economies like U.S., or Japan. This makes it easier to dictate the country's direction in times of economic need or crisis, without the back-and-forth debates and indecision seen elsewhere. In this sense, economic policy plays an important role in stimulating regional growth and influencing the geographical distribution of economic activities in China.

Ever since its foundation in 1949, China has adjusted its regional development strategy three times. The first stage (1949-1978) is characterized as balanced development which highlights balance development across regions with the implementation equality-focused policies. The second stage (1979 -1990) is characterized as efficiency-focused development with the implementation of reform and opening up in eastern regions. The third stage (1991- present) is characterized as coordinated development, which re-focuses the balance between equality and efficiency policies to promote the undeveloped inland regions and reduce regional disparities.

From the perspective of spatial efficiency, the implementation of economic reform and opening up in 1978 has been regarded as one of the most successful strategy of national development in the 20th century. Within three decades, China has succeeded in transforming itself from a central-planned closed economy into a globally-integrated market economy. The dynamics unleashed by Deng Xiaoping's reforms, open-door policies and institutional changes have unleashed enormous entrepreneurial energy and propelled continuous capital accumulation, productivity gains, as well as trade and income growth on an unprecedented scale (Golley and Song, 2010). China's GDP has averaged 9.4% per annum during the period of 1978-2004, which is a 200% increase compared with the average growth rate during the pre-reform period (1960-1978)[1].

From the perspective of spatial equality, all regions in the country have achieved dramatic increase in their economies since the implementation of reform and opening. However, as the speed of development has varied, the disparities among the regions have been widened to a certain extent. Research on post-Mao China has revealed the

[1] Data source: Various issues of China Statistical Yearbook and author's calculation.

intensification of China's coastal-interior divide, although interprovincial inequality on the whole declined in the 1980s (Fan, 2005; Wei, 2000; Peng *et al.* 2002). In 2008, per capita income in coastal cities averaged 7340.76 yuan[1], which is more than 1.4 times that for inland cities. Income disparity between cities is even larger. Per capita income in the richest city Suzhou is nearly 30 times as large as in the poorest city Dingxi[2]. Meanwhile, manufacturing sector also shows a trend of concentration. The share of nine eastern coastal provinces in total manufacturing output increases from 54% in 1978 to 67% in 2008[3]. Since the 1990s, central government turns to pay more attention to the development of the central and western parts of the country, introducing policies which are conducive to slow down the increasing regional disparities.

This dissertation empirically examines the impact of economic policies on regional inequalities and growth in China, focusing on the trade-off between spatial equality and spatial efficiency. In the beginning of this dissertation, Chapter 2 reviews the evolution of China's economic policies over the past six decades, paying attention to the transformation of government's focus in three time period: central-planned economy period (1949-1978), transition period towards market economy (1979-1990), and post-transition period (1991-present). The implementation of economic policies of each time period is also discussed in terms of background, characteristics, and achievements.

The empirical analysis of this dissertation consists of three parts. The first part concerns spatial equality in terms of the geographic distribution of industries across regions in China. In Chapter 3, a model with quadratic utility and linear transport costs is adopted as the theoretical framework underlines the empirical analysis. The theoretical model implies the implantation of economic policies influences the fixed cost of firm's production, as well as the transaction costs between regions, and thereby influences industrial agglomeration in the long run equilibrium. Underling by this model, a static and a dynamic panel data model is respectively estimated to exam the impacts of economic policies on industrial specialization and regional concentration of China's high-tech industries for the period 1996 to 2005. It is found that the implementation of high-technology-oriented export policy

[1, 2, 3] Data source: China City Statistical Yearbook (2009) and author's calculation.

and subsidy for science and high-technology activities encourage specialization and concentration, whereas local governments' protection for local high-tech enterprises results in convergence in regional industrial structure and obstructs regional concentration of high-tech industries.

The second part of the empirical analysis concerns spatial equality in terms of the geographic distribution of workers and their wages across regions in China. In Chapter 4, a wage compensating differential model of urban infrastructure is developed to explain how urban infrastructure policies influence worker's and firm's location decisions in the presence of heterogeneous workers. The wage compensating differential model assumes an increase in the level of urban infrastructure will increase worker's utility through an amenity effect, and decrease firm's production cost through a productivity effect. Given this assumption, urban infrastructure has either a direct or an indirect impact on income distribution and returns to workers characteristics. To examine the theoretical conclusions of wage compensating model, an empirical analysis is conducted using a cross-section dataset of Chinese cities and individuals for the year 2002. It is found that wages are relatively higher in cities with better urban infrastructure. The productivity effect generated by an improvement on urban infrastructure is greater than the amenity effect, so that urban infrastructure plays a more important role in influencing the demand side of urban labor market. It is also found that urban infrastructure policy unevenly affect the structure of wages. Returns to education are relatively higher, whereas returns to experience are relatively lower in cities with better infrastructure.

The third part of the empirical analysis concerns the trade-off between spatial equality and spatial efficiency in terms of industrial location, income distribution, and economic growth. In Chapter 5, a NEG model incorporates growth is adopted as the theoretical framework underlines the empirical analysis. The NEG model assumes two types of public infrastructure, transportation infrastructure and knowledge infrastructure. Each infrastructure plays a different role in stimulating growth and reducing regional inequalities, indicates a trade-off exists between spatial efficiency and spatial equality. To verify the existence of such trade-off and to examine the different role of each public infrastructure, a simultaneous equation model is estimated using a cross-section dataset of Chinese cities and individuals. It is find that an improvement in transportation infrastructure increases growth and decreases income gap at the expense of increasing industrial agglomeration between cities, confirming the existence of a trade-off between spatial equality (more even spatial distribution of economic activities) and spatial efficiency (higher growth rate). On the contrary, an improvement in knowledge infrastructure increases growth, decreases income gap and industrial agglomeration simultaneously. Moreover, the impact of knowledge infrastructure is found to be larger in the case of high labor mobility.

Lastly, Chapter 6 concludes the dissertation and provides some policy suggestions.

Chapter 2 China's Economic Policy and Regional Development Strategy

2.1 Introduction

Planning is a key characteristic of centralized, communist economies, and one plan established for the entire country normally contains detailed economic development guidelines for all its regions. The five-year plans of China are a series of social and economic development initiatives. The economy was shaped by the Communist Party of China (CPC) through the plenary sessions of the Central Committee and national congresses. The party plays a leading role in establishing the foundations and principles of Chinese communism, mapping strategies for economic development, setting growth targets, and launching reforms.

Since 1953, China has announced 12 Five Year Plans up to now. The contents of these five-year plans changed significantly over years and reflected China's transition from a Soviet-style planned economy to a socialist market economy (socialism with Chinese characteristics). This Chapter reviews the evolution of China's economic policy and regional development strategy since 1949. Economic policies are broadly grouped into three periods according to their focus on equality and efficiency.

The reminder of this Chapter is organized as follows: Section 2.2 reviews the equality-focused economic policies implemented during the central-planned economic period. Section 2.3 reviews the efficiency-focused policies implemented during the transition period towards market economy period. Section 2.4 reviews the adjustment and re-focuses on regional equality policies.

2.2 Central-planned Economy Period: Equality-focused Policy (1949-1978)

In the early 1950s, the spatial distribution of economic activities facing the new people's regime was extremely uneven across regions. The east coast region was relatively developed; the central region was at a lower level of development than the east coast: and the west region was underdeveloped with the poorest economic and cultural conditions. The East coast region accounts for 69.4% in total output value of manufacturing, with only

40.6% in the population and 13.6% in total land, whereas the west region accounts for only 8.9% in total output value in manufacturing, with 23.2% in the population and 55.9% of the total land (Guo, 1988).

Given the uneven distribution of production activities, central government planned a balanced development strategy. Equality-focused policies were implemented to reduce regional inequality through a mandatory allocation of industries and productive factors in central and west regions. As stated in China's first Five Year Plan (1953-1956):

> "The regional distribution of industrial construction should be based on long-term national interest. Industry should be located rationally, close to the regions producing raw materials and fuel or regions with highest consumption in the country, and for the benefit of the consolidation of national defiance, so as to gradually improve this unreasonable situation (the concentration of industries in east coast) and raise the economic development of those backward regions."

The key tasks highlighted in the plan were to concentrate efforts on the construction of 694 large and medium-sized industrial projects, including 156 with the aid of the Soviet Union, so as to bulid the primary foundations for China's socialist industrialization. Within industry, iron and steel, electric power, coal, heavy engineering, building materials, and basic chemicals were given first priority. From 1953 to 1962, 472 out of 694 key construction projects were located in the northeast, central and western regions.

Together with the construction and relocation of industrial enterprises, skilled labor forces are also planned to be transferred from eastern to central and western regions. Transfer varies in the following patterns: (1) planned migration of enterprises, including managers, technicians and workers; (2) transfer of key personnel from economic activities in the east coast regions to enhance the new industrial bases in the central and western regions; (the assignment of college students to the central and west regions); and (3) the assignment of troops to settle in the sparsely populated far west regions such as Xinjiang. Since the 1950s, Shanghai has transferred 1.5 million skilled workers and technicians to the inland regions (Guo, 1988).

From the early 1960s, with its Soviet ties deteriorating and the Vietnam War escalating, China became concerned of a possible nuclear attack. As a result, central government ordered an evacuation of military and other key state enterprises away from Shanghai and other coastal areas as well as from the northeastern frontier region bordering the Soviet Union. In 1964, these enterprises were moved to the interior in Sichuan, Guizhou, Yunnan and other inland provinces. This would later become known as the "Third Line" project[2], which aimed to build a range of industrial bases in China's remote yet strategically secured hinterland. To further secure these "Third Line" industrial areas, central government ordered that industrial projects be located "in mountains, in dispersion and in caves" to protect them from possible air strikes.

Figure 2.1 shows the geographic distribution of production activities in terms of regional share in the total number of state-owned enterprises for the period of central-planned economy[3]. In 1952, with eastern region accounts for 50% of state-owned enterprises, industry is evenly distributed across east and inland regions (including Central and Middle regions). With the implementation of a series of balanced-development policy, a great number of enterprises are designed to relocate to inland regions, which is reflected by a 9% increase of inland share in total numbers of stated-owned enterprises in 1978.

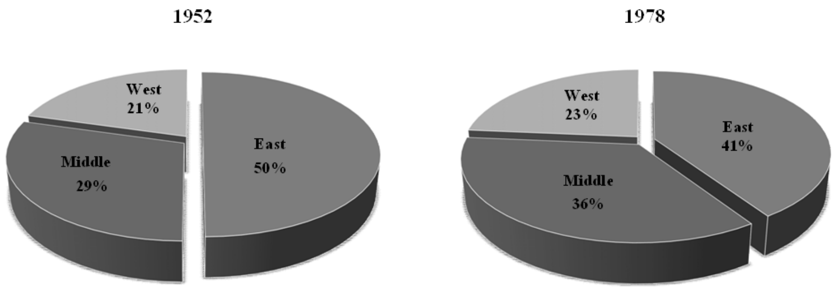

Figure 2.1 Share of State-owned Enterprises in China (1952 and 1978)

[2] In those days, the coastal and the northeastern frontier regions were known as the "first front line" and the inland regions in the southwest as the "third front line", whereas all the land area in between were designated as the 'second front line.

[3] Data source: Comprehensive statistical data and materials on 50 years of new China and author's calculation.

China has implemented the unified urban wage system during the period of the central planned economy. Wages were designated into different levels for different types of occupation. The country was divided into 12 wage districts, with the remote minority regions or those with a higher living cost being allocated a higher ranking so as to achieve an overall convergence of real income for workers in the same level of occupation but in different regions. A number of privileges, such as reduction or remission of taxes and public subsides, were granted to the underdeveloped regions.

Table 2.1 shows the trends and changes of income distribution during the period of the central-planned economy[4]. Columns one and three report the average employee wages of state-own enterprise, whereas columns two and four report the difference between national averages for each province. First, the wage disparity across regions shows a trend of convergence during the central-planned economy period. In 1952, eastern municipality Shanghai has the highest average wage of 782 yuan, which is 2.8 times as much as the average wage of western province Guizhou. This wage disparity was reduced dramatically in 1978: Westen province Qinghai has the highest average wage of 907 yuan, which is 1.8 times more than that of the eastern province Jiangsu, which has the lowest average wage of 513 yuan.

Second, the bottom part of Table 2.1 reports the average wage for East, Central, and West regions, respectively. It is shown that the average wage level of central and western regions surpassed that of the eastern regions in 1978. In this sense, central government achieved its objective to reduce regional inequalities.

In summary, the most significant characteristic of economic geography during the central-planned economy period is the even distribution of industrial productivity and income across regions. From the perspective of spatial equality, the implementation of equality-focused economic policy successfully adjusts the imbalance between east and inland regions. The industry policy that favors heavy industries constructed a group of heavy industry bases, which greatly improved economic development in relatively underdeveloped inland regions. Key industries, including iron and steel manufacturing, coal

[4] Data source: Comprehensive statistical data and materials on 50 years of new China and author’s calculation.

mining, cement production, electricity generation, and machine buildings extensively expanded and were positioned on a firm, modern technological footing.

Table 2.1 Trends and Changes of Income Distribution by Provinces

	1952		1978		1952-1978
	Average wage	Difference	Average wage	Difference	Change
Beijing	544	92.79	673	37.11	19.2%
Tianjin	573	121.79	640	4.11	10.5%
Hebei	435	-16.21	692	56.11	37.1%
Liaoning	549	97.79	637	1.11	13.8%
Shandong	362	-89.21	597	-38.89	39.4%
Shanghai	782	330.79	672	36.11	-16.4%
Jiangsu	421	-30.21	513	-122.89	17.9%
Zhejiang	421	-30.21	544	-91.89	22.6%
Fujian	334	-117.21	567	-68.89	41.1%
Guangdong	387	-64.21	615	-20.89	37.1%
Heilongjiang	508	56.79	721	85.11	29.5%
Jilin	480	28.79	651	15.11	26.3%
Inner Mongolia	454	2.79	712	76.11	36.2%
Shanxi	675	223.79	632	-3.89	-6.8%
Shaanxi	495	43.79	654	18.11	24.3%
Anhui	400	-51.21	543	-92.89	26.3%
Henan	347	-104.21	590	-45.89	41.2%
Hubei	354	-97.21	579	-56.89	38.9%
Hunan	288	-163.21	563	-72.89	48.8%
Jiangxi	338	-113.21	552	-83.89	38.8%
Guangxi	287	-164.21	543	-92.89	47.1%
Sichuan	325	-126.21	581	-54.89	44.1%
Guizhou	283	-168.21	616	-19.89	54.1%
Yunnan	371	-80.21	608	-27.89	39.0%
Gansu	499	47.79	760	124.11	34.3%
Qinghai	597	145.79	907	271.11	34.2%
Ningxia	403	-48.21	726	90.11	44.5%
Xinjiang	722	270.79	717	81.11	-0.7%
East	481	29.59	615	-20.89	21.8%
Central	434	-17.31	620	-16.19	30.0%
West	436	-15.335	682	46.36	36.1%
Average	451.21	-	636	-	29.0%

From the perspective of spatial efficiency, the balanced-development policy also suffered from the low efficiency of resource allocation and low regional growth rate. As shown in Table 2.1, the national average wage increased from 452 yuan in 1952 to 636 yuan in 1978, with an average annual growth rate of 1.12%. The mandatory fragmentation of domestic market led to a large scale of low-level redundant development, which led to remarkable similarities in economic structure.

2.3 Transition Period towards Market Economy: Efficiency-focused Policy (1979-1990)

In the late 1970s, Deng Xiaoping and other policy-makers began to re-evaluate the guiding principles and policies of the previous 30 years. The main leaders of Communist Party has reached a consensus that a central-planned system was not only difficult to manage but also economically inefficient. In December 1978, the Third Plenary Session of the 11th Communist Party Central Committee shifted the work focus of the Communist Party to modernization. The Session emphasized that the development should follow economic rules and proposed readjustment and reform measures, which indicated that national economic development had entered a new phase, one of economic reform and transition. Meanwhile, guidelines for regional development began to shift from the equality-focused policy to the efficiency-focused strategy. In the 6th Five Year Plan (1981-1985), central government formally announced one of the objectives of China's development, which is "to strengthen production and improve economic efficiency".

Meanwhile, in the 7th Five Year Plan (1986–1990), economic reform was put "at the top of the agenda". Deng Xiaoping proposed the goal of reform as the Four Modernizations, those of agriculture, industry, science and technology as well as the military. The strategy used to achieve these modernizations was the socialist market economy. Deng argued that China was in the primary stage of socialism and interpreted the relationship between planning and market as follows:

> "Planning and market forces are not the essential difference between socialism and capitalism. A planned economy is not the definition of socialism, because there is planning under capitalism; the market economy happens under socialism, too. Planning and market forces are both ways of controlling economic activity."

Since the 1980s, the economic system has been gradually reformed from a highly central-planned economy to a market-oriented economy. Such a process of economic transition was conceptualized as a process of globalization and decentralization, which exerted profound impacts on regional economic development.

First, following the 6th (1981–1985) and 7th Five Year Plan (1986–1990), China gradually opened up to the outside world, combining domestic economic growth with expanding external economic and technological exchanges. Since the 1980s, opening to trade and utilizing foreign direct investments (FDI) have become the key components for regional development.

In the 1980s, central government passed several stages, ranging from the establishment of special economic zones as well as opening coastal cities and areas to the designation of open inland and coastal zones for economic and technology development. Between 1980 and 1984, China established special economic zones (SEZs) in Shantou, Shenzhen, and Zhuhai in Guangdong Province and Xiamen in Fujian Province and designated the entire island province of Hainan a special economic zone. In 1984 China opened 14 other coastal cities to overseas investment (listed north to south): Dalian, Qinhuangdao, Tianjin, Yantai, Qingdao, Lianyungang, Nantong, Shanghai, Ningbo, Wenzhou, Fuzhou, Guangzhou, Zhanjiang, and Beihai. Then, beginning in 1985, the central government expanded the coastal area by establishing the following open economic zones (listed north to south): Liaodong Peninsula, Hebei Province (which surrounds Beijing and Tianjin), Shandong Peninsula, Yangtze River Delta, Xiamen-Zhangzhou-Quanzhou Triangle in southern Fujian Province, Pearl River Delta, and Guangxi.

In 1990 the Chinese government decided to open the Pudong New Zone in Shanghai and more cities in the Yang Zi River Valley to overseas investment. Since 1992 the State Council has opened a number of border cities and all the capital cities of inland provinces and autonomous regions. In addition, 15 free-trade zones, 32 state-level economic and technological development zones, and 53 new and high-tech industrial development zones have been established in large and medium-sized cities. As a result, China formed a multilevel diversified pattern of opening and integrating coastal areas with river, border, and inland areas. Adopting different preferential policies, these open areas play the dual roles of “windows” in developing the foreign-oriented economy, generating foreign exchanges through exporting products as well as importing advanced technologies and of “radiators” in accelerating inland economic development.

China has undertaken a series of reforms in the foreign trade system while running the special economic zones. Such reforms include the expanding local governments' examination, approving authority over foreign trade and exports, as well as enlarging foreign trade enterprises' autonomy over export trade and operations. Consequently, the old system featuring monopolized operation by the state, highly centralized management, integration of government administration with enterprise operations and the state assuming responsibility for profits and losses has basically been changed. The state gradually reduced the mandatory plans for foreign trade enterprises. A management system was established step by step to indirectly regulate and control foreign trade through Customs duties, foreign exchange rates, credits and tax refunds.

Since the founding of the first Sino-foreign joint venture in 1980, China has taken the utilizing of foreign capital as an important aspect of basic state policy, and great efforts have been made to promote it. In the beginning Sino-foreign joint ventures first entered the processing industry, and later they expanded toward the basic industries and export-oriented enterprises, commerce, finance, information, consultation, real estate, and other fields. Foreign investments have become an important capital source for China's economic construction. In 1999, direct foreign investments in real terms totaled 40.3 billion US dollars; and projects with direct foreign investment numbered 16,918. Between 1979 and 1999, of foreign capital utilized by China, the accumulative total of direct foreign investment came to 305.9 billion US dollars. By 1999, China had approved the founding of 342,000 foreign-funded enterprises, of which over 100,000 have gone into operation[5].

Economic reform in China facilitated growth both by enhancing incentives for managers and workers (increasing technical efficiency) and by promoting allocative efficiency through mobility of capital and labor away from uses in which China does not have a comparative advantage (Desai and Martin, 1983; Lin *et al.*, 1996). However, the progress of reform was uneven in terms of time, type, and geographical transmission. Although resources were allocated more efficiently among industries within provinces and regions, the benefits of reform differed across regions from the perspective of spatial equality (Cai,

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[5] Data source: China statistical yearbook.

et al., 2002). The preferential policies received by the coastal provinces played an important role in accounting for growth and regional disparity in China (Démurger, 2001).

Second, together with the process of reform and opening up, fiscal decentralization began in 1980 and took the form of tax contracting between central government and local governments. The purpose of this reform is to allow local governments have more and more powers in financing their needs, and gradually build up their accountability.

The initial reform was conducted in Jiangsu province in 1977. As an experimental province, Jiangsu was contracted to remit a share of its total revenue each year to central government. The share was determined by historical record of local revenues and expenditures of the province. From 1980 to 1984, the reform was successively implemented in other provinces using a variety of contracting methods. The basic concept was apportioning revenues and expenditures between the central and local authorities while holding the latter responsible for their own profits and losses. There were three basic types of revenues under the reformed system: central-fixed revenues, local-fixed revenues, and shared revenues. Approximately 80% of shared revenues were remitted to the central government and 20 % were retained by local governments. The bases and rates of all taxes, whether shared or fixed, were determined by the central government. Enterprises were supposed to pay taxes to the level of government to which they were subordinate. Most revenues were collected by local finance bureaus (Shen *et al.,* 2012).

The uniform-sharing formula reform during from 1980 to 1984 created large surpluses in affluent provinces but also deficits in poor provinces. In 1985, the State Council redesigned revenue-sharing arrangements by varying schedules based on localities' budget balances in previous years. The financially weak provinces were allowed to retain more revenues, but the wealthier regions, like Shanghai, Beijing, Tianjin, Liaoning, Jiangsu, and Zhejiang, were penalized by a requirement to remit more revenues to the center. As a consequence, the revenues from these regions generally grew more slowly than the national average, since the high level of remittance curbed local enthusiasm for expanding their tax bases.

In 1988, the fiscal contracting system gradually formed into six contracting categories: (1) Incremental contracting, (2) Basic Proportional sharing, (3) Proportional sharing and incremental sharing, (4) Remittance incremental contract, (5) Fixed remittance, (6) Fixed subsidy. The contracting fiscal system gave sub-national governments a certain space to decide their own affairs (a kind of fiscal deregulation), encouraging them to develop regional economy and collect revenues.

Fiscal decentralization increases the efficiency of resources allocation, which contributed significantly to economic growth (Lin and Liu, 2000). Nevertheless, the different contracting methods were too complicated and unjust, enlarging fiscal gap between different regions. The rich province with more bargaining power (e.g., Guangdong) benefited more from a favorable contract system.

Moreover, research on reform and opening up implies that domestic decentralization may trigger interregional protection. By decentralization, the central government delegates the following three functions to local governments during the reform period: fiscal responsibility and taxation authority, investment and financing authority, and the authority of managing enterprises (Li, *et al.*, 2003). After the decentralization, local governments gained greater incentives to protect local firms to generate more revenues exclusively for their regions (Yin and Cai, 2001).

2.4 Post-transition Period: Balance between Equality and Efficiency Policy (1991-present)

The Fifth Plenary Session of the 14th CPC Central Committee adopted the Proposal on the 9th Five Year Plan on National Economy and Social Development and Long-Range Objectives to the Year 2010 on September 28, 1995. As the first medium-length plan made under a socialist market economy, the 9th Five Year Plan (1996-2000) emphasized adjustment and balance between equality and efficiency in both China's industrial structure and regional development.

First, in the main move toward market allocation, China took advantage of its low cost production factors to actively participate in domestic and foreign market competition in an open manner, rapidly expanding production capacity and market share. Local municipalities and provinces were allowed to invest in industries that they considered most profitable, which encouraged investment in light manufacturing. Therefore, Deng's reform gradually adjusted the heavy industry-based development strategy of the central-planned period. As announced in the 9th Five Year Plan (1996-2000), the objective in relation to industry development is "actively promote readjustment in industrial structure", which highlights the importance of developing light industries and high-tech industries as follows:

> "Developing light industry and textiles is of major importance in meeting the daily needs of the people, expanding exports and accumulating funds for construction. We must accelerate the readjustment of the product mix to adapt to the changes in the domestic and international market. We must improve product quality and increase variety and specifications, thus enhancing product competitiveness."

> "……developing high and new technologies and the related industries, striving to approach or reach the world's most advanced level in some important areas, transform traditional industries with new and high technology and run well the high technology industrial development areas. Strengthen scientific and technological development in fields on the cutting edge of science and technology. Deepen the reform of the management systems in science and technology and accelerate the integration of scientific research, development and production with the market."

Second, in 1995, central government proposed a strategy of "coordinated development of regional economies", which is a guideline to correctly handle the relationships between the overall development of the national economy and the development of regional economies. In particular, central government turned to pay more attention to the development of the central and western parts of the country, implementing region-preferential policies that help to reduce the significantly regional disparities across east and inland regions. The 9th Five Year Plan summarized the region-preferential policies as follows:

> " (1) stepping up resources surveying in the central and western parts of the country, giving priority to resource development and infrastructure projects and gradually increasing financial support to these regions and the investment in their construction; (2) adjusting the distribution of the processing industries by guiding the transfer of resource-processing and labor-intensive industries to the central and western parts of the country; (3) rationalizing the prices of resources products so as to enhance the self-development capabilities of the central and western regions; (4) improving the investment environment in the central and western parts of the country and directing more foreign investment towards these regions; (5) strengthening economic association and co-operation between the eastern and the central and western parts of the country; (6) encouraging the eastern part to invest more in the central and western parts and directing talented personnel flow towards these regions. The strategy of coordinated development was further emphasized in the 10th Five-Year Plan (2001-2005), which formally proposed the implementation of "Western China Development" strategy."

"Western China Development" strategy began in 2000. As shown in Figure. 2.2, the policy covers 6 provinces (Gansu, Guizhou, Qinghai, Shaanxi, Sichuan, and Yunnan), 5 autonomous regions (Guangxi, Inner Mongolia, Ningxia, Tibet, and Xinjiang), and 1 municipality (Chongqing). This region contains 71.4% of mainland China's area, but only 28.1% of its population, and 19.9% of its total GDP, as of the end of 2000[6].

The main components of the strategy include the development of infrastructure (transport, hydropower plants, energy, and telecommunications), enticement of foreign investment, increased efforts on ecological protection (such as reforestation), promotion of education, and retention of talent flowing to richer provinces.

[6] Data source: Author's calculation and China Statistical Yearbook (2001).

Figure 2.2 Regions Involved in "Western China Development" Strategy

Between 2000 and 2005, 70 main construction projects were started, and the total amount of investment reached 1 trillion yuan. More than one-third of the funds raised by long-term government bonds for construction were directed toward the western region during this period, and the percentage exceeded 40% from 2002 to 2005. Approximately 220,000 kilometers of new roads were built in the region in the six years of 2000–05, among which 6,853 kilometers were highways. In addition, 5,000 kilometers of railways were built, and 10 airports were under construction. Among these projects, some, such as the Qinghai-Tibet Railway, West-East Power Transmission Project, and West-East Natural Gas Pipeline Project, have become national landmarks (Yao, 2009).

GDP per capita of Western China grew much faster after "Western China Development" strategy. From 1991 to 2000 average annual growth rate of real GDP per capita was only 6.6%, then it rose to 13.26% from 2001 to 2010. Western China's ratio of GDP per capita to national GDP per capita ended descending trend and began to rise after "Western China Development" strategy. The GDP per capita rose from 61.24% in 2000 to 71.28% in 2010 (Zheng and Deng, 2009).

In recent years an exciting performance of China's economic development is that China's interregional disparities has put up a declining trend (Liu and Zhang, 2007; Fan and Sun, 2008). Nevertheless, Western China's intraregional disparities have enlarged significantly after "Western China Development" strategy. Theil index based on real GDP per capita of western regions rose from 0.031 in 2000 to 0.065 in 2010 (Zheng and Deng, 2009).

As summarized in this chapter, the evolution of China's economic policy and regional development strategy reflects the transformation of central government's focus between efficiency and equality. The implementation of different economic policies also plays an important role in affecting economic geography and regional development for different time periods. This dissertation turns to examine the impacts of economic policies in the following three chapters.

3. Economic Policies and Industry Distribution

3.1 Introduction

China's regional industrial policy has gone through remarkable changes during the past decades. Until the late 1970s, based on heavy-industry-oriented development strategy and the consideration of national security, most manufacturing enterprises are designed to locate dispersedly across regions. This mandatory fragmentation of domestic market leads to remarkable similarities in economic structure and thus low level of regional specialization. Since the 1980s, policymakers shifted their attention to the promotion of high-tech industries, aiming to upgrade traditional manufacturing and rejuvenation export by making full use of science and high technology. In 1988, the State Council of China officially approved "Torch Program" as a main national guideline for accelerating the development of high-tech industries in China[7]. With the general purpose of reinforcing the overall environment for technology innovation and promoting high-tech industrialization, "Torch Program" includes various high-tech development projects and policies, such as organizing and carrying out projects of developing high-tech products with high technological standards and good economic benefits in domestic and foreign markets; establishing some high-tech industrial development zones around China; improving the financing and investment system for high-tech industrialization.

Following central government's plan, local governments are committed to develop high-tech industries through various approaches such as high-tech-oriented export policies, subsides to high-tech-related activities and establishment of high-tech industrial bases. In addition to these promotion policies, local protectionism also plays an important role in the geographic distribution of industries. China's reform on central-planned economy has led to both administrative and fiscal decentralization. This, in turn, gives local government more authorities but also more incentives to pursuit more tax revenues by protect local manufacturing.

[7] Beginning in the 1980s, China formulated a series of general programs for scientific and technological research and development, aiming to improve China's competitiveness in science and technology in the 21st century. The specific introduction of these programs is provided in Appendix 3.1.

So far, these high-tech industry promotion and protection policies have been implemented for more than two decades. China's high-tech industry has scored world-acclaimed achievements: China boasts the first largest high-tech export in the world in 2012, stepping into a new phase of growth. The scale of the high-tech industry in the three regions of the Yangtze River Delta, the Pearl River Delta, and Bohai Bay accounts for more than 80% of the national total since 1990s. Major cities in these three regions have become core areas of industrial development with accelerated development of industrial bases of bio-medicine, aviation and aerospace, micro-electronics, photoelectron and software[8].

Given the significantly uneven distribution and rapid growth of high-tech industries, several questions arise: To what extent is the high-tech industry sector geographically concentrated? What is the impact of promotion and protection policies on high-tech industrial location? This chapter attempts to answer such questions by addressing two empirical issues in relation with high-tech industry location and economic policies. First, a dissimilarity index of specialization is used to investigate changes in the high-tech industrial specialization from 1996 to 2005. Second, using static and dynamic panel data analysis, this chapter empirically examines the impact of both promotion and protection policies on high-tech industrial structure while controlling for other driving forces that have been proposed by theories.

The reminder of this chapter is organized as follows: Section 3.2 reviews literature in relation to industrial specialization and regional concentration. Section 3.3 briefly describes the geographic distribution of high-tech industry sector and measures industrial specialization and regional concentration of China's high-tech industries by calculating the dissimilarity indices. Section 3.4 introduced a model which is used as the theoretical framework of the following empirical analysis. Section 3.5 presents the empirical framework, which includes: model specification, estimation methods, and results. Section 3.6 concludes this chapter.

[8] Data source: China Statistics Yearbook on High Technology Industry (2012) and author's calculation.

3.2 Review of Related Literature

Substantial theoretical studies have provided explanations for the driving forces that impact the geographical distribution of economic activities. Neo-classical trade theory suggests that industrial specialization depends on comparative advantage that is determined by cross-region disparities in the relative abundance of factor endowments (Ohlin, 1935). In a model of two regions (North and South), two tradable goods (food and machinery), and two factors of production (high-skilled labor and low-skilled labor), suppose that North is relatively well endowed with high-skilled labor, and South with low-skilled labor. Production of both goods requires both factors, but the production of machinery is relatively high-skilled intensive. In a closed economy, North can more efficiency produce machinery which is high-skilled intensive than South. This results in relatively low prices for machinery in North and food in South. With bilateral trade that incurs no transport costs, prices will be equalized, which results in a higher price for machinery in North and a higher price for food in South. Consequently, North and South will have incentive to specialize in the production of machinery and food, respectively. The factor abundance model thus accounts for regional patterns of specialization as a result of regional disparities in endowments, such as nature resources, technologies and human resources.

Contrary to the limited role for geography in neo-classical trade theory, in New Economic Geography (NEG) models, the location of production emerge endogenously. Krugman (1991) develops a two-region, two-good model involving labor mobility, plant-level scale economies and transport costs. Monopolistic firms tend to locate their production in large markets so as to save on transport costs. Firms' location choice in turn impacts local market condition. Goods tend to be cheaper in the region with more firms since consumers in this region will import a narrower range of products and thus avoid more of the trade costs (Baldwin *et al*. 2003). These two aspects (known as backward and forward linkages) work together to shape the distribution of production activities into a manufacturing core and an agricultural periphery. In the framework of NEG models, the location of manufacturing is highly associated with the level of transport costs. In general, further integration characterized by lower transport costs will lead to higher level of regional concentration of manufacturing.

One key issue discussed frequently in related empirical studies is to measure the trends and determinants of specialization and concentration. Kim (1995) investigates the long-run trends in U.S. regional manufacturing structure over the period 1860 to 1987. He finds that industrial specialization rose significantly from 1860 while fell substantially and continuously since the 1930s. Meanwhile, he finds that trends and changes in regional concentration of manufacturing are consistent with specialization. Manufacturing became more concentrated (dispersed) as regions become more specialized (de-specialized) during the given period. However, in the case for European countries, Midelfart-Knarvik *et al.* (2000) find an increasing trend in industrial specialization but a decreasing trend in regional concentration of EU manufacturing from the early 1980s onwards. Aiginger and Davies (2004) explain this divergence using the entropy index methodology. They find that the increasing specialization has been offset by faster growth in the smaller counties since 1980s. In turn, industries have become less concentrated across countries.

Notably, the impact of various economic policies, or the role of government in industrial geography has also been investigated broadly in recent studies from theoretical and empirical perspectives. Ludema and Wooton (2000) analyze competition between national governments using tax policies to influence the location of manufacturing activities. They find that regional integration, in terms of higher labor mobility or lower trade costs may result in a decrease in the intensity of tax competition, and thus higher equilibrium taxes. Forslid and Midelfart (2005) employ a model with vertically linked firms to examine the design of industrial policy in a high wage economy hosting an industrial cluster of vertically linked industries. Government's decision to tax or subsidize the industries in the cluster highly depends on the level of integration. Li *et al.* (2003) develops a two-regional model and examines how and when interregional trade protection may arise. They find that domestic fiscal decentralization, particularly tax reform, together with high external trade protection, cause interregional protection. As for empirical studies, Holmes (1998) examines the impact of pro-business and antibusiness policies on industrial location. He finds that on average, there is a large, abrupt increase in manufacturing activity when one crosses a state border from an antibusiness state into a pro-business state. Head *et al.* (1999) study the location choice of Japanese manufacturing establishments and evaluate the effectiveness of US state promotional policies and find that states which offered foreign trade zones, job-created subsides and low taxes are found to attract more foreign investment. Deverux *et al.* (2005) evaluate the impacts of discretionary government grants on location of new plants in UK. They find the effectiveness of grants increases as agglomeration externalities, measured by the number of other plants in that location in the same industry.

There is also a rich body of empirical literature that investigates industrial agglomeration and specialization in China. Young (2000) investigates the specialization of five sectors in China between 1978 and 1997 and finds an increasing trend of convergence in economic structure. Consequently, the reform and opening up in 1978 results in more severe segmentation of domestic market. Consistent with Young's findings, using data of inter-regional trade flows, Poncent (2003) shows that not only that the extent of regional integration, measured by the inter-provincial trade flow intensity is low, but also that it has decreased between 1987 and 1997.

On the contrary, using data from the input-output table among provinces, Naughton (2003) finds that inter-provincial trade was growing more rapidly than either provincial GDP or foreign trade between 1987 and 1992, so that national economic integration was increasing. Bai *et al.* (2004) calculate the Hoover coefficient using more disaggregated data of 32 2-digit industries and finds specialization in China increased over the period 1985 to 1997. Consistent with the conclusion of Bai et al., recent studies have provided more evidence supporting the steadily increasing trends of specialization and concentration in China since 1980s (Wen, 2004; Catin *et al*, 2005; Ge, 2009; Zheng and Kuroda, 2012).

Despite the controversy on the extent of domestic integration, empirical studies have produced clear consensus on the relationship between local protection and industrial specialization. In general, it is found that industrial agglomeration is lower in industries with greater contributions to local tax revenues and in industries with higher degrees of state ownership, suggesting the important role of local protectionism in obstructing the process of spatial concentration of manufacturing industries (Lu and Tao, 2009).

3.3 Trends and Changes of High-tech Industry Location in China

3.3.1 Definitions, Measures and Data

Industrial specialization focuses on the production structure of a specific region, and refers to the extent to which a given region concentrates its activities in a small number of industries. A region is said to be highly specialized if a few high-tech industries account for a large share of its total production. Regional concentration, on the other hand, is the extent to which production activity in a given high-tech industry is concentrated in only a small number of regions. An industry is said to be highly concentrated if a few regions account for a large share of its total output. These two terms are highly related and reflects the distribution of industries from different perspectives. Nevertheless, whether specialization and concentration changes in parallel or not varies across periods and countries[9]. For example, EU-studies investigate the location of industries find that the two terms go in different directions in 90s (Brülhart and Torstensson, 1996; Midelfart-Knarvik *et al,* 2002.; Aiginger and Davies, 2004). By contrast, this divergence is not found in the case of China, where both specialization and concentration of manufacturing as a whole shows increasing trends since 1980s.

A number of measures have been constructed to measure the geographic distribution of production activities. This chapter primarily uses a dissimilarity measures based on the Krugman specialization index (Krugman, 1991) to investigate the extent of specialization and concentration. For a country with J geographic units and I high-tech industries (J=30, I=5), q_{ij} is output of high-tech industry i for region j (i = 1, … , I; j = 1, ... , J). $Q_j = \sum_i q_{ij}$ is total output of all high-tech industries in region j. $Q_i = \sum_j q_{ij}$ is total output of all regions in industry i. $Q = \sum_i Q_j = \sum_j Q_i$ is the national total output in all high-tech industries.

The dissimilarity index of specialization $DIS_{j,k}$ compares the differences in industrial structure of region j and region k and is defined as:

[9] Specialization and concentration reflects the characteristic of a region and an industry, respectively. See Aignger and Davies (2004) for a thorough analysis on the differences and relations between the two terms.

$$DIS_{j,k} = \frac{1}{I}\sum_{i=1}^{I}\left|\frac{q_{ij}}{Q_j} - \frac{q_{ik}}{Q_k}\right| \tag{3.1}$$

Summing up the dissimilarity indices, get the specialization index of a specific region *j* as follows:

$$SPEC_j = \frac{1}{J}\sum_{j=1}^{J} DIS_{j,k} \tag{3.2}$$

The $SPEC_j$ index reflects the average level of industrial specialization of region *j*. It takes value zero if region *j* has an industrial structure identical to the other regions in a country, and takes a maximum value of 2/*I* if region *j* has no industries identical to the rest of the country.

The extent of regional concentration is measured similarly by the dissimilarity index of concentration DIC_i as follows:

$$DIC_i = \frac{1}{J}\sum_{j=1}^{J}\left|\frac{q_{ij}}{Q_i} - \frac{Q_j}{Q}\right| \tag{3.3}$$

The DIC_i index measures the degree of regional concentration by summing up the absolute differences between regional and national shares in total output in high-tech industry *i*. The index equals zero if high-tech industry *i* is distributed evenly across regions and increases if industry *i* become more and more concentrated in a few regions.

The calculation of dissimilarity indices requires data on output across a set of regions and industries. This chapter choose 5 high-tech industries defined by the Catalog for High-technology Industrial Statistics Classification (2002) as follows[10]: (1) Aircraft and Spacecraft (A&S), (2) Electronic and Telecommunication Equipment (E&T), (3) Computers and Office Equipment (C&O), (4) Pharmaceutical Manufacturing (P&M), (5) Medical Equipment and Meters (M&M). The data of high-tech industries are from the

[10] The definition is compatible with OECD's classification of high-technology industries, which take the share of R&D expenditure in manufacturing output or value added (namely R&D intensity) as criteria for classification.

National Bureau of Statistics (NBS), China Statistics Yearbook on High Technology Industry (2002, 2003 and 2008), which provides the data on 5 high-tech industries for 30 provinces over the period of 1996 to 2005.

According to current administrative division of China, This chapter choose 30 provinces as geographical units and divided them into three coastal regions and four inland regions: Northern Coast, Middle Coast, Southern Coast; Northern Inland, Middle Inland, Southern Inland and Far West[11].

3.3.2 Industrial Specialization and Regional Concentration of High-tech Industries

This section starts to investigate the geographic distribution of high-tech industries and primarily focus on three aspects: the similarity of high-tech industrial structure between regions; the extent of industrial specialization and regional concentration of high-tech industries; and the relation between trends and changes in industrial specialization and regional concentration.

Table 3.1 and Table 3.2 reports the dissimilarity indices $DIS_{j,k}$ for seven regions, respectively. The national average $DIS_{j,k}$ goes up significantly from 0.101 in 1996 to 0.132 in 2005, indicating that regions become more specialized compared with other regions. The last column reports the specialization index $SPEC_j$ of each region, Southern Coast is the most specialized region, whereas Southern Inland is the least specialized region over years.

In addition, the specialization index for each region shows that three coastal regions have more similar industrial structures. Specifically, the $SPEC_j$ index of Middle Coast and Southern Coast goes down from0.087 to 0.036, indicating convergence of high-tech industrial structure over years. On the other hand, the Inland average specialization index

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[11] Similar division has been used in Guo (1999) and Gao (2003). Northern Coast includes 5 provinces, which are Beijing, Tianjing, Hebei, Liaoninig and Shandong; Middle Coast includes 3 provinces, which are Shanghai, Jiangsu and Zhejiang; Southern Coast includes 4 provinces, which are Fujian, Guangdong, Guangxi and Hainan; Northern Inland includes 5 provinces, which are Shanxi, Inner Mongolia, Jilin, Heilongjiang and Shanxi; Middle Inland includes 5 provinces, which are Anhui, Henan, Hubei, Jiangxi and Hunan; Southern Inland includes 4 provinces, which are Chongqing, Sichuan, Guizhou and Yunnan; Far West includes 4 provinces, which are Gansu, Qinghai, Ningxia and Xinjiang. Tibet is not included due to the incomplete data collection.

increases from 0.067 in 1996 to 0.082 in 2005[12], which is considerably lower than the national average level during the same period, suggesting that inland regions are also more similar to each other. On the contrary, the dissimilarity indices $DIS_{j,k}$ among three coastal regions and four inland regions increases significantly over years. Therefore, the increase in specialization indices is mainly caused by the widening differences between the high-tech industrial structures of coast and inland regions.

Table 3.1 Dissimilarity Index of Specialization in 1996

	Northern Coast	Middle Coast	Southern Coast	Northern Inland	Middle Inland	Southern Inland	Far West Inland	***SPEC$_j$***
Northern Coast	0.000	0.024	0.088	0.110	0.143	0.056	0.138	0.093
Middle Coast		0.000	0.087	0.131	0.149	0.072	0.147	0.098
Southern Coast			0.000	0.190	0.230	0.143	0.225	0.146
Northern Inland				0.000	0.072	0.069	0.096	0.093
Middle Inland					0.000	0.087	0.037	0.096
Southern Inland						0.000	0.106	0.080
Far west Inland							0.000	0.102
National average								**0.101**

Note: Indices calculated based on output data.

The increasing differences in regional industrial structures could also be reflected by the changes in regional concentration of industries. Table 3.3 reports the concentration indices DIC_i for each high-tech industry form 1996 to 2005. The extent of concentration at individual industry level varies significantly over the period. A&S manufacturing is the most concentrated high-tech industry with the largest concentration indices far greater than other industries, while E&E manufacturing is the most dispersed high-tech industry with consistently lowest indices. The concentration indices of P&M manufacturing, which is not very concentrated in 1995, have increased significantly over years. On the contrary, initially

[12] Inland average specialization index $SPEC_j$ are calculated based on the $DIS_{j,k}$ reported in Table 3.1 and Table 3.2.

highly concentrated industries, such as C&O and M&M, have become more and more dispersed during the given period.

Table 3.2 Dissimilarity Index of Specialization in 2005

	Northern Coast	Middle Coast	Southern Coast	Northern Inland	Middle Inland	Southern Inland	Far West Inland	***$SPEC_j$***
Northern coast	0.000	0.107	0.110	0.213	0.139	0.142	0.215	0.132
Middle coast		0.000	0.036	0.253	0.180	0.183	0.257	0.145
Southern coast			0.000	0.286	0.216	0.218	0.292	0.165
Northern inland				0.000	0.090	0.078	0.106	0.147
Middle inland					0.000	0.047	0.090	0.109
Southern inland						0.000	0.114	0.112
Far west inland							0.000	0.135
National average								**0.132**

Note: Indices calculated based on output data.

Table 3.3 Regional Concentration of High-tech Industry (1996-2005)

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Change (1996-2005)
A&S	1.094	1.094	1.227	1.198	1.286	1.276	1.354	1.387	1.475	1.471	34.4%
C&O	0.683	0.683	0.653	0.542	0.549	0.573	0.519	0.485	0.424	0.474	-30.6%
M&M	0.574	0.615	0.547	0.588	0.561	0.595	0.615	0.562	0.491	0.497	-13.4%
P&M	0.515	0.550	0.581	0.646	0.669	0.704	0.731	0.793	0.858	0.908	76.6%
E&T	0.266	0.252	0.245	0.219	0.197	0.191	0.178	0.147	0.180	0.183	-31.3%
Average	**0.627**	**0.639**	**0.650**	**0.639**	**0.653**	**0.668**	**0.679**	**0.675**	**0.685**	**0.707**	**12.8%**

Note: Indices calculated based on output data.

The last row of Table 3.3 reports the concentration indices of high-tech industry sector as a whole, calculated as the average of indices of each high-tech industry for each year. The concentration indices for high-tech industry sector increases form 0.627 in 1995 to 0.707 in 2005, indicating an increase in the level of regional concentration of high-tech industry sector in China. In 1996, 75.5% of China's high-tech industry sector was located in Coast regions; this share continues to increase and reaches 89.6% in 2005 (See Table 3.4). Therefore, despite of the variations in individual high-tech industry, at the nation-level, high-tech industry sector as a whole, become more and more concentrated in coastal regions as regions become more and more specialized.

Table 3.4 Region's Share in High-tech Industry Output (1996-2005)

	1996 (%)	2005 (%)	Change (%)
Coast regions' share in total high-tech industries	75.5	89.6	18.7
Inland regions' share in total high-tech industries	24.5	10.4	-57.6
Large regions' share in total high-tech industries	52.0	70.3	35.2
Small regions' share in total high-tech industries	8.2	3.4	-58.5
Large regions' share in Large high-tech industries	52.9	77.8	47.1
Large regions' share in Small high-tech industries	35.7	44.1	23.5

Notes: Indices calculated based on output data. Large regions are Middle Coast and Southern Coast; small regions are Northern Inland and Far west inland. Large industries are the high-tech industries ranked first and second in industrial output in China in 1996 and 2005.

In summary, this section calculates the dissimilarity indices to measure the extent of specialization and concentration of high-tech industries in China for the period 1996 to 2005. The dissimilarity index reveals that the extents of industrial specialization increase significantly while the differences in industrial structures between Coast and Inland regions become larger. Furthermore, the whole high-tech industry sector becomes more concentrated in coast regions.

The increasing trends of specialization and concentration is consistent with previous studies investigating the distribution of production activities in China (Bai, 2004; Lu and Tao, 2009) but inconsistent with those studies in the case of European manufacturing. The direction of changes in specialization and concentration lies with the changes in the size of industries and regions in different periods. Specifically, EU studies show that smaller member states increase their shares in total manufacturing over decades. That is, smaller member states tend to grow more rapidly than the larger states (Aiginger and Davies, 2004).

The opposite case happens in China. As shown in Table 3.4, small regions has experienced a sharp drop in their shares in high-tech industry sector, while large regions increase their shares in high-tech industry sector from 52.0% in 1996 to 72.3% in 2005. Moreover, the shares of large regions in large and small industries also increase significantly over years. In this sense, the increase in specialization and concentration indeed reflects the same fact that high-tech industries become more and more concentrated in some large coastal regions in China. For simplicity, this chapter treats these two terms interchangeably and uses industrial specialization of regions as a denotation of the two terms in the following analysis.

3.4 Theoretical Framework: A Model with Quadratic Utility and Linear Transport Costs

In this section, following Ottaciano (1999), a simple model with quadratic utility and linear transport costs is introduced to explain the possible channel through which economic policies influence the geographic distribution of high-tech industries.

3.4.1 Basic Setup and Assumptions

Consider the economic space is made of two regions (East and West). The economy has two sectors, the Agriculture sector *A* and the high-tech industry sector *H*. Each sector use two production factors, capital K and labor L. Labor is immobile whereas capital is perfectly mobile between regions. This model mainly describe the economy in East since West is almost symmetric (West economy variables are denoted by asterisk). Let θ denotes eastern shares of labor and capital in country total labor and total capital, so that, $\theta = L/(L+L^*) = K/(K+K^*)$. In particular, East is chose as the larger regions, so that $\theta > 1/2$.

The *A* sector is characterized by constant returns to scale and perfect competition, and uses only labor to produce its homogenous goods. Let one unit of *A*-sector's goods requires one unit of labor, profits maximization then implies that price of *A*-sector's goods, p_A , equals the price of labor, *w*. Furthermore, the trade on *A*-sector's product is assumed to be costless between regions, so that its price must be equal across regions. For simplicity, choose *A*-sector's product as mumeraire, so that, $p_A = p_A^* = w = w^* = 1$.

The *H* sector consists of a large number of firms that produce differentiated goods under increasing returns to scale. To produce one variety of *H*-goods, a typical firm needs to input *f* unit capital as its fixed cost and $mx(s)$ unit labor as its variable cost. Therefore, let *r* denotes the rental rate of capital in East. A typical firm in East has a total cost as follows:

$$TC = rf(z) + wmx(s) \tag{3.4}$$

Let λ denotes the share of capital employed in East, so that $(\theta - \lambda)L > 0\ (< 0)$ measures the extent of capital flows into (out of) East. Moreover, the varieties of *H* sector are traded at a cost of $\tau > 0$ units of the numeraire per unit shipped between the two regions.

3.4.2 Equilibrium Location of High-tech Industry

On the demand side, consider an infinitely-lived representative consumer with preferences described by the quasi-linear quadratic utility as follows:

$$U = \alpha \int_0^N q(s)ds - \frac{(\beta-\gamma)}{2}\int_0^N [q(s)]^2 ds - \frac{\gamma}{2}\left[\int_0^N q(s)ds\right]^2 + Z \qquad (3.5)$$

where $\alpha > 0$, which implies the intensity of preferences for differentiated product. In addition, $> \gamma > 0$, which implies that consumers are biased toward a dispersed consumption of varieties. For a given value of β, γ reflets the substitutability between varities: the higher γ, the close substitute the varieties.

Utility optimization yields a linear demand by residents in East for a variety produced in West, denoted as $q_w(s)$, as follows:

$$\begin{aligned} &q_w(s) = a - (b + cN)p_w(s) + cP \\ &a \equiv \frac{\alpha}{\beta + (N-1)\gamma} \;;\; b \equiv \frac{1}{\beta + (N-1)\gamma} \;;\; c \equiv \frac{\delta}{(\beta-\gamma)[\beta + (N-1)]} \end{aligned} \qquad (3.6)$$

where $P \equiv np + n^* p_w$, and p_w is the consumer price of a variety produced in West and sold in East.

On the supply, a representative firm in *i maximizes* its profits as follows:

$$\begin{aligned} \pi(\mathrm{s}) = &[p(s) - m][a - (b+cN)p(s) + cP]M + \\ &[p_E(s) - m - \tau][a - (b+cN)p_E(s) + cP]M^* - rf \\ M = &\theta(L+K) \;;\; M^* = (1-\theta)(L+K) \end{aligned} \qquad (3.7)$$

where M and M^* are the number of consumers in East and West, respectively; p_E is the consumer price of a variety produced in East and sold in West.

Solving the first order conditions for profit maximization yields the equilibrium prices as follows:

$$P=\frac{2\left[a+m(b+cN)\right]+\tau cn^{*}}{2(2b+cN)}=\frac{P}{N}-\frac{\tau n^{*}}{2N}$$
$$p_E=p^{*}+\frac{\tau}{2}=\frac{P}{N}-\frac{\tau n}{2N} \qquad (3.8)$$

Using Eq. (3.8), the rental rate of capital prevailing in East and West are given by the following quadratic expression in λ, respectively:

$$r(\lambda)=\frac{b+cN}{f}\left[(p-m)^{2}\theta+(p_E-m-\tau)^{2}(1-\theta)\right](L+K+L^{*}+K^{*})$$

$$r^{*}(\lambda)=\frac{b+cN}{f}\left[(p^{*}-m)^{2}\theta+(p_W-m-\tau)^{2}(1-\theta)\right](L+K+L^{*}+K^{*}) \qquad (3.9)$$

Given the assumption of perfect capital mobility across regions, the location equilibrium is determined by the condition: $r(\lambda)=r^{*}(\lambda)$, which implies capital earn the reward in both regions. Solving this condition with Eq. (3.8) and Eq. (3.9), the location equilibrium is:

$$\lambda=\frac{1}{2}+\frac{2f(a-m)(2b-\tau b)}{\tau c(K+K^{*})}(\theta-\frac{1}{2})>\frac{1}{2} \qquad (3.10)$$

3.4.3 Impacts of Economic Policies on High-tech Industry Location[13]

Eq. (3.10) reveals that the geographic distribution of high-tech firms is determined by three factors: local market size, inter-regional transaction cost, and the level of fixed cost.

First, differentiate number of high-tech firms, λ, with respect local market size, ϑ, as follows:

[13] The theoretical framework is used to explain the possible channels through which economic policies may influence high-tech industry locations rather than model the impacts of any specific economic policies directly.

$$d\lambda / d\theta = \frac{2f(2a - 2mb - \tau b)}{\tau c(K + K^{*})} \tag{3.11}$$

Subtracting m and τ from Eq. (3.8), it is shown that frims' prices net of transport costs are positive regardless of their spatial distribution if and only if the following condition holds:

$$\tau \equiv \tau_{trade} = \frac{2(a - mb)}{2b + cN} \tag{3.12}$$

With this condition holds, the differential of Eq. (3.11) is always greater than zero. Specifically, Eq. (3.11) reveals the presence of the Home Market Effect (HME), which indicates that region with larger local demand, i.e., lager ϑ, tend to attract more high-tech firms. As regional expenditure on high-tech industrial goods consist of capital rewards and wages, any economic policies influence the geographic distribution of capitals and worker will influence local market size, and thereby influence industrial concentration.

Second, industrial location is influenced by inter-regional transaction cost. Therefore, the geographic condition such as access to the sea may influence the distribution of industries. In addition to the natural geography of a region, investment on infrastructure also influences trade costs across regions. In this sense, an improvement on road network will reduce transportation cost across regions, so that will facilitate industrial concentration. On the contrary, trade barriers caused by local protection increase transaction cost and will disperse the concentration process.

Lastly, rewriting Eq. (3.10) as follows:

$$2f(2a - 2mb - \tau b)(\theta - \frac{1}{2}) - \tau c(K + K^{*})(\lambda - \frac{1}{2}) = 0 \tag{3.13}$$

The first term on the left is positive and reflects the larger region has the advantage of market access, whereas the second term is negative and thus reflects that larger region has the disadvantage of market crowding. In particular, the market crowding effect rises as the level of fixed cost, *f*, falls. Therefore, local protection for high-tech industrial firms tends to reduce the level of local fixed cost. This in turn, will increase the market crowing effect and thereby impedes industrial concentration.

3.5 Empirical Framework: Static and Dynamic Panel Data Model

3.5.1 Empirical Specification and Methodology

This empirical study uses a panel data set of 5 high-tech industries and 30 provinces during the period 1996 to 2005. The utilization of panel data set can control for time-invariant individual heterogeneity and the lagged effect of variables.

This section starts by estimating a simple static panel model in the following specification:

$$SPEC_{jt} = \alpha + \beta X_{jt} + f_j + \varepsilon \quad (3.14)$$

where $SPEC_{jt}$ is the specialization indices calculated in section 3.3, which measures the extent of specialization of region j in year t. X_{jt} is the vector of independent variables. α and β denote the constant and coefficient vectors respectively. f_j stands for the time-invariant fixed effect. (e.g. local reserves of mineral resources or regional cultural backgrounds). The error term ε_{jt} is assumed uncorrelated with the vector $X1_{jt}$ so that all independent variables are strictly exogenous.

The static specification of Eq. (3.10) indicates that high-tech industrial structure adjusts instantaneously after the implementation of certain economic policy. However, in reality, adjustment often progresses slowly and highly depends on its previous pattern (Bai *et.al*, 2004). Therefore, a dynamic panel data model is constructed to explore the potential lagged effects of both dependent and independent variables as follows:

$$SPEC_{jt} = \alpha + \delta SPEC_{j,t-1} + \gamma_0 X1_{jt} + \gamma_1 X1_{j,t-1} + \theta X2_{jt} + f \quad (3.15)$$

where $SPEC_{j,t-1}$ is the lagged dependent variable, which measures the lagged impact of specialization in previous year t-1. Other independent variables are divided into two groups. In the first group, $X1_{jt}$ and $X1_{j,t-1}$ are the vectors of current and lagged economic policy variables, respectively. In the second group, $X2_{jt}$ is the vector of other controlled variables.

δ, γ_0, γ_1 and θ are coefficient vectors. In addition, the error term ε_{jt} is assumed not to be autocorrelated.

As $SPEC_{j,t-1}$ is positively correlated with the error term due to the presence of individual effects, the inclusion of lagged dependent variable $SPEC_{j,t-1}$ as regressor would induce the biased estimation results of Ordinary Least Squares (OLS) or other common regression methods for panel data set (Bond, 2002). This section adopts first-difference Generalized Method of Moments (first GMM) developed by Arellano and Bond (1991) to solve this problem. First, the individual effect f_j is eliminated by the first-differencing transformation of Eq. (3.11). Second, the lagged $SPEC_{j,t-l}$ (l=2,3,…) are used as valid instruments for the difference term $\Delta SPEC_{j,t-1}$.

Although the first-difference GMM estimator is consistent according to the initial assumption, it may perform poorly when the estimation attempts to explore the times series properties of individual series. The instruments available for the equation in first-differences tend to be weak when the individual series are highly persistent (Bond, 2002). In such case, the system GMM estimator developed by Arellano and Bover (1995) and Bllunell and Bond (1998) provides better estimation results with smaller bias and greater precision. Specifically, the lagged first difference $\Delta SPEC_{j,t-1}$ is also valid instrument for $SPEC_{j,t-1}$ in the level Eq. (3.11). Moreover, other independent variables $X1_{jt}$ and $X2_{jt}$ which are assumed to be exogenous, serve as their own instruments, indicating the complete time series ($X1_{j,1}$, $X1_{j,2}$,…$X1_{j,t}$) and ($X2_{j,1}$, $X2_{j,2}$,…$X2_{j,t}$) are valid instrumental variables.

3.5.2 Data and Variable Definitions

High-tech oriented export policy

Eastern coastal regions where reform and opening-up were initially performed, have gradually become the center of high-tech industrial production since 1980s. After further acceleration of economic opening to inland in 1990s, middle and western regions also implement high-tech export-oriented policy based on the successful experiences of eastern region. Consequently, those export-oriented high-tech industries, such as C&O and E&T

manufacturing, grow rapidly and play an important role in transforming regional structure. The importance of high-tech oriented export policy is measured by the variable openness to export, which is defined as the share of regional export in regional high-tech industrial output.

Subsidy for science and technology (S&T) activities

Local governments tend to promote high-tech industries and high-tech enterprises through various subsidies. However, more subsidies form governments do not indicate higher level of industrial specialization. Indeed, the impact of subsidy on regional industrial structure is highly related to the allocation of subsidies across high-tech industries. A variable, subsidy for S&T, which is defined as the index of subsidy allocation ISA_j , is constructed as a proxy to measure the impact of local governments' subsidies on regional high-tech industrial structure:

$$ISA_j = \sum_{i=1}^{I} \left| \frac{subsidy_{ij}}{subsidy_j} - \frac{1}{I} \right| \quad (3.16)$$

for region j, $subsidy_{ij}$ is the percentage of high-tech industry i's subsidy in total $subsidy_j$. In an extreme case, if government equally allocates subsidies across industries, each high-tech industry gets $1/I$ of total subsidies. Thus the ISA_j index measures the differences between actual allocation ratio and equal allocation ratio for each high-tech industry. Significant differences indicate high level of concentration of subsidies in few high-tech industries.

State-level high-tech industrial base (SHIB) policy

In 1980s, the emerging high-tech industrial cluster represented by Silicon Valley has received a great deal of attention throughout the world. Over the same time period, the State Council of China officially approved the first SHIB in Jiangsu province. By 2005, 113 high-tech industrial bases have been established across 17 provinces in China. These industrial bases facilitate the high-tech industrial agglomeration in two ways. First, some knowledge, such as tacit knowledge cannot be formalized or written down; therefore, knowledge spillovers are expected to be more localized within the geographic scope of industrial base. Second, although State Council approves the establishment of high-tech industrial base, local governments are responsible for their overall administration and guidance. Consequently, various preferential policies are often implemented to attract high-tech enterprises. Therefore, high-tech enterprises tend to agglomerate in SHIBs to benefit from knowledge spillovers and various local preferential policies. Regions with better-developed SHIBs would be expected to attract more high-tech enterprises to concentrate in their SHIBs. A time-vary dummy variable, local SHIB, is employed to measure the existence of SHIBs in one province. The variable takes a value of 1 if one province has at least one SHIB in any given year.

Local protectionism

Unlike the trade barriers among countries in the context of international trade, it is very difficult to measure local governments' protection for local high-tech enterprises within a country directly. One common measurement of local protection is to consider the motives of local government. In particular, local government tends to protect those industries that can provide higher tax, or those industries which are consist of more state-owned enterprises (Bai, et al., 2004). This motive-related measurement may face the problem that local government promotes local high-tech industries following central government's high-tech industry development strategy. In this sense, at region-level, local government will protect local high-tech firms, helping them to compete with firms form other regions. Local protectionism is in variety of forms. For example, according to current tax law in China, qualified high-tech enterprises could enjoy 15% reduction of income tax rate. However, the identification of high-tech enterprise is under the administration of local government, local high-tech enterprises tend to pass the identification more easily with the protection of local governments.

The empirical analysis thus turns to consider the outcome of protectionism. Specifically, local high-tech enterprises could gain surplus profits due to various forms of local protectionism that significantly improves their products' competitiveness in local markets. A variable, local profit ratio, which is defined as the percentage of profit in total sales, is employed to measure the impact of local protectionism on industrial specialization. Since higher profit ratio indicates higher local protectionism, it is expected that the variable has a negative effect on specialization.

Although this section mainly focuses on the impact of economic policy on industrial specialization, it is still necessary to control for other related determinants of industrial specialization proposed by theories.

Local transportation conditions

Since 1980s, both central and local governments have launched large-scale constructions of local infrastructure. The construction of railways and highways may have significant impact on the geographic distribution of high-tech industries since it greatly reduce the transport costs. High-tech enterprises prefer to locate in regions with better provision of transport network, consequently, they could benefit from lower local transaction costs as well as more convenient and rapid connection with other regions. A variable transportation per capita, which is defined as the logarithm of total length of railways and highways for a region weighted by regional population, is employed to measure the impact of local transportation conditions on specialization.

Knowledge resources

Most existing literatures have confirmed the impact of fixed regional resource endowments on industrial specialization. For example, due to the high dependence of some raw materials, most extractive industries highly agglomerated in regions with abundant coals or oils. In contrast to those general manufacturing, high-tech industry is characterized as knowledge-intensive, indicating that regions have more knowledge resources would be more specialized in high-tech industries. However, it is difficult to measure the invisible knowledge flows empirically. An alternative method is to focus on the carriers and transmitters of knowledge. The most effective way to transfer knowledge is by face-to-face communication of high-skilled labors. Therefore, a variable high-skilled labor intensity, which is defined as the share of scientists and engineers in regional total employee weighted by national average, is employed as a proxy for the impact of regional comparative advantages of knowledge resources.

Table 3.5 summarizes definitions and statistics of variables. The data of SHIBs are from Torch High Technology Industry Development Center, Ministry of Science and Technology of China. The data of regional population and length of railways and highways are from (NBS) China Statistical Yearbook (1997-2006); data of other variables are from (NBS) China Statistics Yearbook on High Technology Industry (1997-2006).

Table 3.5 Definitions and Statistics of Variables

	Definition	Mean	SD	Min	Max
Dependent variable					
SPEC	Dissimilarity index of industrial specialization DIS_j	0.201	0.057	0.111	0.336
Independent Variable					
Openness to export	Regional export divided by regional total output	0.136	0.170	0.000	0.716
Subsidy for S&T	Index of subsidy allocation ISA_j	1.133	0.304	0.157	1.600
Dummy SHIB	Dummy SHIB =1; if region *j* has at least one SHIB in year *t*. Dummy SHIB =0; otherwise.	0.240	0.428	0.000	1.000
Local profit ratio	The share of enterprise profit in sales in one region divided by national average level	0.049	0.056	-0.420	0.193
High-skilled labor intensity	The share of scientists and engineers in regional total employee divided by national average level	0.697	0.301	0.133	1.592
Transportation per capita	The logarithm of total length of railways and high-ways of one region divided by regional population	1.160	0.211	0.626	1.759

3.5.3 Estimation Results of Static Panel Data Model

Table 3.6 reports the estimation results of the static model of industrial specialization with three estimation methods: pooled OLS, fixed effects, and random effects. Focusing on economic policy variables, the estimation results vary significantly across estimation methods. Two tests are performed to determine the proper specification for the static model. The F test accepts the significance of individual-specific effects at 1% level, confirming the validity of the specification of fixed effects model. Moreover, the corresponding p-value of Hausman-statistic is smaller than 1%, rejecting the null hypothesis that the individual-specific effects are uncorrelated with the independent variables. Taken together, the specification of the fixed effects model is more preferred than the pooled OLS and random-effects model.

Table 3.6 Estimation Results of Static Model of Industrial Specialization

	Pooled OLS	Fixed effects	Random effects	Fixed effect with AR(1) disturbance
Economic policy				
Openness to export	-0.090*** (0.013)	0.034***(0.011)	0.015 (0.011)	0.007**(0.003)
Subsidy for S&T	0.002 (0.009)	0.0002 (0.007)	0.004 (0.006)	-0.001 (0.002)
Dummy SHIB	0.007 (0.005)	0.010**(0.004)	0.008**(0.004)	0.001*(0.001)
Local profit ratio	0.038 (0.040)	-0.003 (0.025)	-0.012 (0.024)	-0.018*(0.010)
Control for others				
High-skilled labor intensity	0.078***(0.009)	0.048***(0.008)	0.054***(0.007)	0.006***(0.002)
Transportation per capita	0.083***(0.014)	0.052**(0.020)	0.082***(0.017)	0.001 (0.009)
Constant	0.056***(0.014)	0.010***(0.024)	0.061***(0.019)	0.216***(0.013)
AR(1)	-	-	-	0.794***(0.033)
R-squared	0.559	0.886	0.303	0.993
Adjust R-squared	0.550	0.871	0.289	0.992
F test (p-value)	-	26.178(0.000)	-	4.528(0.000)
Hausman test (p-value)	-	-	31.882(0.000)	-
Observations	300	300	300	270

Note: The numbers in brackets are standard errors; ***, **, * denotes significance higher than 0.01, 0.05, and 0.10, respectively.

Focusing on the estimation results of fixed-effects model, openness to export and the SHIB dummy variable have positive and significant coefficients at 1% and 5% level, respectively, which suggests high-tech oriented export policy and the establishment of

SHIB have positive impact on industrial specialization. While the coefficient of subsidy for S&T variable is positive but insignificant, providing only weak evidence supporting the positive effect of this policy. Furthermore, the coefficient of local profit ratio is negative but insignificant. Therefore, the estimation results provide weak evidence that local governments' protection for local high-tech enterprises has a negative effect on industrial specialization. As for other independent variables, the estimation results confirm that local high skilled labors, transportation condition have positive and significant effects on specialization.

To test the robustness of the specification of the fixed effects model, this section loosens the initial assumption of the error term ε_{jt} and allows it follow the first-order autocorrelation as follows:

$$\varepsilon_{jt} = \varphi\varepsilon_{j,t-1} + \mu_{jt} \tag{3.17}$$

The last column of Table 3.6 reports the estimation results of the fixed effects model with AR (1) disturbance. It is worth noting that the estimation result varies significantly as controling for the potential first-order autocorrelation of error terms. Compared with the fixed effects model, the coefficients of all economic policy variables become smaller. Moreover, the coefficient of local profit ratio variable becomes significant whereas subsidy for S&T variable is still statistically insignificant. More importantly, the inclusion of the first-order auto-correlated error term in the static model can partially accounts for the lagged responses of industrial specialization. The positive and significant coefficient (0.794) of AR(1) confirms the existence of first-order autocorrelation of the error term, which suggests that the specification of the static model is incorrectly specified. Therefore, the empirical analysis turns to investigate the dynamic specifications that yield more consistent estimation results.

3.5.4 Estimation Results of Dynamic Panel Data Model

The dynamic model of industrial specialization is estimated with first-difference and system GMM methods. Taking into account that too many instrumental variables would weaken the Sargan test by overfitting the endogenous variable, the estimation includes only one lag of both dependent and independent variables for economic policy in the specification of dynamic model. Table 3.7 reports the estimation results of first-difference GMM and system GMM methods in the first and second columns, respectively. For both estimations, the Sargan test does not reject the null hypothesis that the overidentifying restrictions are valid, and the Arellano-Bond autocorrelation test indicates that there is no evidence of second-order serial correlation.

Table 3.7 Estimation Results of Dynamic Model of Industrial Specialization

	First-difference GMM	System GMM	Pooled OLS	LSDV
Lagged effect SPEC				
SPEC (-1)	0.546***(0.043)	0.894***(0.013)	0.929***(0.025)	0.704***(0.049)
Economic policy				
Openness to export	0.010**(0.004)	0.009***(0.003)	-0.006 (0.012)	0.012 (0.013)
Openness to export (-1)	-0.002 (0.004)	-0.001***(0.004)	-0.005 (0.012)	0.003 (0.012)
Subsidy for S&T	-0.001 (0.002)	0.003*(0.002)	0.001 (0.005)	0.001 (0.005)
Subsidy for S&T (-1)	-0.002 (0.001)	-0.002**(0.001)	-0.001 (0.005)	-0.001 (0.005)
Dummy SHIB	0.011***(0.005)	0.0002 (0.001)	0.002 (0.002)	0.007**(0.003)
Local profit ratio	-0.006**(0.005)	-0.038***(0.008)	-0.038*(0.020)	-0.037*(0.020)
Local profit ratio (-1)	0.002 (0.004)	-0.015**(0.007)	-0.015 (0.018)	-0.018 (0.019)
Control for others				
High-skilled labor intensity	0.014***(0.001)	0.018***(0.002)	0.011***(0.004)	0.023***(0.006)
Transportation per capita	0.028***(0.008)	0.003 (0.002)	0.002 (0.006)	-0.016 (0.016)
Constant	0.049***(0.008)	0.011***(0.003)	0.012**(0.006)	0.065***(0.019)
Sargan test (p-value)	24.034 (0.241)	23.037 (0.400)	-	-
AR (2)	0.803	0.846	-	-
Observations	240	270	270	270

Note: The numbers in brackets are standard errors; ***, **, * denotes significance higher than 0.01, 0.05, and 0.10, respectively.

To assess the bias and precision of first-difference GMM and system GMM estimators, this section first examines stationary properties of each time series by estimating a simple

AR (1) model for all independent variables. (Estimation results and specification in details are presented in Appendix 3.2.) According to the estimation results of the AR (1) model, all variables are found to be highly persistent. Second, the dynamic model is estimated with pooled OLS and Least Squares Dummy Variables (LSDV) method. Table 3.7 reports the estimation results of each method in column three and four, respectively. As Roodman (2009) suggested, given that the lagged explainable variable $SPEC_{j,t-1}$ is positively correlated with the error term, the coefficient of $SPEC_{j,t-1}$ is biased upwards in the OLS estimation but is biased downwards in the LSDV estimation. Therefore, a proper estimate of the true parameter should lie within the range of 0.704 to 0.929. By comparison, the coefficient of $SPEC_{j,t-1}$ in the first-difference GMM estimations (0.546) is far below the lower limit (0.704). These results are in line with Blundell and Bond (1998), confirming that the instruments available for the equations in the first-differences are likely to be weak when the individual series exhibits strong persistence. By contrast, the coefficient of $SPEC_{j,t-1}$ in the system GMM estimation lies suitably within the bonds defined by OLS and LSDV estimation. Therefore, the estimation results obtained from the system GMM methods is robust.

According to the estimation results of the system GMM method, the coefficient of lagged $SPEC_{j,t-1}$ is positive and statistically significant at the 1% level. As expected, the positive impact of previous industrial specialization indicates that the adjustment of regional high-tech industrial structure is a slow process and highly depended on its historical pattern. This result is consistent with the conclusion of Bai et.al. (2004) who investigate regional specialization in China's manufacturing.

As for economic policy variables, openness to export has a positive and significant coefficient, which confirms the impact of economic opening and high-tech export-oriented policy on industrial specialization and concentration. This result is also consistent with the findings in Ge (2008), further confirming that export-oriented high-tech industries have higher degree of concentration in China. Regions with more openness to foreign market would attract more FDIs and MNCs to invest in those export-oriented high-tech industries, and thus tend to have higher shares in total high-tech industries.

The contemporaneous coefficient of local governments' subsidy for S&T activities is positive and significant, indicating that local governments prefer to promote local specialization through allocating disproportionately across high-tech industries. Consequently, the share of the promoted high-tech industry in total industrial output increases rapidly, thereby increasing of the degree of industrial specialization.

The estimation result reveals that the establishment of SHIBs has positive but insignificant coefficient, which indicates that these SHIBs might not successfully attract high-tech enterprises. This finding is in line with the study of Zhao et.al. (2008), who argues that although local governments consider SHIBs as one of the most important instrument to promote local high-tech industries, the actual development of SHIBs is still in its infancy stage, with the scale of most SHIBs being quite small. Moreover, the efficiency of SHIBs could also be weakened by other developed zones which were established prior to SHIBs yet provide roughly similar preferential policies, or by those high-tech enterprises located outside SHIBs but still be eligible to enjoy the preferential policies for SHIBs.

Local profit ratio variable has a negative and highly significant coefficient, suggesting that local protection for high-tech industries has a negative effect on industrial specialization. This result provides strong evidence supporting the hypothesis that local high-tech enterprises tend to obtain higher profits under the protection of local governments. As a result, protection deteriorates segmentation of domestic high-tech product market, eventually impeding industrial specialization and concentration of high-tech industries.

The estimation results do not support a significant impact of local transportation on high-tech industrial specialization. The coefficient of transportation per capita is positive but insignificant. Considering the time period of this empirical study, regional disparity in road and railways has been greatly diminished due to the large-scale construction of infrastructure in inland regions over years. Moreover, the less dependency of high-tech industry on natural resources endowments also indicates that the variation of transport costs might have little impact on regional concentration of high-tech industries.

As for the high-skilled labor intensity variable, it is found to have a positive and significant coefficient at 1% level, which confirms the previous hypothesis that regions with higher high-skilled labor intensity tend to have comparative advantage of knowledge resources. Consequently, such comparative advantage would facilitate the regional concentration of high-tech industry.

3.6 Summary

In addition to the contemptuous impact of economic policy, Table 3.8 summaries the short-run effect, which is measured by the coefficient of γ_0 and the long-run effect, which is measured by $(\gamma_0+\gamma_1)/\ (1-\delta)$ for each economic policy variable (The dummy SHIB variable and transportation variable are not reported here due to their insignificance). According to these calculation results, the implementation of economic opening and high-tech oriented export policy, subsidy for S&T activities have positive long-term effects. On the contrary, local protectionism has a negative long-term impact of on speciation.

Table 3.8 Short-run and Long-run Effect of Economic Policy

	Short-run effect	Long-run effect
Openness to export	0.009	0.075
Subsidy for S&T	0.003	0.009
Local profit ratio	-0.038	-0.500

In summary, the specification of system GMM model can explore the dynamic features of regional high-tech industrial structure as well as the impact of economic policies. These estimation results indicate that various economic policies have a mixed effect on specialization and concentration of high-tech industries. The implementation of high-tech oriented export policy and subsidy for S&T activities have significant and positive effects on industrial specialization; whereas local governments' protection for local high-tech enterprises decrease the level of specialization and concentration. Moreover, it is also found that knowledge resource, which is measured by high-skilled labor intensity, has significant impact of on industrial specialization of high-tech industries in China.

Taken together, these estimation results not only confirm the role of economic policies in determining the geographic distribution of high-tech production activities, but also provide an explanation for the increasing trends in regional concentration of high-tech industries, as described in Section 3.3. Although regions become more specialized over years, the significantly negative effect of local protectionism seriously obstructs the diffusion of high-tech industrial production activities from coastal regions to inland regions. By comparison, most industrial transfer occurs within coastal regions, leading to the convergence of industrial structure between middle and southern coastal regions over years. Consequently, inland regions could not benefit from the rapid growth of high-tech industrial sector in coastal regions, while the disparities between coast and inland regions become more and more large.

3.7 Appendix 1

Beginning in the 1980s, China formulated a series of general programs for scientific and technological research and development, aiming to improve China's competitiveness in science and technology in the 21st century.

Torch Program

Launched in August 1988, Torch Program is China's most important program of high-tech industries. As a guiding program of China, Torch program seeks to achieve four major objectives by cooperating with other pertinent authorities at central and local levels.

(1) To perfect the support system for high-tech industrialization, focusing on promoting indigenous innovation; (2) To foster the growth of tech-based SMEs and boost technological innovation in enterprises; (3) To promote the development of innovation clusters and advance upgrades in high technologies; (4) To mobilize innovative resources including capital, technology and talent to reinforce support for innovation and industrialization.

Key Technologies R&D Program

The Key Technologies R&D Program was launched in 1982 as the largest science and technology program in China in the 20th century. Oriented toward national economic construction, it aims to solve the key and comprehensive problems directing the national economic and social development, covering agriculture, electronic information, energy resources, transportation, materials, resources exploration, environmental protection, medical and health care, and other fields. This program, engaging tens of thousands of persons from more than 1,000 scientific research institutions nationwide, has been so far the largest national scientific and technological plan that has been invested with most funds, employed most personnel, and made the greatest impact on the national economy.

863 Program

In March 1986, after several hundred Chinese scientists made a thorough study, the National Hi-tech R&D Program (or 863 Program) was launched. The program includes 20 themes, such as biotech, space flight, information, laser, automation, energy, new material and marine. In the operation of the program, the main functions of the government departments are macro-control and service. The general direction of research is decided by scientists after discussion, and specific projects are decided by a committee of experts, whose responsibility is to closely observe the latest development of the international scientific research, and submit an annual report on investigations in their own fields, so as to set new research directions. Another distinctive feature of the program is that its results can be quickly used in industries.

973 Program

A national key program for development of basic scientific research, the 973 Program began to be implemented in 1998. It mainly involves multi-discipline, comprehensive researches on important scientific issues in such fields as agriculture, energy, information, environment of resources, population and health, and material, providing theoretical basis and scientific foundation for solving problems. The program encourages outstanding scientists to carry out key basic scientific researches regarding cutting-edge sciences and important issues in science and technology in fields with great bearing on economic and social development. Representing the national goals, it is aimed to provide strong scientific and technological support for significant issues in China's economic and social development in the 21st century.

Spark Program

Launched in 1986, the Spark Program aims to revitalize rural economy through science and technology and to popularize science and technology in rural areas. Today, there are more than 100,000 scientific and technological demonstration projects being carried out in 85 percent of rural areas throughout China.

3.8 Appendix 2

To investigate the stationary properties of each series, two standard unit root tests are performed. Table 3.1A reports the results, which indicate that for all lagged variables, the unit root tests reject the null hypothesis that series has a unit root.

Table 3.1A Unit Root Tests for Time Series

	LLC test (*p*-value)	Fisher-ADF test (*p*-value)
SPEC	-8.979 (0.000)	79.474 (0.047)
Openness to export	-12.424 (0.000)	85.930 (0.016)
Subsidies for S&T	-9.911 (0.000)	71.734 (0.054)
Local profit ratio	-9.096 (0.000)	83.597 (0.024)
High-skilled labor intensity	-13.068 (0.000)	112.395 (0.000)
Transportation per capita	-6.271 (0.000)	53.597 (0.707)

Note: Probabilities for Fisher-ADF tests are computed using an asymptotic Chi-square distribution. All other tests assume asymptotic normality. The data are balanced for each series.

Table 3.2A reports the estimation results of the simple AR(1) specifications for each time series. It is found that all series but local profit ratio has a positive and significant coefficient higher than 0.900, which provides strong evidence supporting the high persistence of each series.

Table 3.2A AR(1) Specifications for Time Series

Specifications		Estimation results		
Dependent variable	Independent variable	Coefficients	Adjust R-squared	Observations
SPEC	SPEC (-1)	0.980 (0.016)	0.929	270
Openness to export	Openness to export (-1)	0.945 (0.030)	0.784	270
Subsidies for S&T	Subsidies for S&T (-1)	0.990 (0.010)	0.564	270
Local profit ratio	Local profit ratio (-1)	0.740 (0.042)	0.080	270
High-skilled labor intensity	High-skilled labor intensity (-1)	0.996 (0.015)	0.645	270
Transportation per capita	Transportation per capita (-1)	0.990 (0.012)	0.964	270

Note: The numbers in brackets are standard errors.
All coefficients are significant at 1% level.

Chapter 4 Economic Policy and Income Distribution

4.1 Introduction

Along with the rapid development of China's national economy and the continuous expediting of urbanization, demand for urban infrastructure is rapidly increasing in the past three decades. The role of urban infrastructure in economy development has been studies by many researchers. On one hand, urban infrastructure served as a productive input that increases firm-, region-, or nation-level economic growth. On the other hand, urban infrastructure served as an amenity factor that increases household's utility. Therefore, a high-infrastructure city, which refers to city that provides high-quality urban infrastructure such as developed transportation networks, convenient public facilities for entertainment, health care, education, is attractive for not only firms but also workers. In particular, workers prefer to reside in high-infrastructure cities so as to obtain higher level of utility, while firms concentrate in high-infrastructure city to benefit from lower costs and higher productivity. For example, 52.5% of China's urban employees and 70.1% firms are concentrated in eastern coastal cities which account for 27.8% of national total area of land[14].

In this sense, urban infrastructure influences the location decisions of firms and workers and thereby influences the demand and supply side of urban labor market. In addition, the geographic concentration of workers and firms in high-infrastructure cities will also increase the demand for land and thereby lead to an increase in local rents (Roback, 1982), which implies an increase in local living cost.

The geographic concentration of workers, together with the higher living cost in high-infrastructure cities, points out an interesting question that why workers still choose to reside in high-infrastructure cities? It is either because they receive higher wages that can compensate the higher cost of living or they just prefer infrastructure consumptions which consist of part of their wages in the form of forgone wages. In this sense, urban infrastructure plays an important role in determining urban employment and wage

[14] Data source: Author's calculation according to China City Statistical Yearbook (2003).

distribution across cities. To our knowledge, most existing studies examining wage inequalities take into account the heterogeneity of worker characteristics and decompose the differential into those due to differentials in the distribution of worker attributes and those due to differentials in the returns to those attributes (Knight and Song, 2003; Park, et al., 2005). By comparison, the study of this section contributes to exiting literature by arguing that not only individual characteristics, but also city characteristics, in particular, urban infrastructures, will affect the distribution of wages and workers across cities.

Using micro-level data of worker in 2003, this chapter examines the impact of urban infrastructure on rents, wages and returns to worker characteristics in urban China. Following the seminal framework of Roback (1982), a wage compensating differential model of urban infrastructure is developed to explain how urban infrastructure policies influence worker's and firm's location decisions in the presence of heterogeneous workers. The wage compensating differential model assumes an increase in the level of urban infrastructure will increase worker's utility through an amenity effect, and decrease firm's production cost through a productivity effect. Given this assumption, urban infrastructure has either a direct or an indirect impact on income distribution and returns to workers characteristics. To examine the theoretical conclusions of hedonic analysis model, an empirical analysis is conducted using a cross-section dataset of Chinese cities and individuals. It is found that wages are relatively higher in cities with better urban infrastructure. The productivity effect generated by an improvement on urban infrastructure is greater than the amenity effect, so that urban infrastructure plays a more important role in influencing the demand side of urban labor market. It is also found that urban infrastructure policy unevenly affect the structure of wages. Returns to education are relatively higher, whereas returns to experience are relatively lower in cities with better infrastructure.

The chapter is structured as follows. Section 4.2 briefly reviews the literature on the theoretical and empirical analysis in relation to urban infrastructures. Section 4.3 describes the basic theoretical model and the impact of urban infrastructure on rents, wages and return to workers characteristics. Section 4.4 describes data used in empirical analysis and calculates the composite urban infrastructure index, using a factor analysis approach.

Section 4.5 reports the estimation results on the impacts of urban infrastructure on rents, wages and return to workers characteristics. Section 4.6 concludes the section.

4.2 Review of Related Literature

The relationship between public infrastructure and regional economic development has been analyzed by many researchers. A general consensus is achieved around the idea that basic infrastructure facilities are important factors related to economic performance in terms of growth, employment and wage differentials.

The early studies of public infrastructure focus on its productivity effect on economic growth. Mera (1973) was the first study that empirically examining the role of social capital in regional production on the basis of a multi-regional econometric model by the Economic Planning Agency in Japan. He estimated for nine Japanese regions a production function including some form of public capital (e.g., transportation and communications infrastructure, soil and water conservation, health and educational infrastructure), which he refers to as "social capital." for the period 1954 to 1963. Mera found that a 1% increase in infrastructure investment would yield 0.35% increase in manufacturing output and a 0.40% increase in service sector output. The work of Mera was followed by several papers by Blum, (1982); Ratner (1983); and Da Costa et al. (1987). Nevertheless, none of these studies generated much interest among mainstream macroeconomic analysts (Mikelbank and Jackson, 2000; Lakshmanan, 2010). The level of research interest was dramatically increased with the seminal work of Aschauer (1989). Using an aggregate Cobb-Douglas production function to analyze U.S. economic output from 1949 to 1985, Aschauer (1989) found that a 1% rise in the public capital stock increased private output by 0.39%. Subsequent studies by Aschauer (1990) and Munnell (1990) further confirmed the existence of large positive economic effects from infrastructure investment for U.S. during same time period. The studies are then undertaken for other OECD countries. The findings of these studies generally extend from a significantly negative or nonexistent effect (e.g., Hulten and Schwab, 1991; Holtz-Eakin, 1994; Holtz-Easkin and Schwarts, 1995) to a strongly positive effect (Flores de Frutos, *et al*, 1998; Canning and Bennathan, 2000; Charlot and Schmitt, 2000; Yamano and Ohkawara, 2000; Kemmerling and Stephan, 2002; Zheng and Kuroda, 2013) of public capital on output.

A second strand of infrastructure literatures has examined the productivity effect and amenity effect of infrastructure on employment and wage differentials. In this regard, public infrastructure served as a productive input to firm and an amenity to household. Therefore, the extent of urban infrastructure influences the mobility of households and firms and thereby influences the wage distribution across regions. The impact of amenity on wage differentials has been discussed by many researchers in the context of the Rosen's (1974) hedonic model (e.g., Rosen, 1979; Graves and Linneman, 1979; Graves, 1983). At the heart of hedonic analysis is a compensating wage differential model in which the implicit price of an attribute (e.g., location-specific infrastructure) reflects both the marginal valuation to consumers and the marginal cost to firms. Following Rosen's (1979) work, Roback (1982) develops a model in which firm and household behavior are simultaneously considered in equilibrium. She finds that the value of amenity is reflected in both wage and land rent gradient. If amenity is productive, the impact of amenity on wage is ambiguous, whereas the rent is increasing with amenity.

One of the most important applications of Rosen/Roback model in empirical analysis is to account for the considerable wage differences across regions. For example, using 1997-survey data for individuals in 98 largest U.S. cities, Roback (1982) finds that much of the regional wage differences can be explained by local amenities, which are measured by urban infrastructure facilities and natural condition. Blomquist *et al.* (1988) estimate the quality of life indices in U.S. urban areas and find evidence supporting the existence of substantial compensation for location-specific amenities in both labor and housing market. Using data from the 1985-1989 American Housing Survey, Gabriel and Rosenthal (1999) find that nominal wage rates rise with the local cost of living but fall with the value of local amenities. In addition to empirical analysis on U.S. cities, Berger *et al.* (2008) apply the Rosen/Roback model into the study on transition economy, such as Russia. They analyze Russian labor and housing markets with Russian Longitudinal Monitoring Survey (RLMS) for the period 1992 to 2005. Estimation results from the wage and housing value equation suggest that workers are compensated for differences in urban amenities, after controlling for worker and housing characteristics.

Another strand of empirical studies focus on the impact of amenities on return to a specific type of workers (e.g., highly educated worker) and investigate the wage differences across different types of workers. Beeson (1991) extends Roback's model to allow for workers being different in their characteristics such as education attainment. In the empirical analysis she uses data form U.S. 1980 population census to examine the relationship between regional differences in returns to schooling and regional characteristics. She finds that differences in returns to schooling across regions can be fully explained by differences in amenities. Recent studies on wage differentials in U.S. cities find evidence that returns to education is decreasing with urban amenities (Adamson, *et al*., 2004). Returns to college degree is lower in high-infrastructure and expensive cities, compared to low-amenity towns (Black, *et al.*, 2005). In addition to education, Addario and Patacchini (2008) investigate the impact of urban agglomeration on the structure of earning in Italy and find that returns to experience are nearly zero while returns to tenure are lower in large cities which are endowed with higher level of urban amenities.

There are also many empirical studies attempting to apply the hedonic analysis to examine on effects of various urban amenities in China. Some researchers conduct study on specific metropolis in China. For example, Jim and Chen (2006) investigate impacts of urban environmental elements on residential housing price in Guangzhou, which is one of the most developed cities in eastern China. Using the hedonic prices method to value a set of environmental amenities, they find that view of green spaces and proximity to water bodies raised housing price in Guangzhou, contributing notably at 7.1% and 13.2%, respectively. Their study provides evidence that hedonic pricing method could be applied in Chinese context with an increasingly expanding and privatized property market. In a similar analysis, Kong *et al.* (2007) use hedonic price model to estimate the amenity value of urban green space in another eastern city, Jinan. The results confirm that green space amenity such as size-distance index of scenery forest, accessibility to park and plaza green space types, has positive impact on house prices. In addition, they find that a 1% increase in education environment will, on average, increase urban house prices by 1.9%, implying that homeowners may trade off amenity to get a good education environment.

In very recent studies, the single-city case study has been extended to multi-cities spread over the mainland in China. Using a panel data over the time period from 1997 to 2006 for 35 major cities, Zheng (2010) *et al.* analyze the impact of local amenities (disamenities) such as ambient air pollution, climate, and green space, on housing prices in China. They find that housing price is positively related to green amenities measured by green space per-capita but is negatively related to the level of air pollution. The contents of amenity have also been extended. For example, in the study of Wang *et al.* (2011), urban economic openness is regarded as a special type of amenity which could not only enhance urban productivity but also create a pleasant 'open' environment for its citizens. While their empirical analysis employs panel dataset which is similar to that of Zheng *et al.* (2010), the estimation results show that an increase in urban openness increases real estate prices by 0.282%, implying that the openness amenity plays an important role in explaining the appreciations of Chinese real estate prices from the year 1998 to 2006.

4.3 Theoretical Framework: A Wage Compensation Differential Model

In this section, following the pioneer study by Roback (1982), a hedonic model of urban infrastructure is developed to analyze the equilibrium mechanism in labor and land market.

4.3.1 Basic Setup and Assumptions

City

Consider a country with J cities, where city j is endowed with a unique bundle of infrastructure s_j. Urban infrastructure may be firm-specific, so that it only has productivity impact on firms; or may be worker-specific, so that it only has amenity effect on worker's utility; or may affect both firms and workers. According to the magnitudes of productivity effect and amenity effect, a high-productivity city is defined as city where productivity effect dominates, whereas a high-amenity city is defined as city where amenity effect dominates.

Workers

Workers are indifferent in their characteristics and preferences. In a given city j with extent of urban infrastructure s, A representative worker i maximizes his utility by consuming composite commodity, x_i, and residential land, $l_{c,i}$, subjected to his income constraint[15].

$$\max \ u\left(l_{c,i}, x_i; s\right)$$

$$s.t. \ w_i + I_i = x_{ij} + l_{c,ij} \times r_i \tag{4.1}$$

where w_i is worker i's wage, r_i is the rent for residential land, and I_i is worker i's non-labor income. Following Roback (1982), non- labor is assumed to be independent of location.

Associated with Eq. (4.1) is worker's indirect utility function, $V(w_i, r_i; s)$. Worker's migration across cities is assumed to be costless. In addition, an improvement in urban infrastructure has a positive effect on worker's utility, so that, $\partial V / \partial s > 0$.

[15] In the following analysis in this section, the subscript for city, j, is omitted for simplicity.

Firms

Firms produce the composite commodity, x, whose price is assumed to be numeraire, using q^s workers of heterogonous characteristics, and land, l_f, according to constant returns to scale production process. A representative firm's unit cost function is denoted as, $c(w_1, \cdots, w_n, r;\ s)$. Firms' relocation across cities is assumed to be costless. Given the productivity effect of urban infrastructure, an improvement of urban infrastructure has a negative impact on firm's unit cost, so that, $\partial c / \partial s < 0$.

4.3.2 General Equilibrium of Labor and Land Markets

The equilibrium condition of labor market requires the labor supply equals labor demand so that neither a labor excess nor a labor deficit is observed in the job market. Similarly, the equilibrium condition of land market requires land supply equals land demand. More importantly, for given city, workers and firms compete for scare locations with wages and rents adjusting so that the equilibrium wages and rents are simultaneously determined by both labor and markets. In particular, migration is assumed to be costless and thus utility must be equated across cities in equilibrium for each type of worker in a given city j. The zero profit condition for firm is that unit cost is equal to the price of numeraire in the equilibrium.

These equilibrium conditions are summarized as follows:

$$
\begin{aligned}
q^d &= q^s && \text{(Labor market)} \\
l^d &= l^s && \text{(Land market)} \\
V(w_i, r_i;\ s) &= \overline{V} && \text{(Equal utility condition)} \\
c(w_i, r; s) &= 1 && \text{(Equal cost condition)}
\end{aligned}
\tag{4.2}
$$

Demand for labor, q^d

First consider the demand side, i.e., firm's behavior, in urban labor market. Firm's demand for labor can be derived by solving for its problem of minimization of cost.

$$\min\left\{r \times l_f + \sum_{i=1}^{n}(w_i \times q_i^d)\right\}$$

$$s.t. \qquad f(x) \geq Q \tag{4.3}$$

where $f(x)$ is firm's production function.

From Eq. (4.3), the total demand for labor in city j can be obtained by summing up firm's demand for each type of workers as follows:

$$q^d = \sum_{i=1}^{n} q_i^d (w_i, r_i, s) \tag{4.4}$$

Supply for labor, q^s

Second, consider the supply side, i.e., worker's behavior in urban labor market. Worker i's demand for residential land can be obtained by solving the problem of utility maximization. Summing up each worker's demand yields the total demand for residential land in city j as follows:

$$l_c = \sum_{i=1}^{n} l_{c,i}(w_i; r_i, s) \tag{4.5}$$

Furthermore, letting the amount of total land in city j, L , be fixed, the number of workers employed in city j, i.e., the total supply for labor in city, q^s , equals:

$$q^s = L / l_c = \sum_{i=1}^{n} L / l_{c,i}(w_i; r_i, s) \tag{4.6}$$

Eq. (4.6) indicates that both workers' demand for land and workers' supply is determined by workers' wage, local rent, and the extent of local amenity infrastructure.

Demand for land, l^d

Third, consider the demand side of urban housing and land market. Urban land broadly consists of two parts: (1) developed land, which is allocated to workers and firms for living and production, respectively; (2) undeveloped land, which is allocated to farmers and agriculture production.

Worker's demand for developed land is a derived demand for urban housing. On the other hand, firm's demand for land is a derived demand for worker's consumption on the composite good *X*, which is negatively related with worker's consumption on housing for given income constraint. Therefore, both of worker's and firm's demand for developed land, l_c, and, l^f, can be converted into worker's demand for housing, h_i . The total demand for land in a given city, $l^d = l_c + l^f$, can also be denoted as worker's demand for housing, h_i , as follows:

$$l^d = \sum_{i=1}^{n} h_i^d ;$$
$$h_i^d = h_i^d(l_c) = h_i^d(q^s) = h_i^d(w_1, \ldots, w_n, p_i; s) \qquad (4.7)$$

where $p_i = p_i(r_i)$ is the housing price paid by worker, which is the function of urban rent r.

Supply for land l^s

In China, urban land is owned by state. The land leasehold is owned by local land officials. Therefore, the supplier in land market is local officer who decides on the pattern of land use (developed land for urban housing vs. undeveloped land for agriculture).

Suppose an land officer has some land endowments, $l = (l_h, l_a)$, of housing land l_h and agriculture land l_a. With his endowment of land, this land officer's income is the market value of his endowment, which is the income he received by selling housing land and agriculture he owned.

Let the land rent for agriculture be fixed and is denoted as $\bar{r}$, officer's income, m ,is then a function of the land rent for housing, r_h , as follows:

$$m = m(r_h) = r_h \times l_h + \bar{r} \times l_a \qquad (4.8)$$

For a given level of urban infrastructure *s*, land officer's objective is to maximize his utility under his budget constraint.

$$\max \mathrm{U}(x_h, x_a; s\ ) \\ s.t.\ \ \mathrm{r}_h \times x_h + \mathrm{r}_a \times x_a \le m \tag{4.9}$$

Officer's demand for housing land is derived by solving this problem of maximization as $x_h\ (r_h\ , m, s)$.

The total derivative of the demand function for housing land with respect to the rent for housing land is:

$$\frac{\partial x_h(r_h\ , m, s)}{\partial r_h} = \frac{\partial x_h\ (r_h\ , m\ \ s)}{\partial r_h} + \frac{\partial x_h\ (r_h\ , m, s)}{\partial m} \frac{\partial m}{\partial r_h} \\ \frac{\partial x_h(r_h\ , m, s)}{\partial r_h} = \frac{\partial x_h^s(r_h s)}{\partial r_h} - \frac{\partial x_h(r_h\ , m, s)}{\partial m} x_h \\ \frac{\partial m}{\partial r_h} = l_h \tag{4.10}$$

where the second equation is derived from the Slutsky equation; the last equation is derived from definition of *m* (See Eq. (4.8)).

Combing these equations gives:

$$\frac{\partial x_h(r_h\ , m, s)}{\partial r_h} = \frac{\partial x_h^s(r_h s)}{\partial r_h} + \frac{\partial x_h(r_h\ , m, s)}{\partial m}(l_h - x_h) \tag{4.11}$$

The first term in the right-hand side of Eq. (4.11) denotes the substitution effect. As the rent for housing land increase, officer's demand for housing land will be decreased. The second term denotes the income effect, which depends on the net demand, $(l_h - x_h\ )$ of housing land. Given the role of local officer played in China's land market, net demand for housing land is always positive, so that, $l_h - x_h\ > 0$. Because officer is the net seller (supplier) of housing land, the net income effect of a rent increase will be positive.

The term in the left-hand side denotes the total effect of an increase in land rent. The sign of this term is determined by the difference substitution effect, the income effect, and the net demand of housing land. In particular, if the substitution effect is larger (smaller) than the income effect, an increase in land rent will increase (decrease) the supply of housing land.

4.3.3 Impacts of Urban Infrastructure on Wages and Rents

According to the determinants of supply and demand in labor and land markets, the equilibrium conditions described by Eq. (4.2) can be rewritten as follows:

$$\begin{aligned} & q^d(w_i, r_i, s) = q^s(w_i, r_i, s) && \text{(Labor market)} \\ & l^d(w_i, r_i, s) = \sum_{i=1}^{n} h_i^d(q^s) = l^s(r_h, r_a, \mathrm{s}) && \text{(Land market)} \\ & V(w_i, r_i; s) = \overline{V} && \text{(Equal utility condition)} \\ & c(w_i, r; s) = 1 && \text{(Equal cost condition)} \end{aligned} \quad (4.12)$$

To ease analysis, the relationships described by these equations are shown in figures. The (I) quadrant in Figure 4.1 describes the equal utility and equal cost condition. The horizontal axis shows rent and the vertical axis shows wage. At a given level of urban infrastructure, the downward-sloping line denotes combinations of wage and rent which equalized unit cost, whereas the upward-sloping line denotes the combinations of wage and rent which equalized utility. The (II) quadrant describes labor market equilibrium described by the labor market equation in Eq. (4.5). The vertical axis shows employment. The downward-sloping line and upward-sloping line respectively denotes the demand and supply and demand curves for labors. The (III) quadrant describes the connection between demand for land and supply for labor, as described by the first equality of land market equation in Eq. (4.5). The vertical axis shows the amount of land. An increase in supply for labor also increase demand for land in local land market. Moving the demand curve in parallel, the demand and supply curves of land market are shown in the (IV) quadrant, which reflects the second equality of land market equation.

The four-quadrant figure explicitly shows that the equilibrium wage and rent is solved from the interaction of the equilibrium conditions of the two sides of two markets. Given the different impact of urban infrastructure, its impacts on urban infrastructure in labor and rent markets are discussed in three cases.

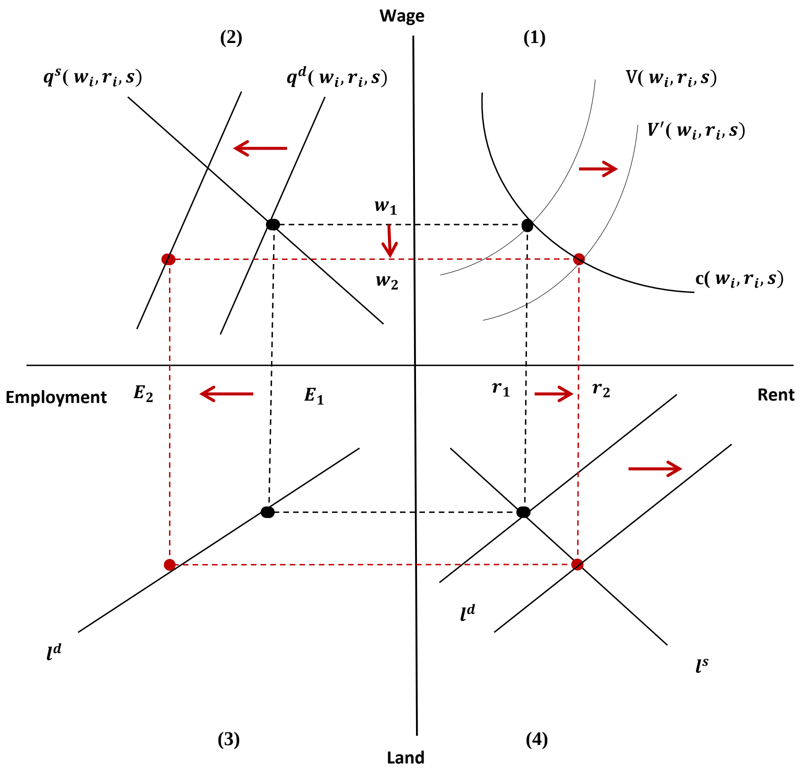

Figure 4.1 General Equilibrium with Pure Amenity Effect

Case 1: worker-specific urban infrastructure and pure amenity effect

If an urban is endowed with infrastructure (e.g., entertainment facility such as cinema) which is particularly desirable to a worker but has no direct impact on firms, then this high-amenity city tend to attract more workers. Other things being equal, an increase in urban worker-specific infrastructure increase worker's utility, as well as the supply of workers in local labor market. This amenity effect is respectively reflected by an upward shift of the iso-utility curve in the (I) quadrant and a downward shift of the supply curve in the wage-employment in the (II) quadrant.

As a result, an exogenous improvement in worker-specific infrastructure has a positive impact on the supply side of labor market, the equilibrium wage decreased from w_1 to w_2. Meanwhile, improving worker-specific infrastructure also directly increases the demand for land and thereby increases the rent from r_1 to r_2 in land market.

Case 2: Firm-specific urban infrastructure and pure productivity effect

If a city is endowed with urban infrastructure (e.g., developed transportation network facilitates intra- and inter-regional trade on the composite good) which is particularly desirable to a firm but has no direct impact on workers, then this high-productivity city tend to attract more firms. The agglomeration of firms results in an increase in demand for both labors and land. In Fig. 4.2, these increases are respectively reflected by an upward shift of the demand curve in the (II) quadrant and a downward shift of the demand curve in the (IV) quadrant.

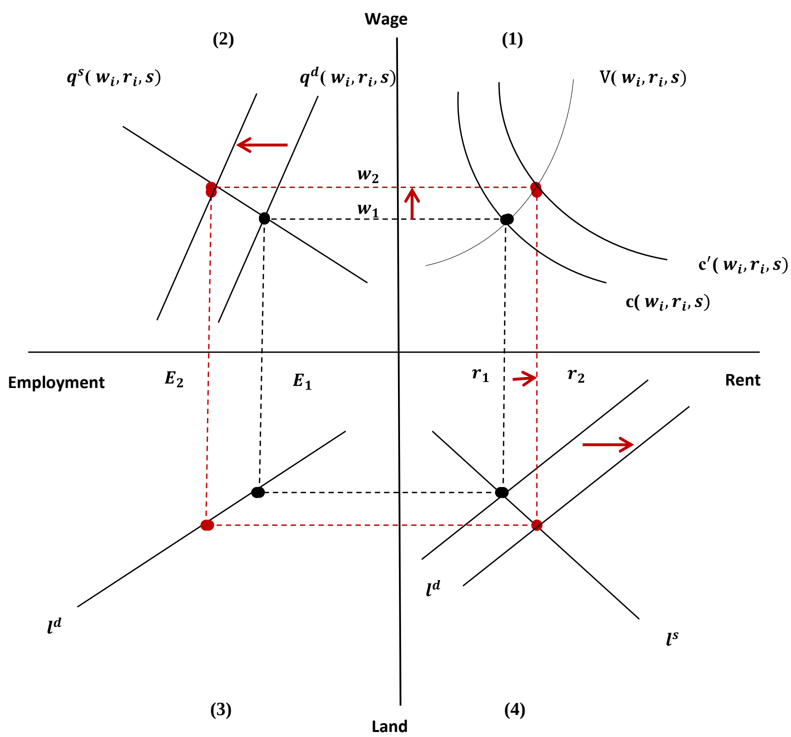

Figure 4.2 General Equilibrium with Pure Productivity Effect

As a result, firm-specific infrastructure is directly related to labor market and is thereby indirectly related to land market. First, an exogenous improvement in firm-specific infrastructure directly influences the demand side of local labor market, leading to an increase in both local employment and wages. This then causes an increase in demand for land and thereby an increase in rent in local land market.

Case 3: Mixture of worker-specific and firm-specific urban infrastructure

In reality, it is more rational to consider the level of urban infrastructure as an integral bundle that consists of both worker-specific and firm-specific infrastructures. In this case, the level of urban infrastructure might affect both worker utility and firm profitability (e.g., metropolitans, such as Beijing and Shanghai, attract both of workers and firms).

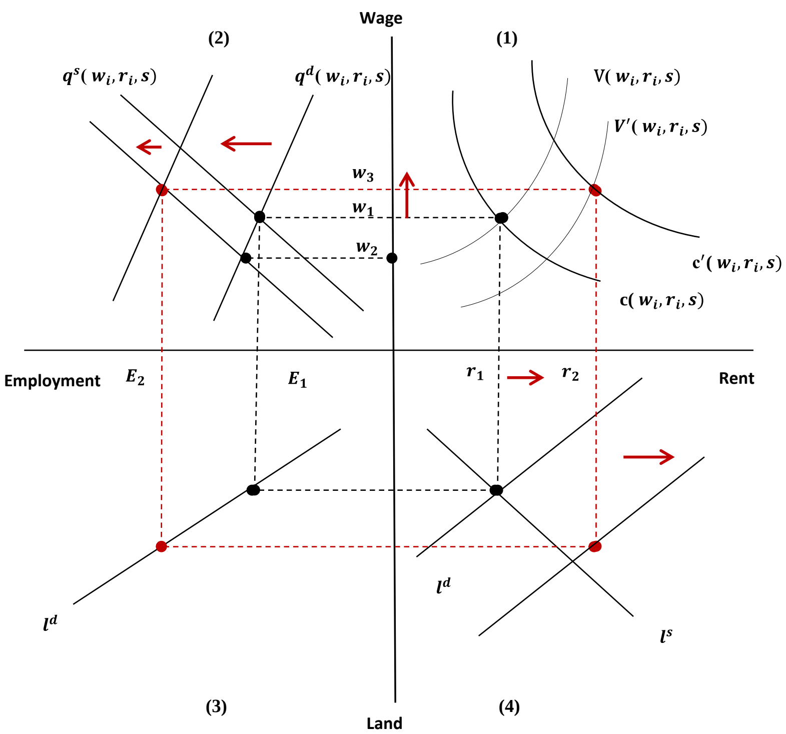

Figure 4.3 General Equilibrium when Productivity Effect Dominates

The equilibrium wage and rent is then determined by the interaction between the productivity effect and the amenity effect. The presence of both firm-specific and worker-specific infrastructure attracts both firms and workers, which increase local demand for land and thereby increase local rent. Meanwhile, the geographic concentration of workers raises local labor supply whereas the geographic concentration of firms raises local labor demand. In Fig. 4.3, these relations are respectively reflected by the downward shift of supply curve and the upward shift of the demand curve in the (II) quadrant.

In the case of high-productivity city where productivity effect dominates, infrastructure has greater value to firms than to workers. Therefore, wages increase from w1 to w3, implying that much of the rent increase in local land market are compensated for by higher wages. By contrast, In the case of high-amenity city where amenity effect dominates, infrastructure has greater value to workers than to firms. As shown in Figure 4.4, when amenity effect outweighs productivity, equilibrium wages decreases form w1 to w3, indicating that much of the rent increase are paid in the form of forgone wages.

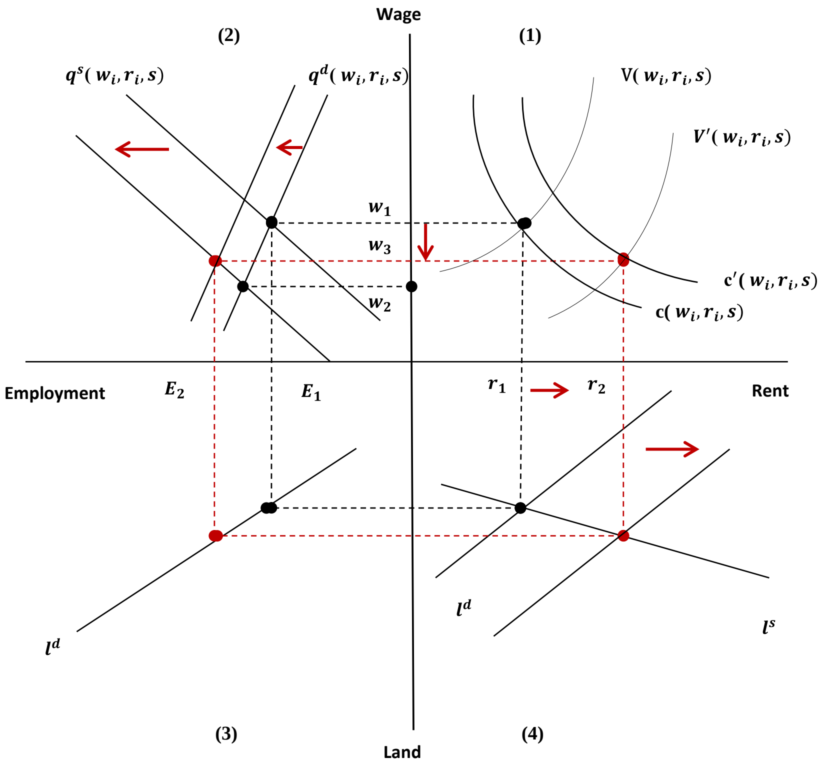

Figure 4.4 General Equilibrium when Amenity Effect Dominates

Table 4.1 summarizes the impact of urban infrastructure on urban labor and land markets in high-productivity city and high-amenity city, respectively. It shown that in both cities, an exogenous improvement in urban infrastructure will increase urban employment, land development, and rent. The only distinction between two types of city is that wages become higher in high-productivity city but become lower in high-amenity city.

Table 4.1 Impacts of Urban Infrastructure in Different Cases

	High-infrastructure city (Productivity effect dominates)	High-infrastructure city (Amenity effect dominates)
Employment	+	+
Wage	+	-
Land development	+	+
Rents	+	+

4.3.4 Urban Infrastructure and Returns to Workers Characteristics

In this section, the basic model is extended to incorporate the heterogeneous workers. In particular, workers are assumed to differ in their endowments of a specific characteristic, *z*, such as education tenure, and experience. Urban infrastructure is assumed to be both worker-specific and firm-specific, so that this extended model excludes the case of pure amenity effect and pure productivity effect. The other setup remains the same as the basic model. The equal utility and equal cost condition still holds in the extended model and are rewrote as follows:

$$V(w^i, r, s) = \overline{V}^i \qquad (4.13)$$

$$C(w^1, \cdots, w^n, r, s) = 1 \qquad (4.14)$$

where *i* indexes the workers by discrete levels of characteristic, w is the nominal wage of workers in type *i*.   is the nationally given utility for workers in class *i*.

Differentiating Eq. (4.13) and Eq. (4.14) with respect to the level of urban infrastructure as follows:

$$\frac{dr}{ds} = (-\frac{\partial C}{\partial a}x + \sum_i N^i p^i)/L > 0 \qquad (4.15)$$

$$\frac{dw^i}{ds} = (l^c)^i(\frac{dr}{ds}) - p^i = (l^c)^i\left[(-\frac{\partial c}{\partial s}x + \sum_i N^i p^i)/L - p^i\right] \gtreqless 0 \qquad (4.16)$$

where $p^i = -\frac{\partial V}{\partial s}\Big/\frac{\partial V}{\partial w^i} = l^c\frac{dr}{ds} - \frac{dw^i}{ds}$, is the value of amenities to type *i* workers; $L = l^f + \sum_i N^i(l^c)^i$, is the total developed land in a given city *j*.

According to Eq. (4.15), the rent-infrastructure gradient equals the total value of amenities divided by total land of city *j*, i.e., the infrastructure value per unit of land. In this case, infrastructure value is capitalized into rents. As infrastructure as a whole is assumed to be productive, the cost savings to a firm associated with infrastructure $(\partial C/\partial s)x > 0$, so that the rent-infrastructure gradient is greater than zero. Therefore, rents are higher in city with higher level of urban infrastructure. The positive rent-infrastructure gradient is consistent with the analysis in the basic model. City with higher level of urban infrastructure attracts both workers and firms, whose concentration in turn increase local demand for land and thereby increase local rents.

Eq. (4.16) indicates that the wage-infrastructure gradient depends on the differences between infrastructure value per unit of land and the value of infrastructure to type *i* workers, p^i. Further transform Eq. (4.16) by averaging over all workers *N* and get:

$$\frac{d\bar{w}}{d\bar{s}} = \frac{1}{N}\sum_i N^i\left(\frac{dr^i}{ds}\right) = \frac{l^f\bar{l}^c}{L}\left(-\frac{\partial c}{\partial s}\frac{x}{l^f} - \frac{\bar{p}}{\bar{l}^c}\right) \gtreqless 0 \qquad (4.17)$$

where $\bar{p} = \frac{1}{N}\sum_i N^i p^i$, is the average value of the infrastructure to workers, i.e. the amenity effect described in the basic model; $\bar{l}^c = \frac{1}{N}\sum_i N^i(l^c)^i$ is the average land per worker.

According to Eq. (4.17), the impact of infrastructure on wages is reflected in the difference between the average value to workers, i.e., the amenity effect, and the value to firms, i.e. the productivity effect. The wage-infrastructure gradient actually reflects the net effect of urban infrastructure in labor and land market. Specifically, a city with positive wage-infrastructure gradient is identified as high-productivity city, whereas a city with negative wage-infrastructure gradient is identified as high-amenity city.

Similar to the way that difference in amenity effect and productivity effect are reflected in wage-infrastructure gradient, differences in amenity effect and productivity effect across different types of workers are also reflected in their respective wage-infrastructure gradients. Differentiate Eq. (5) with respect to *z* in logarithms as follows:

$$\frac{\partial}{\partial z}\left(\frac{d\log w^i}{ds}\right)=\frac{1}{z}\left[\left(\frac{d\log w^i}{ds}\right)(\frac{x^i}{w^i})(\theta_{l^c,z}-\theta_{x,z})-(\frac{p^i}{w^i})(\theta_{s,z}-\theta_{l^c,z})\right]\gtreqless 0 \quad (4.18)$$

where $\theta_{l^c,\ z}$, $\theta_{s,z}$, and $\theta_{x,z}$ are the elasticity of demand for land, infrastructure, and composite commodity with respect to worker characteristic *z*, respectively. x^i/w^i and p^i/w^i are the shares of composite commodity and amenities in consumer's budget, respectively.

For simplicity, the elasticity of demand for housing and the composite commodity are assumed to be equal, so that $\theta_{l^c,\ z}=\theta_{x,z}$. Rearrange Eq. (4.18) with this assumption as follows:

$$\frac{\partial}{\partial z}\left(\frac{d\log w^i}{ds}\right)=\frac{1}{z}(\frac{p^i}{w^i})(\theta_{s,z}-\theta_{l^c,z})\ \gtreqless 0 \quad (4.19)$$

Eq.(4.19) indicates that whether return to a specific worker characteristic, say experience, varies with the level of local urban infrastructure depends on the differences between the elasticity of demand for housing and infrastructure. If workers' consumption of urban infrastructure increases with experience in the labor market, that is, experienced workers have a greater preference for living in city with higher level of urban infrastructure than inexperienced workers. In this sense, as shown in Eq. (4.19), experienced workers value infrastructure relatively more than inexperienced workers, so that p^i of experienced workers is greater than inexperienced workers. For given level of the average of infrastructure value per unit of land, returns to experienced workers is relatively lower than returns to inexperienced workers in city with higher level of infrastructure. However, the opposite happens if workers' consumption of housing increases with experience.

4.4 Measuring Urban Infrastructure

4.4.1 Data

The data for individuals used in this paper are drawn from Chinese Household Income Project (CHIP), conducted by the Institute of Economics, Chinese Academy of Social Sciences, with the assistance for the National Bureau of Statistics for the year 2002. This project collects information on the distribution of personal income, level of education, occupation, employment status and other related economic factors. As shown in Figure 4.5, CHIP-2002 survey covers 10 provinces (Anhui, Beijing, Gansu, Guangdong, Henan, Hubei, Jiangsu, Liaoning, Shanxi, Chongqing, Sichuan and Yunnan) and 2 municipalities (Beijing and Chongqing) within China's mainland.

Figure 4.5 Regions Involved in CHIP-2002 Survey

The data for cities[16] are drawn from the China City Statistical Yearbook (2003). Within the mainland of China, there are three levels of cities: municipalities, prefecture-level cities and county-level cities. Municipalities are higher level of cities which are directly under the control of Chinese central government. Therefore, their political statuses are higher than that of other kind of cities. Prefecture-level cities are cities that are given prefecture status and the right to govern surrounding counties. County-level cities are usually governed by prefecture-level divisions. The main purpose of creating country-level cities is to replace county. In 2002, there are 4 municipalities (Beijing, Tianjin, Shanghai and Chongqing), 275 prefecture-level cities and 381 county-level cities in China. Given that county-level cities usually include rural areas many times the size of their urban, built-up area, the empirical analysis excludes these cities and restrict our attention on the urban area of municipalities and prefecture-level cities. In accordance with the CHIP-2002 survey, our final empirical analysis uses a cross-sectional dataset of 57 cities, including 2 municipalities (Beijing and Chongqing) and 55 prefecture-level cities for the year 2002.

This chapter focuses on individuals aged 16 to 65, who live in urban areas and report positive wage and salary earnings. Owners of private or individual enterprise are excluded, because it is difficult to disentangle their wages from profit income. Observations with missing values on personal level of education, occupation, etc. are also excluded. With these data restriction, the total sample includes 8,973 individuals located in 57 cities in China.

4.4.2 Measures: A Factor Analysis Approach

According to its impact on workers and firms, the level of urban infrastructure can be measured in many aspects. For households, a high-amenity city is characterized as good local schooling system, wider offer of cultural and entertainment venues, or beautiful scenery and fresh air. On the other hand, cities that provides more “productive” infrastructures like airports, transportation networks are more attractive for firms (Di Addario, S. and Patacchini, E., 2006). Previous studies attempt to include variables reflecting different aspects of amenities in regressions as much as possible. For example,

[16] In this dissertation, cities’ data only include built-up districts and suburbs.

Roback (1982) uses six variables (crime rate, unemployment rate, micrograms/cubic meter of particulates, population, population density of SMSA, and percentage change in population), and Blomquist, G. *et al.*(1988) use eighteen variables (precipitation, humidity, heating degree days, etc.) as proxies for urban amenities. Nevertheless, this approach remains open to the possibility of omitted (locational) variable bias, because it is impossible to fully specify the complete set of local amenities (Gabriel and Rosenthal, 1999). Moreover, it is worth noting that some measurements of amenities reflect similar information (e.g., precipitation and humid weather; population and population density) so that they would be highly correlated. The inclusion of such highly correlated variables in the regression analysis would result in multicollinearity, so that the estimation results using OLS would be biased.

Given the limitations of such multi-dimensional measurements, this chapter adopts the factor analysis method to measure urban amenities. Specifically, factor analysis attempts to summarize a set of observed variables of amenities in terms of a small number of common factors plus a factor which is unique to each variable. It is the common factor that explains the correlations among various measurements of amenities. The utilization of factor analysis method could find these common factors and thereby reduce the multi-dimensional variables into a one-dimensional composite index of urban infrastructure.

Suppose that there are *n* observed variables and *m* common factors, the factor analysis model is then specified as follows:

$$X = AF + \varepsilon \qquad (4.20)$$

where X is the $1 \times n$ matrix of observed variables, F is the $1 \times m$ matrix of common factors, A is the $n \times m$ matrix of coefficients, A is also called factor loading matrix, and ε is the $1 \times n$ vector of errors with diagonal covariance equal to the unique factors.

To measure the level of urban infrastructure, information on cities' urban infrastructure is broadly grouped into three categories, each with several variables, as described in Table 4.2.

To construct a composite index of urban amenities for city *j*, this setion proceeds in three steps. First, each equation as described in Eq. (9) is estimated to get the coefficients, which is also called loadings in factor analysis, a_{11}, a_{22}, …, a_{nm}, for each common factor. Then the factors are extracted according to their eigenvalues, which is equal to the sum of the squared loadings for a given factor. The last three row of Table 4.3 reports the eigenvalues and the amount of variance explained by each factor. The standard criterion on deciding number of factors suggests that all factors which have eigenvalues greater than one should be kept. Therefore, factor 1 and factor 2 are retained and used for further analysis in the following factor analysis. Factor 1 and factor 2 add up to explain 93.5% of the amount of variance. Therefore, these two factors are adequate enough to explain the most information described by the initial 10 indicators.

Table 4.2 Categories and Variables of Urban Infrastructure

Variables	Definition
Environmental infrastructure	
Ratio of daily sewage treatment	The share of disposed daily sewage in total daily sewage
Ratio of daily waste treatment	The share of disposed daily waste in total daily waste
Ratio of green covered area	Green covered area divided by completed area
Living infrastructure	
Theatres and cinemas per capita (entertainment)	Sum of theatres and cinemas divided by total population of municipal districts
Collections of public library per capita (culture)	Total collections of public library divided by total population of municipal districts
Number of teachers per capita(education)	Sum of teachers in elementary school, junior high-school, high-school, and college and university divided by total population of municipal districts
Number of doctors per capita (health care)	Sum of doctors divided by total population of municipal districts
Transportation infrastructure	
Transportation network density	Area of paved roads divided by total population of municipal districts
Public vehicles per capita	Sum of buses, trolley buses and other public vehicles divided by total population of municipal districts
Taxi per capita	Total number of taxi divided by total population of municipal districts

Second, the initial pattern of factor loadings is adjusted so that each individual variable has substantial loadings on as few factors as possible. This adjustment procedure, which is also called rotation to simple structure, provides a more interpretable and clear outcome for the factor analysis model. Table 4.3 reports the rotated loadings of factor 1 and factor 2 on each observed variable. Three variables in the categories of environmental infrastructure, healthy, and education have higher loadings on factor2, whereas culture, entertainment, and three variables in the category of transportation have higher loadings on factor 1. The rotation adjustment offers a clearer picture of the relevance of each sub-indicator in the factor. Specifically, factor 1 is mostly defined by variables of culture, entertainment and transportation, whereas factor 2 is mostly defined by variables of environmental condition, healthy and education.

Table 4.3 Factor Loadings and Factor Scores

	Factor1	Factor2
Ratio of daily sewage treatment	0.377	0.295
Ratio of daily waste treatment	0.220	0.391
Ratio of green covered area	0.142	0.179
Theatres and cinemas per capita	0.223	0.099
Collections of public library per capita	0.724	0.499
Number of teachers per capita	0.267	0.890
Number of doctors per capita	0.161	0.882
Transportation network density	0.807	0.116
Public vehicles per capita	0.905	0.324
Taxi per capita	0.866	0.057
Eigenvalue	4.148	1.174
Proportion	0.729	0.206
Cumulative proportion	0.729	0.935

Finally, the weighted factor score i.e., index of urban infrastructure for each city, is calculated, using each common factor’s share in the amount of variance explained by the retained factors. Table 4.4 reports the factor scores and the composite index of amenities of each city.

Table 4.4 Factor Socres and the Composite Index of Urban Infrastructure

City	Factor 1	Rank of factor 1	Factor 2	Rank of factor 2	Urban infrastructure index	Rank of urban infrastructure index	City group
Beijing	3.734	1	2.048	2	3.362	1	High
Lijiang	3.396	2	-3.193	57	1.897	2	High
Guangzhou	1.860	3	1.382	5	1.754	3	High
Nanjing	1.800	4	0.939	7	1.610	4	High
Wuhan	0.930	9	1.634	4	1.086	5	High
Shenyang	1.070	6	1.105	6	1.078	6	High
Dalian	1.083	5	0.602	11	0.977	7	High
Kunming	0.969	8	0.638	10	0.896	8	High
Wuxi	0.977	7	0.201	22	0.806	9	High
Taiyuan	0.702	11	0.543	13	0.667	10	High
Hefei	0.753	10	0.149	24	0.620	11	High
Yichang	0.593	13	0.138	25	0.492	12	High
Huainan	0.689	12	-0.930	51	0.331	13	High
Fuoshan	0.309	15	0.292	20	0.305	14	High
Zhengzhou	0.134	16	0.889	9	0.301	15	High
Chengdu	-0.166	23	1.755	3	0.258	16	High
Wuhu	0.496	14	-1.049	54	0.155	17	High
Yangzhou	0.086	17	0.062	30	0.081	18	High
Datong	-0.031	20	-0.195	34	-0.067	19	Low
Jinzhou	0.011	18	-0.626	42	-0.129	20	Low
Jinmen	-0.240	25	0.071	29	-0.172	21	Low
Huizhou	-0.206	24	-0.398	38	-0.248	22	Low
Xiangfan	-0.497	36	0.563	12	-0.263	23	Low
Taizhou	-0.405	31	0.107	27	-0.292	24	Low
Xuzhou	-0.662	50	0.937	8	-0.309	25	Low
Bengbu	-0.123	21	-0.978	53	-0.312	26	Low
Lanzhou	-0.481	35	0.280	21	-0.313	27	Low
Wuwei	-0.127	22	-0.978	52	-0.315	28	Low
Changzhi	-0.361	28	-0.217	35	-0.329	29	Low
Tieling	-0.255	26	-0.744	48	-0.363	30	Low

(Continued)

(Continued)

Luzhou	-0.357	27	-0.412	39	-0.369	31	Low
Huangshan	-0.019	19	-1.618	56	-0.372	32	Low
Nantong	-0.646	48	0.542	14	-0.384	33	Low
Chongqing	-1.186	57	2.449	1	-0.384	34	Low
Anyang	-0.556	42	0.134	26	-0.404	35	Low
Kaifeng	-0.538	41	0.038	31	-0.411	36	Low
Zhaoqing	-0.427	32	-0.359	36	-0.412	37	Low
Pingdingshan	-0.515	39	-0.059	33	-0.414	38	Low
Xinxiang	-0.606	45	0.172	23	-0.434	39	Low
Shaoguan	-0.505	38	-0.373	37	-0.476	40	Low
Leshan	-0.440	33	-0.627	43	-0.482	41	Low
Neijiang	-0.452	34	-0.607	41	-0.486	42	Low
Qujing	-0.760	51	0.436	17	-0.497	43	Low
Yuncheng	-0.646	49	0.019	32	-0.500	44	Low
Xuchang	-0.520	40	-0.441	40	-0.503	45	Low
Xianning	-0.402	30	-0.913	50	-0.515	46	Low
Huanggang	-0.802	53	0.448	15	-0.526	47	Low
Guangyuan	-0.497	37	-0.628	44	-0.526	48	Low
Yancheng	-0.825	55	0.438	16	-0.547	49	Low
Baoshan	-0.371	29	-1.214	55	-0.557	50	Low
Zhanjiang	-0.820	54	0.326	19	-0.567	51	Low
Nanchong	-0.762	52	0.099	28	-0.572	52	Low
Suqian	-0.560	43	-0.726	47	-0.597	53	Low
Pingliang	-0.596	44	-0.717	46	-0.623	54	Low
Jieyang	-0.644	47	-0.707	45	-0.658	55	Low
Haozhou	-0.617	46	-0.850	19	-0.668	56	Low
Xinyang	-0.966	56	0.329	18	-0.681	57	Low

4.4.3 Urban Infrastructure and Geographical Distribution of Economic Activities

As the capital of China, Beijing ranks first in two out of three factor scores. The rank of other cities' factor scores varies significantly between factors. For factor 1 defined by transportation, culture and entertainment, the top-three cities on the ranking list are Beijing, Lijiang, and Guangzhou. For factor 2 defined by environment, health and education, the top- three cities on the ranking list are Chongqing, Beijing and Chengdu. The significant difference on factor scores suggests that it is difficult to compare the level of urban infrastructure among cities. For example, Lijiang has very high score on factor 1 (3.396) but very low score on factor 1 (-3.193). Then how to compare its level of urban infrastructure with another city, say Chongqing, which has higher score on factor 2 but lower score on factor 1. To solve this problem, the weighted scores are calculated as a composite index of urban infrastructure. The weights are each factor's share in the cumulative proportion (0.779 for factor 1 and 0.221 for factor2). According to their respective urban infrastructure index, Beijing, Lijiang, Guangzhou, Nanjing, and Wuhan rank top-five in 57 cities.

In addition, all cities are further divided into two groups: the first group includes 18 high-infrastructure cities, which are defined as cities with positive infrastructure indices; the second group includes 39 low-infrastructure cities, which are defined as cities with negative infrastructure indices.

Table 4.5 Comparison of High-infrastructure Group and Low-infrastructure Group

	High-amenity group			Low-amenity group		
	Ob.	Mean	S.D.	Ob.	Mean	S.D.
City-level						
Urban infrastructure index	57	0.926	0.816	57	-.043	0.146
Population density	57	654	284	57	444	270
Firms	57	1201	1149	57	681	874
Dummy if East	57	0.444	0.511	57	0.205	0.409
Dummy if Middle	57	0.389	0.502	57	0.461	0.505
Dummy if West	57	0.167	0.383	57	0.333	0.478
Individual-level						
Living cost	4436	1844.762	75094.501	4537	841.786	18672.2
Years of education	4436	12	3	4537	11	3
Working experience	4436	21	10	4537	20	9
Tenure	4436	15	11	4537	15	9

Table 4.5 summarizes some descriptive statistics on city-specific characteristics and individual characteristics for each group, using data from China City Statistical Yearbook

and CHIP survey, respectively. First, it is found that the level of urban infrastructure is generally higher in eastern and middle regions than in western regions. Second, most of Chinese urban populations are concentrated in high-infrastructure cities. The average population density of high- infrastructure cities is 654 people per squared kilometer, which is nearly 1.5 times than that of low- infrastructure cities. In addition to labor force, the geographic distribution of economic activities also shows higher level of concentration in high-infrastructure cities. High-infrastructure cities attract more firms than low-infrastructure cities. Third, the living costs in high- infrastructure cities are more than twice higher than those in low- infrastructure cities. Lastly, the distribution of workers with different characteristics varies significantly across cities. Workers residing in high-infrastructure cities are more experienced and more educated. Specifically, high-infrastructure residences, on average, have one year more education and working experience than those reside in low- infrastructure cities.

4.5 Empirical Framework: A Reduced-form Model

4.5.1 Model Specification and Methodology

The empirical analysis first examines the impact of local amenities on local housing prices by estimating a log-linear housing hedonic function in the following specification:

$$\ln \mathrm{R}_{ij} = \alpha_0 + \alpha_1 \mathrm{H}_{ij} + \alpha_2 S_j + \mu_{ij} \tag{4.21}$$

where R_{ij} is the natural logarithm of individual i's monthly housing expenditure in city j. H_{ij} is the vector of variables that describe individual i's housing conditions (e.g., total usable area, type of resident house, location, sanitary facilities, etc.). S_j is the level of urban infrastructure of city j, which is defined by the composite index of urban infrastructure calculated in Section 4.4. To further compare the rent differences between high-infrastructure cities and low-infrastructure cities, a high-infrastructure dummy variable is constructed, which equals 1, if city j's index of urban infrastructure is greater than zero; otherwise 0. In addition, the two variables, urban infrastructure index and high-infrastructure dummy are highly correlated (the correlated coefficient is 0.745); they are controlled to enter the regression separately in the following empirical analysis.

The theoretical model predicts a positive relationship between local infrastructure and local housing price when infrastructure is desirable for firms and households. As a result, high-infrastructure city attracts firms and workers, the competition in the land market increase rents. Therefore, the sign on the rent-infrastructure gradient is expected to be positive (i.e., $\alpha_2 > 0$), which implies that urban housing prices in increasing with the average extent of urban infrastructure.

To examine the impact of amenities on wages, a Mincerian function augmented with city's amenities level measured by S_j is estimated as follows:

$$\ln w_{ij} = \beta_0 + \beta_1 Z_{ij} + \beta_2 S_j + \beta_3 X_{ij} + \mu_{ij} \tag{4.22}$$

where w_{ij} is the natural logarithm of wage of individual i who lives in city j. Z_{ij} is the vector of variables that describe individual i's specific characteristics: education level, working experience and tenure. X_{ij} includes the vector of variables that describe other personal and job information (e,g., gender, occupation and sector).

When both firms and households value local infrastructure, the impact of infrastructure on individual wages depends on the differences between their valuations. The coefficient of urban infrastructure variable reflects the net effect of urban infrastructure on wages. If household values infrastructure more than firms, amenity effect is greater than productivity effect, a lager increase in the supply side of local labor market reduces wages, so that the sign of wage-infrastructure gradient is negative ($\beta_2 < 0$). That is, wages are decreasing with the average extent of urban infrastructure. On the contrary, if household values infrastructure less than firms, productivity effect outweighs amenity effect, a lager increase in the demand side of local labor market increase wages ($\beta_2 > 0$). In this case, the rent payments by workers exceed their valuation of infrastructure. As a result, wages are higher in high-infrastructure cities, which indicate workers get compensation from firms.

In addition to the differences on the valuation of amenities between firms and household, the differences on valuation may also exist across different types of workers. That is, for any given city, since workers differ in their characteristics (e.g., education level, experience), preferences for infrastructure and housing consumption, returns to a certain type of workers (e.g., highly educated workers and low educated workers, experienced workers and inexperienced workers) should also be different. To examine the relationship between urban infrastructure and returns to workers characteristics, an interaction term of urban infrastructure and worker characteristics in the Eq. (4.22) as follows:

$$\ln w_{ij} = \gamma_0 + \gamma_1 Z_{ij} + \gamma_2 S_j + \gamma_3 S_j Z_{ij} + \gamma_4 X_{ij} + \mu_{ij} \tag{4.23}$$

One problem in relation to the interaction term is how to interpret the coefficients. Similar to the way that wage-infrastructure gradient is determined by differences in the valuation of infrastructure on firms and household, the signs of the intersection terms depends on the differences in the valuation of amenities and housing among different types of workers. The specification of Eq. (4.22) indicates that the total effect of worker characteristics, say education level, on wage is $(\gamma_1 + \gamma_3 S_j)$. When the dummy high-infrastructure variable is used as a proxy for urban amenities, holding other variables constant, the main effect of education (i.e., returns to education) is $(\gamma_1 + \gamma_3)$ for high-infrastructure cities group and γ_1 for low- infrastructure cities group. In the specification where the continuous urban amenity index is employed to measure infrastructure, first center all continuous variables that consist of the interaction term (i.e., subtract the mean from each variable). After centering, the main effect of education on wages can be explained as returns to education in a city with an average level of urban infrastructure. In all specifications, a positive coefficient for the effect of the interaction term (i.e., $\gamma_3 > 0$) would imply that the higher the level of urban infrastructure, the higher the returns to education. Similar interpretation holds for returns to other workers characteristics.

Table 4.6 reports definitions and summary statistics of the main variables. In addition, among individual's characteristics, the endogenous bias of education has been discussed by many studies that investigate the economic returns to schooling (Heckman and Li, 2004; Li and Luo, 2004; Fleisher et al., 2005). Recent studies further confirm that conventional OLS estimation tends to underestimate the returns to education in China (Chen *et al.*, 2009). To control for the potential endogenous problem, a Two-Stage Least Square (2SLS) estimation method is performed to estimate the wage equations of Eq.(4.21) and Eq. (4.22) . Specifically, individuals' education level is instrumented with the education years of their parents. The interaction term including the endogenous variables will also suffer from endogeneity problem. Following the standard procedure, the endogenous interaction term of education and infrastructure are instrumented with the interaction term of the education level of individual's parents and infrastructure.

4.5.2 Estimation Results: Rent-infrastructure Differential and Wage-infrastructure Differential

The estimation results of the impact of amenities on urban housing prices are reported in Table 4.7, where infrastructure index variable (in columns (1) and (2)) and high-infrastructure variable (in columns (3) and (4)) enters the regression separately. In addition, variables of housing type, housing facilities, and housing location are gradually introduced into regression.

Table 4.6 Definitions and Statistics of Variables

Variables	Definition	Mean	S.D.
Individual characteristics			
Housing expenditures	Monthly rent for leasehold housing (for renters), or estimated monthly rent of owned housing (for owner occupants)	5.486	0.834
wage	The natural logarithm of individual's annual wage income, including bonus and subsidies.	9.211	.669
Education	Education in years	11.517	2.947
Male	Dummy variable: Male=1 if male, otherwise 0.	0.558	0.497
Married	Dummy variable: Married=1 if married, otherwise 0.	0.877	0.329
Experience	Individual's working experience, which equals the years of working by the end of 2002.	23.110	10.330
Tenure	Years of working in current work unit	14.779	10.035
Director	Dummy variable: Director=1 if individual is the director or department director of government agent, institution and enterprise, otherwise 0.	0.108	0.310
Professional	Dummy variable: Professional=1 if individual is professional, otherwise 0.	0.216	0.411
Clerical staff	Dummy variable: Clerical staff=1 if individual is clerical staff, otherwise 0.	0.212	0.408
Salesclerk and service worker	Dummy variable: Salesclerk and service worker=1 if individual is Salesclerk and service worker, otherwise 0.	0.131	0.337
Secondary industry sector	Dummy variable: Secondary industry sector=1 if individual works in secondary sector, including Mineral, Manufacturing, Electricity, gas and water supply facilities, Construction, otherwise 0.	0.346	0.476
City-specific characteristics			
Infrastructure	City's index of urban amenities	0.457	1.151
High-infrastructure	Dummy variable: High-amenity=1 if city's index of urban amenities is greater than zero, otherwise 0.	0.494	0.500
Housing conditions			
Kitchen	Dummy variable: Kitchen＝1 if housing is with independent kitchen, otherwise 0.	0.940	0.238
Area	Total usable area of house	54.175	28.477
Centre	Dummy variable: Centre＝1 if housing locates in the center of the city, otherwise 0.	0.106	0.308
Room1	Dummy variable: Room1=1 if housing has one bed room, otherwise 0.	0.015	0.122
Room2	Dummy variable: Room2=1 if housing has two bed rooms, otherwise 0.	0.026	0.158
Room3	Dummy variable: Room3=1 if housing has three bed rooms, otherwise 0.	0.233	0.423
Sanitary	Dummy variable: Sanitary=1 if housing has bathroom and toilet, otherwise 0.	0.607	0.489
Heating	Dummy variable: Heating=1 if housing has air-condition or central heating, otherwise 0.	0.160	0.367
Fuel	Dummy variable:	0.401	0.498
Telephone	Number of telephones, including fixed and mobile phones.	0.941	0.304

After controlling for housing conditions, two variables measuring urban infrastructure have positive and significant coefficients, which indicate that infrastructure have positive impact on local housing prices. In particular, an increase in the extent of urban infrastructure increases local housing prices by 44.2%.

Table 4.7 Impact of Urban Infrastructure on Urban Housing Prices

Dependent variable:	OLS estimates			
Housing expenditure	(1)	(2)	(3)	(4)
Infrastructure	0.460***	0.442***		
	(0.006)	(0.006)		
High-infrastructure	-	-	0.840***	0.737***
			(0.015)	(0.015)
Area	0.008***	0.006***	0.006***	0.004***
	(0.0004)	(0.0004)	(0.0004)	(0.0004)
Room1	0.142**	0.278**	0.190***	0.319***
	(0.071)	(0.067)	(0.068)	(0.065)
Room2	0.111***	0.089***	0.275***	0.235***
	(0.040)	(0.039)	(0.043)	(0.042)
Room3	0.175***	0.231***	0.183***	0.129***
	(0.018)	(0.014)	(0.019)	(0.019)
Sanitary	-	0.231***	-	0.188***
		(0.014)		(0.016)
Heating	-	0.062***	-	-0.014
		(0.018)		(0.020)
Fuel	-	0.229***	-	0.248***
		(0.013)		(0.015)
Kitchen	-	0.316***	-	0.162***
		(0.045)		(0.047)
Telephone	-	0.145***	-	0.240***
		(0.026)		(0.027)
Centre	-	-0.178***	-	-0.009
		(0.018)		(0.024)
Constant	5.803***	5.126***	5.380***	4.840***
	(0.006)	(0.049)	(0.011)	(0.053)
R-squared	0.410	0.481	0.276	0.331
No. of Observations	8973	8973	8973	8973

Note: The numbers in brackets are robust standard errors.
***, **, * denotes significance higher than 0.01, 0.05, and 0.10, respectively.

This estimation result further confirms that urban infrastructure affect housing prices, in accord with the prediction of theoretical model. Households living in high- infrastructure cities pay, on average, 73.7% higher than those living in the relatively low amenity cities. The positive amenity-rent gradient is consistent with the findings of existing studies on the impact of amenities on housing prices in China urban housing market (e.g., Kong *et al.*, 2007; Zheng *et al.*, 2009).

The positive impact of infrastructure on housing prices, as confirmed by our estimation and the concentration of labor force in high-infrastructure cities, as described by statistical data, points out an interesting question: why do workers still prefer to reside in high-infrastructure cities since they will incur higher costs of living? It is either because they receive higher wages that can compensate the higher cost of living or they just prefer infrastructure consumptions which consist of part of their wages in the form of forgone wages. In the former case, higher wages should be observed in high- infrastructure cities, while the opposite happens in the latter case. The estimation for the wage equation provides some answer for this question.

Table 4.8 reports the 2sls estimates of Eq. (4.21), using infrastructure index and high-infrastructure city dummy variable as proxies for urban infrastructure. To ease comparison with other studies on returns to individual characteristics in China, Eq. (4.21) is also estimated with OLS method. The OLS estimation results are reported in Appendix 4.7. Similar to the layout of Table 4.7, urban infrastructure variable and standard individuals' characteristics are first introduced in the regression, as shown in column (1) and (2). Then all other controlled variables, (i.e. firm size, sector, occupation) are included, as shown in columns (3) and (4). In relation to the IV estimation method, three tests are performed for robust check. The results of these three tests are reported in the bottom lines of Table 4.7. For all specifications and samples, the endogenity of education variable are first tested. The Wu-Hausman statistic is highly significant, which rejects the null hypothesis of exogeneity. Then the validity of instrumental variables is tested. The first stage F-static and the Sargan test of overidentification are significant at 1%, confirming the validity of the instrumental variables.

Table 4.8 Impact of Urban Infrastructure on Wages

Dependent variable:	2SLS estimates			
Individual wage	(1)	(2)	(3)	(4)
Infrastructure	0.098***	0.079***		
	(0.009)	(0.016)		
High-infrastructure			0.171***	0.127***
			(0.017)	(0.030)
Education	0.230***	0.287***	0.232***	0.295***
	(0.019)	(0.043)	(0.019)	(0.042)
Experience	0.035***	0.048***	0.036***	0.050***
	(0.004)	(0.007)	(0.004)	(0.007)
$\text{Experience}^2/100$	0.009	0.001	0.012*	0.002
	(0.007)	(0.008)	(0.007)	(0.008)
Tenure	0.025***	0.025***	0.024***	0.025***
	(0.003)	(0.003)	(0.003)	(0.003)
$\text{Tenure}^2/100$	-0.071***	-0.080***	-0.070***	-0.080***
	(0.008)	(0.009)	(0.008)	(0.010)
Male	-	0.076***	-	0.071***
		(0.022)		(0.022)
Married	-	-0.127**	-	-0.151***
		(0.052)		(0.050)
Small firm	-	-0.047*	-	-0.040
		(0.027)		(0.026)
Middle firm	-	-0.026***	-	-0.019
		(0.031)		(0.031)
SOE	-	-0.067***	-	-0.063***
		(0.021)		(0.021)
Director	-	0.398***	-	0.420***
		(0.127)		(0.127)
Clerical staff	-	0.221***	-	0.229***
		(0.071)		(0.071)
Professional	-	-0.355***	-	-0.376***
		(0.110)		(0.109)
Salesclerk and service worker	-	-0.184***	-	-0.181***
		(0.029)		(0.029)
Secondary industry sector	-	0.008	-	0.006
		(0.031)		(0.032)
Constant	6.561***	5.605***	6.459***	5.440***
	(0.220)	(0.616)	(0.037)	(0.602)
No. of Observations	8973	8973	8973	8973
Tests in relation to 2SLS estimation				
First stage *F*-statistic	553.181	502.870	533.281	488.810
(*p*-value)	(0.000)	(0.000)	(0.000)	(0.000)
Test of endogeneity	82.821	61.162	77.689	62.492
(*p*-value)	(0.000)	(0.000)	(0.000)	(0.000)
Test of overidentification	1.316	0.491	2.135	0.795
(*p*-value)	(0.251)	(0.484)	(0.144)	(0.373)

Note: The numbers in brackets are standard errors.
***, **, * denotes significance higher than 0.01, 0.05, and 0.10, respectively.

As for returns to individual's characteristics, estimation result is consistent with conventional estimates of earning functions. The coefficients of all variables but the quadratic terms of experience are significant at 1% level. Specifically, the 2SLS estimate of return to education ranges from 23% to 29.5% in different specification, which is considerably larger than those of OLS estimates (4.4% to 8.6%). This is consistent with recent empirical studies of economic returns to education in urban China (Heckman and Li, 2004; Li and Luo, 2004; Chen and Hamori, 2009). In addition, an extra year of working experience increases wages by 3.5% to 5% in different specifications. The earning function is concave in individual's job tenure. An extra year of job tenure raises wages by 2.4% to 2.5% in different specifications. The estimation result also confirms the existence of wage disparities across genders, marital status, firm size and ownership, and occupations.

Focusing on the wage-infrastructure gradient, it is found that the coefficients of two urban infrastructure variables are both positive and statistically significantly at 1% level, indicating that urban infrastructure has positive impact on local wages. The impact of infrastructure on wages does not decrease considerably after controlling for other characteristics that may affect individual earnings. As discussed in our theoretical model, the positive wage-infrastructure gradient suggests that firms' valuation on urban infrastructure exceeds individuals' valuation, so that the productivity effect outweighs amenity effect. Given the positive rent-infrastructure gradient confirmed in last section, the rent payments by firms are less than their valuation of amenities, while the rent payments by individuals are more than their valuation. As a result, wages are higher in high-infrastructure cities. Specifically, an increase of local infrastructure level, measured by urban infrastructure index raises wages by 7.9%. Workers live in high-infrastructure cities earn 12.7% higher wages than their counterparts live in low-infrastructure cities.

The estimation result provides an explanation for the concentration of workers in high-infrastructure cities. When both firms and workers value local amenities, workers get wage compensation from firms for higher living cost in high-infrastructure cities. The positive wage-infrastructure gradient is inconsistent with the results of Gabriel and Rosenthal (1999) who find that, wages rates are decreasing in local amenities in U.S. cities. However, in their study, amenities are assumed to be only attractive for workers. The concentration of households in high-amenity cities increases rents and supply of labor market, so that wages are lower in high-amenity cities. While the real world is more complex, not only households but also firms consider amenities when choosing their location to live or produce goods. Therefore, it is more rational to consider the impact of amenities on individual utility and firm cost in the theoretical model. The estimation result is consistent with Graves *et al.* (1999), who argue that from the perspective of empirical analysis, urban areas tend to be relatively more desirable for firms than for households. When only relatively populous areas, such as SMSAs or larger counties in US or prefecture-level cities in China are observed, amenities tend to have greater value to firms than to households. As a result, both rents and wages are higher in high-infrastructure cities.

4.5.3 Estimation Results: Urban infrastructure and returns to workers characteristics

Table 4.9 reports the key estimation results of Eq. (4.22) including workers characteristic and their interaction with urban infrastructure measured by infrastructure index (in columns (1) to (3)) and dummy high-infrastructure city variables (in columns (4) to (6)), respectively. Similar to the specification of Table 4.7, Table 4.8 respectively reports the estimates that excludes other controlled variables (in columns (1) and (3)), and estimates that includes them (in columns (2) and (4)). The first two parts in Table 4.8 present the estimates of γ_1 and γ_3 for each specification, while the last part shows the results of tests on instrumental variables, which confirm the endogenity of education and interaction terms and reject the null hypothesis that instrument are invalid. First focus on the estimation results of γ_1, which reflects returns to workers characteristics in the city with an average level of urban infrastructure. In all four specifications, γ_1 for all variables but the quadratic terms is positive and significant at 1% level. In addition, the conditional returns to education (0.200 to 0.282), experience (0.036 to 0.060) and tenure (0.021 to 0.025) do not change considerably, comparing with the unconditional returns reported in Table 4.7.

Next turn to focus on γ_3, which reflects the effect of interaction terms. It is found that returns to workers characteristics vary significantly across cities. First, the coefficients of interaction term of education and urban infrastructure index is positive and significant at 10% level, which implies that returns to education increase with extent of urban infrastructure. The coefficients of interaction term of education and high-infrastructure city variable is positive and significant at 5% level. Returns to education are significantly higher in high-infrastructure cities. In particular, a 1% increase in the extent of urban amenities increase returns to education by 3.9% when holding other variables constant. Similar to the case that worker resides in high-infrastructure cities receives positive wage compensation for the higher living cost, high educated workers receive higher wage compensation and thus earn more than those low educated workers in high-infrastructure cities. Second, the estimation result provides evidence of negative return-to-experience differentials in high-infrastructure cities. In particular, returns to experience decrease with urban infrastructure: returns to experience are significantly lower in high- infrastructure cities, a 1% increase in the extent of urban amenities decrease returns to experience by 1.2%.

Table 4.9 Urban Infrastructure and Returns to Workers Characteristics

Dependent variable:	Amenity index		High-amenity city	
Individual wage	(1)	(2)	(3)	(4)
Education	0.236***	0.282***	0.200***	0.256***
	(0.020)	(0.042)	(0.026)	(0.046)
Experience	0.036***	0.045***	0.047***	0.060***
	(0.004)	(0.007)	(0.006)	(0.010)
$Experience^2/100$	0.009	0.005	-0.025***	-0.034***
	(0.007)	(0.009)	(0.010)	(0.011)
Tenure	0.025***	0.026***	0.021***	0.021***
	(0.003)	(0.003)	(0.005)	(0.005)
$Tenure^2/100$	-0.073***	-0.081**	-0.056***	-0.061***
	(0.008)	(0.009)	(0.013)	(0.013)
Urban infrastructure interacted with				
Education	0.034*	0.039**	0.070*	0.075*
	(0.017)	(0.020)	(0.039)	(0.043)
Experience	-0.012***	-0.012***	-0.025***	-0.025***
	(0.003)	(0.003)	(0.008)	(0.009)
$Experience^2/100$	0.033***	0.033***	0.078***	0.082***
	(0.007)	(0.008)	(0.014)	(0.017)
Tenure	0.005	0.002	0.009	0.011
	(0.002)	(0.003)	(0.006)	(0.007)
$Tenure^2/100$	-0.010	-0.011	-0.037**	-0.045**
	(0.007)	(0.008)	(0.017)	(0.019)
Constant	6.478***	6.214***	6.812***	6.450***
	(0.227)	(0.424)	(0.297)	(0.455)
No. of observations	8973	8973	8973	8973
Tests in relation to 2SLS estimation				
First stage *F*-statistic	300.94	373.54	289.060	362.560
(*p*-value)	(0.000)	(0.000)	(0.000)	(0.000)
Test of endogeneity	43.530	29.984	41.429	32.451
(*p*-value)	(0.000)	(0.000)	(0.000)	(0.000)
Test of overidentification	2.421	1.989	2.327	1.192
(*p*-value)	(0.298)	(0.370)	(0.313)	(0.551)

Note: The numbers in brackets are robust standard errors.
***, **, * denotes significance higher than 0.01, 0.05, and 0.10, respectively.

Given the fact that both highly educated workers and more experienced workers are more concentrated in high-infrastructure cities, our estimation result indicates that the motive driving for their concentration is different. For workers with higher level of education, they concentrate in high-infrastructure cities so as to get higher payments. On the other hand, for experienced workers, it is because they have greater preference for urban infrastructure than inexperienced workers. Our estimation results are in line with Beeson (1991), who find that returns to schooling are positively related with amenities measured by urban healthy infrastructure, using SMSA level data in US. While the negative returns to experience in high-infrastructure cities are consistent with Addario and Patacchini (2008), who find that in large and high-amenity Italian cities, employees does not have monetary incentives to invest in their human capital accumulation, and the returns to experience are virtually zero.

4.6 Summary

Using micro-data from the Chinese Household Income Projects for the year 2002, this paper investigates the relationship between urban infrastructure and wages in China and attempts to address three related empirical issues.

First, in contrast to the conventional method which introduces every variable in the regression, this chapter adopts a Factor Analysis (FA) method to reduce the multi-dimensional aspects into a one-dimensional variable, i.e., a composite index to measure the level of urban infrastructure across cities. It is found that the extent of urban infrastructure is generally higher in eastern and middle regions than that of other western regions. In addition, it is found that workers and firms are more concentrated in high-infrastructure cities.

Second, this chapter examines the respective impacts of urban amenities on rents and wages by estimating the conventional housing function and earning function augmented with urban amenities variables. Using both OLS and instrumental variable estimation method, it is found that rents, measured by housing prices, are increasing in the extent of urban infrastructure, while wages are also higher in high-amenity cities. Taken together, the estimation results indicate that much of the higher living cost faced by workers in high-infrastructure cities is compensated by higher wages.

The third issue addressed in this paper concerns whether returns to worker characteristics (e.g., education, experience, tenure) vary with urban infrastructure. By estimating an earning function including an interaction term of urban infrastructure and worker characteristics, this chapter finds that returns to workers characteristics vary significantly across cities. Specifically, in high-infrastructure cities, returns to highly educated workers are higher, whereas returns to experienced workers are lower.

This study is a preliminary investigation on the relationship between urban infrastructure and wages in the context of wage compensation theory. The estimation results confirm the important role of city characteristics, in particular, urban infrastructure in explaining wage disparities across regions. Conventional studies on earning regressions that ignore such effects may suffer from omitted variable bias (Gabriel and Rosenthal, 1999). In this regard, it would be worthwhile for future studies on wage determinations to involve not only individual characteristics but also location characteristics to obtain efficient estimates.

4.7 Appendix 4.1

Table 4.1A Impact of Urban Infrastructure on Wages (OLS)

Dependent variable:	OLS estimates			
Individual wage	(1)	(2)	(3)	(4)
Infrastructure index	0.144***	0.161***		
	(0.005)	(0.005)		
High-infrastructure city			0.248***	0.271***
			(0.013)	(0.012)
Education	0.085***	0.044***	0.086***	0.051***
	(0.002)	(0.003)	(0.003)	(0.003)
Experience	0.018***	0.014***	0.014***	0.015***
	(0.003)	(0.003)	(0.003)	(0.003)
$Experience^2/100$	0.007	-0.012**	0.003	-0.001*
	(0.006)	(0.007)	(0.006)	(0.006)
Tenure	0.034***	0.029***	0.032***	0.029***
	(0.002)	(0.002)	(0.002)	(0.002)
$Tenure^2/100$	-0.076***	-0.067***	-0.075***	-0.065***
	(0.007)	(0.007)	(0.007)	(0.007)
Male	-	0.155***	-	0.148***
		(0.012)		(0.013)
Married	-	0.102***	-	0.063***
		(0.024)		(0.025)
Small firm	-	-0.141***	-	-0.128***
		(0.015)		(0.016)
Middle firm	-	-0.080***	-	-0.068**
		(0.021)		(0.022)
SOE	-	-0.131***	-	-0.128***
		(0.013)		(0.014)
Director	-	-0.308***	-	-0.293***
		(0.023)		(0.023)
Clerical staff	-	-0.160***	-	-0.159***
		(0.018)		(0.018)
Professional	-	0.255***	-	0.239***
		(0.018)		(0.019)
Salesclerk and service worker	-	-0.199***	-	-0.194***
		(0.021)		(0.022)
Secondary industry sector	-	-0.126***	-	-0.135***
		(0.015)		(0.015)
Constant	8.234***	9.094***	7.939***	8.901***
	(0.029)	(0.054)	(0.036)	(0.055)
No. of Observations	8973	8973	8973	8973
Adjust R-squared	0.240	0.321	0.228	0.288

Note: The numbers in brackets are standard errors.

***, **, * denotes significance higher than 0.01, 0.05, and 0.10, respectively.

Chapter 5 Economic Policy, Regional Inequalities, and Growth

5.1 Introduction

Along with the past decades of substantial economic growth, cities in China have witnessed growing inequities in terms of income distribution and industrial agglomeration. In 2008, per capita income in coastal cities averaged 7340.76 yuan[1], which is more than 1.4 times that for inland cities. Income disparity between cities is even larger. Per capita income in the richest city Suzhou is nearly 30 times as large as in the poorest city Dingxi[2]. Meanwhile, manufacturing sector is also highly concentrated in China, where nine eastern coastal provinces account for 67% manufacturing output value in 2008[3]. Chinese central government has been placing reducing these substantial regional inequalities as a top policy priority over years. With the implementation of "Western Development Strategy" in 1999, central government significantly enhanced its investment in urban infrastructure, in particular in construction of road network in western regions. From 2000 to 2005, new road built in west reached 220,000 km, which has greatly improved inter-regional transportation condition in western regions (Yao, 2009).

Government's intervention is justified by studies which find positive impact of infrastructure on regional growth (Aschauer, 1989; Jimenex and Emmanuel, 1995; Canning and Pedroni, 1999; Calderón and Servén, 2004)[4]. In recent literature using Chinese data, Mody and Wang (1997) find that transport and telecommunication infrastructures contribute industrial growth in coastal regions in China during the period 1985 to 1998. Using panel data for a sample of 24 Chinese provinces, Démurger (2001) investigates the relationship between regional disparities in the availability of infrastructure and economic growth in China from 1985 to 1998 and finds that differences in transport infrastructure and telecommunication facilities play an important role in explaining variation in the growth performance of province. Similarly, Pravakar *et al.* (2010) find that infrastructure has played an important role in growth in China from 1975 to 2007. Moreover, their empirical

[1, 2, 3] Data source: China City Statistical Yearbook (2009) and authors' calculation.
[4] This chapter mainly reviews related studies investigating the case of Chinese economy. For a specific overview on the impacts of infrastructure, see Calderón and Servén (2004).

study reveals that infrastructure development has more significant positive contribution to growth than both private and public investment.

Nevertheless, the role of infrastructure in reducing regional inequalities has, up to now, not been studied extensively yet. Robets *et al*. (2010), among others, use data for 331 prefectural level regions in 2007 to estimate the effects of National Express Network (NEN) in China. Their finding shows that, contrary to its objectives, the construction of NEN has done little to alleviate inland-coast disparities on real income level. Moreover, improving road infrastructure is found to encourage regional industrial concentration in eastern regions (Wen, 2004).

The significantly different role of infrastructure in stimulating growth and reducing regional inequalities points out a dilemma for policymakers. For example, from the spatial efficiency perspective, improving road network across regions increases growth. From the spatial equality perspective, it also leads to higher industrial agglomeration and therefore widens regional inequality. The existence of such trade-off between spatial efficiency and equity has important implications for public policies. As investing in road infrastructure turns out to be a kind of “win-lose” policy instrument, it is worthwhile for policymakers to reconsider the gain and loss of different pubic infrastructures.

However, to our knowledge, there have been very little empirical studies investigating the existence of such trade-off and its impact on regional inequalities and growth. By contrast, using a simultaneous equations approach, this chapter empirically investigates the impact of two types of public infrastructure, transportation infrastructure and knowledge infrastructure, on industrial geography, regional income disparities and growth across 286 cities in China. It is found that an improvement in transportation infrastructure that reduces trade costs on goods increases growth and decreases income gap at the expense of increasing industrial agglomeration between cities. Therefore, this chapter confirms the existence of a trade-off between spatial equity (more even spatial distribution of economic activities) and spatial efficiency (higher growth rate). However, for knowledge infrastructure that reduces trade costs on ideas, it is found that it increases growth but also decreases income gap and industrial agglomeration simultaneously. Moreover, the impact of knowledge infrastructure is found to be larger in the case of high labor mobility.

In addition, this chapter extends the empirical analysis to incorporate the role of regional openness to foreign direct investment (FDI). The effect of FDI has been discussed extensively in recent studies investigating how FDI affects economic development in China, suggesting that FDI is positively related with industrial location (Ge, 2008), economic growth (Li and Liu, 2005) and regional inequality across regions (Wei, 2002). One possible explanation for this positive relationship is that, FDI augments the supply of fund for investment and thereby stimulates capital accumulation in the host region (Sun, 1998). This chapter thus regards FDI as a part of regional capital stock.

Another extension of the empirical study is that this chapter considers the impact of two types of infrastructures in the case of high and low labor mobility across cities. By contrast to the focus of FDI, the role of labor mobility and its impact on infrastructure has, up to now, received little attention[17]. In 2008, the national average labor mobility rate, measured by the share of a city's incoming population without local household registration in city's total population, is 20.2 per 1000 inhabitants, which is as much as three times the immigration rate of Europe for the same time period[18]. Research neglects this large-scale labor mobility across cites would yield incomplete, and probably biased estimates in the case that either transportation infrastructure or knowledge infrastructure is correlated with the mobility of labor force across cities. The empirical analysis of this chapter contributes to existing studies in this regard and finds that knowledge infrastructures tend to have a larger effect in stimulating growth and decreasing regional inequalities in the case of high labor mobility. This result has significant policy implications for China, where the majority of government's subsides to poor inland regions are used to construct transportation infrastructure. Given the side effect of transportation infrastructure, our paper suggests that

[17] Hering and Poncet (2010a, 2010b), among others, find that the effect of market access on per capita income heavily depends on inter-regional immigration intensity in China during the period of 1995 to 2002.

[18] Chinese cities data are from the China City Statistical Yearbook (2009), European data are from PORDATA, http://www.pordata.pt/en/Europe/Gross+immigration+rate-1934. It is worth noting that considerable incoming population cannot own the household registration so that the mobility rate, in principle, reflects the intensity of labor mobility across cites rather than immigration in China. Therefore, the true difference in immigration rate between China and European countries would be smaller.

developing knowledge infrastructure and improving labor mobility across cities will lead to a desired outcome for policy makers to escape from the trade-off between spatial efficiency and equality.

The chapter is structured as follows. Section 5.2 describes the basic theoretical model and the impact of urban infrastructure on regional inequality and growth in different conditions. Section 5.3 first constructs a structural system of equations for econometric estimation and then describes data and variable measurements. Discussion on estimation methods is also presented in this section. Section 5.4 reports the estimation results of the system of equations. Section 5.5 concludes the chapter.

5.2 Theoretical Framework: A NEG Model

5.2.1 Basic Setup and Assumptions

The theoretical framework of this paper, which is based on Martin (1999), is a standard new economic geography model in which industrial location, income disparity and endogenous growth are simultaneously determined. Figure 5.1 summarizes the basic setup and assumptions as follows:

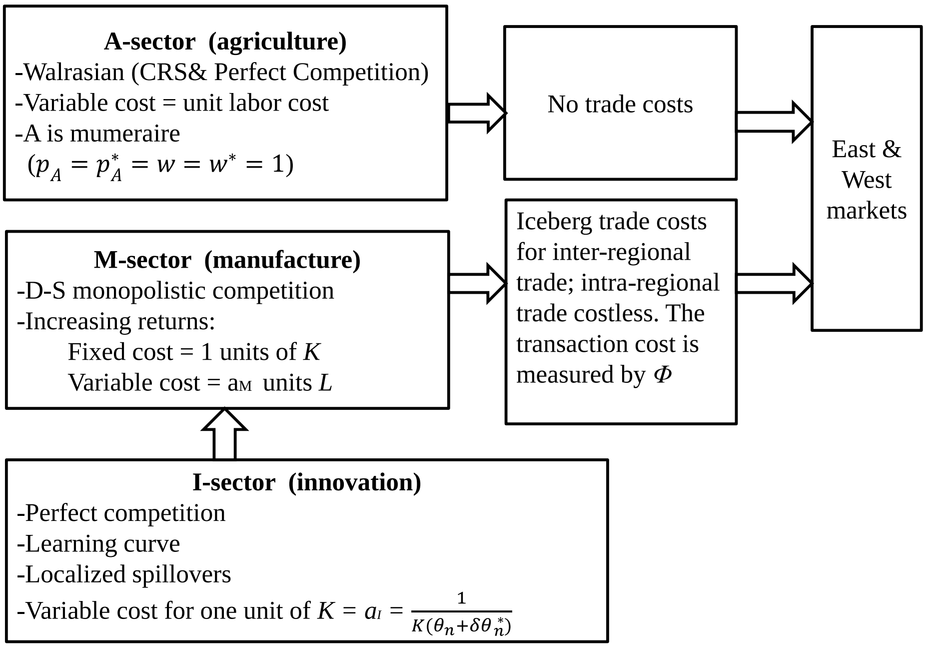

Figure 5.1 Basic Setup and Assumptions of NEG Model

Consider the economic space is made of two regions (East and West). The economy has two sectors, the Agriculture sector *A* and the high-tech industry sector *M*. Each sector use two production factors, capital *K* and labor *L*. Labor is immobile whereas capital is perfectly mobile between regions. This model mainly describe the economy in East since West is almost symmetric (West economy variables are denoted by asterisk). Let θ_L and θ_K denotes eastern shares of labor and capital in country total labor and total capital, so that, $\theta_L = L/(L + L^*)$, $\theta_K = K/(K + K^*)$.

The A sector is characterized by constant returns to scale and perfect competition, and uses only labor to produce its homogenous goods. Let one unit of A-sector's goods requires one unit of labor, profits maximization then implies that price of A-sector's goods, p_A, equals the price of labor, w. Furthermore, the trade on A-sector's product is assumed to be costless between regions, so that its price must be equal across regions. For simplicity, choose A-sector's product as mumeraire, so that, $p_A = p_A^* = w = w^* = 1$.

Following the framework of monopolistic competition developed by Dixit and Stiglitz (1977), the M sector consists of a large number of firms that produce differentiated goods under increasing returns to scale. To produce one variety of M-goods, a typical firm needs to input one unit capital as its fixed cost and a_M unit labor as its variable cost. Therefore, the East's share in total high-tech industry firms, $\theta_n = n/(n + n^*)$, also denotes the share of capital employed in East and the share of all varieties produced in East. M-goods trade needs transport costs in the form of iceberg costs. Specifically, a typical firm located in East must ship $\tau \geq 1$ units to sell one unit of M-goods to West and vice versa, so that, $\tau = \tau^* \geq 1$. Consequently, producer prices are equalized in H sector as well so consumer prices vary only with trade costs. As A-sector goods are chosen as numeraire, so that, $p_W = 1$, $p_W^* = \tau$.

The A sector (agriculture) is characterized by constant returns to scale and perfect competition, and uses only a_A unit of labor to produce one unit of its homogenous goods. Following the framework of Dixit and Stiglitz (1977), the M sector (manufacturing) consists of a large number of differentiated goods. To produce one variety of M-goods, a typical firm needs to input one unit of capital as its fixed cost and a_M units of Las its variable cost, so that the cost function is $(\pi + wa_M x_i)$, where π and w are factor rewards of capital and labor, respectively, x_i is the output of a variety i. By choice of units, the production of one unit of A-goods requires one unit of *labor* and the production of one unit of M-goods requires $(1\text{-}1/\sigma)$ unit of labor, so that $a_A = 1$ and $a_M = 1\text{-}1/\sigma$.

The theoretical model further assumed that all sector goods are tradable across regions. A-goods and I-goods are traded without cost inter-regionally, while M-goods trade faces transport costs in the form of iceberg costs. Specifically, regions are identical in their bilateral openness on trade and hence their inter-regional trade costs. A typical firm located in East must ship $\tau \geq 1$ units to sell one unit of *M*-goods to West and vice versa, so that, $\tau = \tau^* \geq 1$.

Growth is driven by the accumulation of capital. To allow for growth, the model includes a perfectly competitive *I* sector (innovation) which produces new capital. This *I* sector employs a_I units of *L* as its variable cost for the production of one unit capital. Following Romer (1990) and Grossman and Helpman (1991), in the absence of depreciation, the theoretical model assumed a sector-wide learning curve so that the amount of labor needed to produce a new unit of capital decreases as the cumulative capital produced rises. Furthermore, the model assumes that this kind of learning spillover is partially localized. Specifically, eastern *I*-sector workers learn more from eastern innovations than they do from western innovations. Eq. (5.1) summaries these assumptions of *I*-sector as follows:

$$Q_K = \dot{K} = \frac{L_I}{a_I}\text{; and } a_I \equiv \frac{1}{Q_K\left(\theta_n + \delta\theta_n^*\right)} \tag{5.1}$$

where Q_K is the output of *I* sector, which equals the flow of capital $\dot{K}$ as the process of deprecation is ignored. L_I is the labor employed by *I*-sector; θ_n is eastern share of total firms (varieties) and *n* denotes the number of firms located in East; δ measures the extent to which *I*-sector learning effects spill over inter-regionally. Consequently, the growth rate of capital, denoted as *g* is related to *I*-sector labor demand L_I and regional share of firms, θ_n.

$$g = \frac{\dot{K}}{Q_K} = L_I(\theta_n + \delta\theta_n^*) \tag{5.2}$$

5.2.2 Key Spatial Equilibriums

An infinitely-lived representative consumer with preferences is given as follows:

$$U = \int_{t=0}^{\infty} e^{-\rho t} \ln(C_{At}^{1-\alpha} C_{Mt}^{\alpha}) dt \quad , \quad \rho > 0$$

$$C_M = \left(\int c_i^{1-1/\sigma} di \right)^{\frac{1}{1-1/\sigma}} , \sigma > 1, 0 < \alpha < 1 \quad (5.3)$$

where ρ is the rate of time preference, C_A and C_M are consumption of A and M, c_i is consumption of M-variety i, α is the expenditure share on industrial verities, and σ is the constant elasticity of substitution among varieties.

Utility optimization yields a constant division of expenditure between sectors and CES demand function for manufacturing varies:

$$C_j = \frac{p_j^{-\sigma} \alpha E}{\int p_i^{1-\sigma} di} \quad (5.4)$$

where p_i and p_j are the consumer price of variety i and j, respectively. E is East's regional income. As usual, under Dixit-Stiglitz competition, the choice of p_i is subjected to "mill pricing" so as to optimize profits of industrial firms. Therefore, the operating profit of a typical variety is simply the value of sales divided by σ. Thus:

$$p_i = \frac{w\alpha_M}{1-1/\sigma} \; ; \quad p_i^* = \frac{\tau w \alpha_M}{1-1/\sigma}$$

$$\pi = \frac{p_i x_i}{\sigma} \; ; \quad \pi^* = \frac{p_i^* x_i^*}{\sigma} \quad (5.5)$$

Isomorphic mill-pricing rules hold for western industrial firms.

On the supply side, the reward of immobile factor, namely the nominal wage rates is equalized due to the free trade on A-goods. Consequently, the producer prices are equalized in M sector as well so consumer prices vary only with trade costs. Using the demand Eq. (5.4) and mill pricing in Eq. (5.5), the equilibrium expressions for rental rate is given as follows:

$$\pi = \frac{\alpha(E+E^*)}{\sigma(\mathrm{Q}_K + \mathrm{Q}_K^*)} \left(\frac{\theta_E}{\theta_n + \tau^{1-\sigma}\theta_n^*} + \frac{\tau^{1-\sigma}\theta_E^*}{\tau^{1-\sigma}\theta_n + \theta_n^*} \right)$$

$$\pi^* = \frac{\alpha(E+E^*)}{\sigma(Q_K+Q_K^*)}\left(\frac{(\tau^*)^{1-\sigma}\theta_E}{\theta_n+(\tau^*)^{1-\sigma}\theta_n^*}+\frac{\theta_E^*}{(\tau^*)^{1-\sigma}\theta_n+\theta_n^*}\right) \tag{5.6}$$

where θ_E is eastern share of total expenditure.

The location equilibrium

Given the assumption of perfect capital mobility across regions, the location equilibrium is determined by the condition $\pi = \pi^*$, which implies capital earn the reward in both regions. Solving this condition with Eq. (5.5), and get the location equilibrium as follows:

$$\theta_n = \frac{1}{2}+\frac{(1+\phi)}{(1-\phi)}(\theta_E-\frac{1}{2}) \tag{5.7}$$

where $\emptyset \equiv \tau^{1-\sigma}$ measures freeness of trade between regions, which increases as τ falls and equals to one if trade in costless. The location equilibrium implies two important determinants of the spatial distribution of industries. First, for given level of trade freeness, (1+$\emptyset$)/(1-$\emptyset$) is greater than one, so that a change in market size (characterized by θ_E) leads to a more than proportional change in the spatial distribution of manufacturing, which could be viewed as an example of home market effect. Second, everything else be equal, since $\partial\theta_n/\partial\emptyset$ and is greater than zero, an improvement on regional openness to trade (characterized by $\emptyset$) raises regional attractiveness to firm

The growth equilibrium

Under the assumption of localized spillovers (see Eq. (5.2)), it is less costly to innovate in the region with more firms (more capital stocks). Since *I* sector goods can be traded without any transaction costs, the price of *I* goods must be the equalized in both regions. This implies that, for example, if initially there are more firms located in East ($\theta_n > \theta_n^*$), West will have no incentive to innovate locally but to simply buy the innovations produced by eastern *I* sector. As a result, the aggregate growth rate is just the growth rate of capital stock in East.

To derive the growth rate, first consider the clear condition of labor market. On the demand side, labor is employed in either *A*-sector, *M*-Sector or *I*-sector. On the supply side, both East and West are assumed to be endowed with the same amount of immobile labor. Using the assumption of a_A and a_M and a_I implied in Eq. (A2):

$$2L = (1-\alpha)(E+E^*) + \alpha(E+E^*)(1-\frac{1}{\sigma}) + \frac{g}{\theta_n + \delta\theta_n^*} \tag{5.8}$$

It can be shown that optimizing consumers set expenditure at the permanent income hypothesis level in steady state. So that $E = L + \rho a_I Q_K$ and $E^* = L + \rho a_I Q_K{}^*$. Therefore, the aggregate expenditure can be expressed as follows:

$$E + E^* = 2L + \rho a_I (Q_K + Q_K^*) \tag{5.9}$$

Using Eq. (5.8) and Eq. (5.9), the equilibrium growth rate of capital can be derived as follows:

$$g = \frac{2\alpha}{\sigma} L(\theta_n + \delta\theta_n^*) - \rho(1-\frac{\alpha}{\sigma}) \tag{5.10}$$

Note that Eq. (3) implies a positive relationship between aggregate growth and industrial location. With the presence of partially localized spillovers, higher spatial concentration of manufacturing (characterized by an increase in θ_n) leads to higher growth rate through the reduction of innovation cost. On the other hand, as $\partial g/\partial\delta$ is greater than zero, less localized spillovers (characterized by an increase in δ) also implies a lower cost of innovation (as the West learn from spillovers in the East) and thus a higher growth rate.

The income equilibrium

Recall that East expenditure equals the rewards of labor force plus the earning of capital. That is, $E = L + \rho v Q_K$, where v is the present value of constructing a new unit of capital. Moreover, v also equals the construction cost of a new unit of capital (the *I*-sector marginal cost a_I), in a steady state. Calculating v requires us to discount the future flow of rental rates (operating profits) π at the steady-state interest rate ρ. In addition, from Eq. (5.5), the present value of a new variety also depends on the rate at which the total capital stock grows in equilibrium, namely g. Therefore, the value of a new unit of capital could be written as:

$$v = \frac{\pi}{\rho + g} \;\; ; \;\; v^* = \frac{\pi^*}{\rho + g} \tag{5.11}$$

Using Eq. (5.11) and the equilibrium value of profits given by Eq. (A6), the income equilibrium is obtained as follows:

$$\theta_E = \frac{1}{2} + (\frac{\alpha\rho}{\sigma})(\frac{1}{g+\rho})(\theta_K - \frac{1}{2}) \tag{5.12}$$

Eq. (5.12) implies that income level is higher in East than in West ($\theta_E > 1/2$), as long as initially East has been endowed with more capital ($\theta_K > 1/2$). Note that 1/2 is just the average share of total income, so that the term ($\theta_E - 1/2$) can be interpreted as a measure of income disparity between East and West. Therefore, regional income disparity increases with its endowment share of total capital stock (characterized by θ_K) and decreases with the aggregate growth rate g.

Figure 5.2 describes the interaction among the equilibrium industrial location, income distribution, and growth rate, according to the equilibrium equations Eq. (5.7), Eq. (5.10), and Eq. (5.12).

The (I) quadrant describes the relationship between industrial distribution θ_n and income distribution θ_{E}. At a given level of freeness of trade $\emptyset$, the upward-sloping curve reflects the HME, which is described in Eq. (5.7). The location with larger local demand (lager θ_{E}) tends to attract a more than proportionate share of firms. Therefore, the large region has the advantage of market access; this is because monopolistic firms tend to locate their production in larger market. The downward-sloping curve reflects market crowding effect, which reflects the fact that imperfectly competitive firms tend to locate in regions with relatively few competitors. In this sense, large region has the disadvantage of market crowding. Market access effect works as an agglomeration force, whereas market crowding effect works as a dispersion force. The equilibrium distributions of industry and income are determined by the interaction between these two forces.

The (II) quadrant describes the relationship between industrial location (θ_n) and growth (g), as defined by Eq. (5.10). For given level of localized spillover (δ), the upward-sloping line reflects the positive impact of industrial agglomeration on growth, industrial agglomeration (higher θ_n) implies a lower cost of innovation and thus a higher growth rate g.

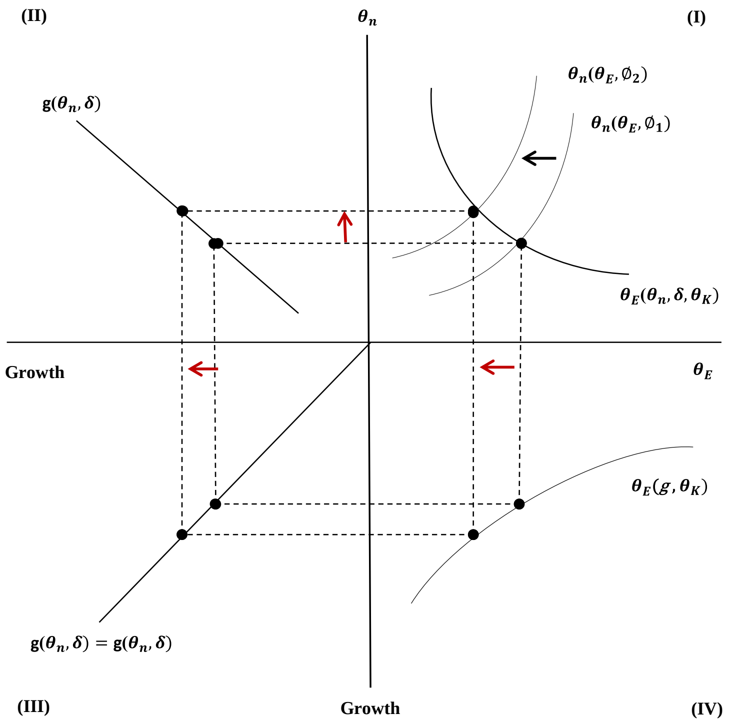

Figure 5.2 General Equilibrium of Location, Income and Growth

The (III) quadrant draws a “y=x” type line, which is used to transfer the equilibrium growth rate to the (IV) quadrant, which reflects the relationship between income distribution (θ_n) and growth (g). For given capital stock (θ_K), Eq. (5.12) implies that growth has a negative impact on income disparity. This is because the value of capital decreases with growth due to faster entry of new firms (Baldwin, 2004).

5.2.3 Impacts of Urban Infrastructures: Trade-off and Extensions

Using the equilibrium equations, this section turns to analyze the impact of different types of urban infrastructures on industrial location, income distribution, and growth.

First, an improvement of transportation infrastructure, (characterized by an increase in $\emptyset$), will increase the attractiveness of the East and thus will reinforce industrial agglomeration in East (characterized by an increase in θ_n). This reflected by an upward shift of the industrial distribution curve in the (I) quadrant, as shown in Figure 5.2. This in turn, increases growth rate of the whole economy g and decreases the Eastern share of total income (θ_E).

In this case, regional income disparity decreases at the expense of higher level of industrial concentration in the richer region, which implies a trade-off between spatial equality (less concentration and income disparity) and spatial efficiency (higher growth).

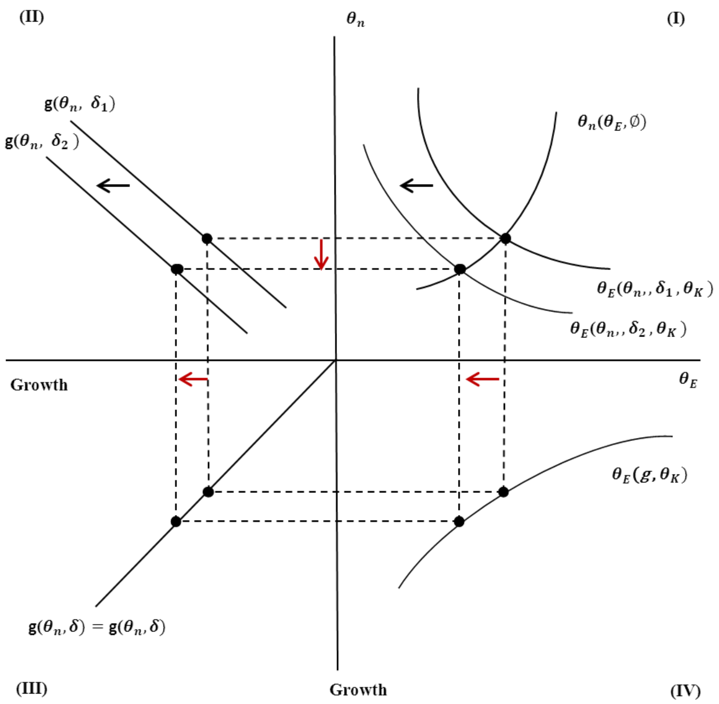

Figure 5.3 Impacts of Infrastructure on Location, Income and Growth

Second, an improvement in knowledge infrastructure, (characterized by an increase in δ), will facilitate knowledge spillovers or human capital formation between two regions, and thus higher growth. This impact is reflected by an upward shift of the growth line in the (II) quadrant, as shown in Figure 5.3. As more enters the market, monopolistic power of existing firms are reduced through competition. This, in turn leads to a decrease in income disparity between East and West, and thus decreases industrial concentration in the East. This impact is reflected by a downward shift of the market crowding curve in the (I) quadrant, as shown in Figure 5.3.

It is worth noting that, in contrast to the impact of infrastructure that facilitate trade on goods, the knowledge infrastructure make policy makers to escape from the spatial trade-off and to attain both the objectives of less industrial concentration, more even income distribution and higher economic growth.

Nevertheless, Martin's (1999) theoretical framework is based on the standard assumptions on NEG models so that it may suffer two problems when applying it to explain the economic phenomenon in real world.

First, the equilibrium relations between industrial location, income distribution and growth are derived under the assumption of a closed economy. This assumption may hold for the rural area which is principally specialized in agriculture, while agricultural products accounts for only 1.4% of China's exports in 2004 (Roberts, *et al.* 2010). However, for the unban sector, the role of regional openness to trade has been emphasized by many previous studies of regional inequality in China (Chen and Fleisher, 1996; Kanbur and Zhang, 1999; Gao, 2004; Fu, 2004), all indicating an positive and significant impact of exports or FDI on industrial growth and regional inequality. The mechanism underlying this positive relationship is that, FDI augments the supply of funds for investment and thereby promotes capital formation in the host region (Sun, 1998). To control for the role of regional openness, FDI are interpreted as a part of regional capital stock as described by θ_K in the income disparity Eq. (2).

Second, the theoretical model is developed based on the key assumption that, capital is perfectly mobile between regions whereas capital owners and labor force are not. A shift in production does not lead to expenditure shifting since all capital reward is repatriated to the region where its owner locates. Therefore the theoretical model presented in this section eliminates the demand-linked circular causality modeled by Krugman (1991). This may not be the case in China, where considerable labor force moves inter-regionally over years.

Labor mobility may affect the impact of urban infrastructures through many channels. For example, labor mobility is highly associated with knowledge or information transfer across regions since labor could be deemed as the carrier of knowledge. In this sense, allowing for labor mobility enhance inter-regional spillovers, which leads to an increase in δ, so that the impact of knowledge infrastructures increase with high labor mobility. In addition, not all rewards are repatriated to the region where there are come from in the case of high labor mobility as labors spend their incomes locally. For example, if some industrial workers decide to move from West to East, this will increase the market size of East and in turn will attract more firms to relocate from West to East (the so called market access effect). On the other hand, industrial agglomeration in East also increases competition of monopolistic firms whereas reduces it in West (the so-called market crowding effect). The equilibrium location is determined by the strength of these effects, so that the effect of transportation infrastructure on industrial location is ambiguous in if labor is mobile across regions. To control for the impact of labor mobility, in the empirical analysis, the impact of labor mobility on different types of urban infrastructures are estimated by dividing regions into two categories: high labor mobility and low labor mobility. Measurements and calculations are discussed in details in the following section 5.3.

5.3 Empirical Framework: A Simultaneous Equations Model

5.3.1 Model Specification and Methodology

Recall that the spatial equilibrium is fully characterized by the relationship of three endogenous variables that solve Eq. (5.7), Eq. (5.10) and Eq. (5.12) simultaneously: regional share of firms (θ_n), regional share of expenditure (θ_E), and aggregate growth rate g. In this section, a structural estimation is adopted to investigate the interaction among these endogenous variables so as to verify the trade-off between spatial equity and efficiency as described in section 5.2. Furthermore, taking parameters describing consumer's preference and substitution among varieties, viz. α, ρ and σ as constants, the empirical analysis also examines the impacts of different kinds of urban infrastructure on industrial location, income disparities and growth.

To apply the two-region model into a *J*-region economy, some transformation is made in the empirical analysis. First of all, this section uses the differences of regional shares of firms, expenditure and capital stock to represent various disparities between the two regions. That is, this section considers the two regions, East and West as a pair selected from *J* regions and focus on the bilateral disparities on regional industrial agglomeration and income[19]. Specifically, transform Eq. (5.7), Eq. (5.10) and Eq. (5.11) as follows:

$$\theta_n - \theta_n^* = \left(\frac{1+\tau^{1-\sigma}}{1-\tau^{1-\sigma}}\right)\left(\theta_E - \theta_E^*\right) \tag{5.13}$$

$$\theta_E - \theta_E^* = \frac{\alpha\rho}{\sigma(g+\rho)}(\theta_K - \theta_K^*) \tag{5.14}$$

$$g = \frac{\alpha L}{\sigma}[(3+\delta)(\theta_n - \theta_n^*) + (1+\delta)] - \rho(1-\frac{\alpha}{\sigma}) \tag{5.15}$$

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[19] Formally, for any give pair of regions, the sum of their shares of economy variables, for example, regional share of firms, $(\theta_n + \theta_n^*)$ always equal a constant c $(0 < c \leq 1)$. For simplicity, by choice of units, c=1 (which is just the case of a country of two regions). The relationship between $(\theta_n - \theta_n^*)$ and θ_n can be derived as: $\theta_n - \theta_n^*$ = $2\theta_n$- 1. The relationship for other share variables, θ_E and θ_K and are isomorphic.

With these transformations, the system of Equations is estimated simultaneously in the following empirical analysis.

$$A_{ij} = \alpha_0 + \alpha_1 I_{ij} + \alpha_2 T1_{ij} + \varepsilon_{1,ij} \tag{5.16}$$

$$I_{ij} = \beta_0 + \beta_1 G_{ij} + \beta_2 K_{ij} + \varepsilon_{2,ij} \tag{5.17}$$

$$G_{ij} = \gamma_0 + \gamma_1 A_{ij} + \gamma_2 T2_{ij} + \gamma_3 L_{ij} + \varepsilon_{3,ij} \tag{5.18}$$

where A_{ij} denotes the extent of industrial agglomeration, I_{ij} is income disparity between region *i* and region *j*, and G_{ij} is aggregate growth rate of the two regions. $T1_{ij}$ and $T2_{ij}$ is the vector of transport costs of goods and ideas variable, respectively. K_{ij} denotes the vector of capital stock variables. L_{ij} is the aggregate labor force of the two regions. A_{ij} , I_{ij} and G_{ij} are all endogenous variables, whereas other variables are exogenous.

5.3.2 Data and Variable Measurements

(1) Data

The empirical study aims at evaluating the impacts of different kinds of urban infrastructure on industrial location, income disparities and economic growth in China. The main dataset used in the econometric analysis comes from the *China City Statistical Yearbook* (2008 and 2009), compiled by Department of Urban Socio-economic Surveys, National Bureau of Statistics.

Within the mainland of China, there are three levels of cities: (a) municipalities, (b) prefecture-level cities and (c) county-level cities.

Municipalities are higher level of cities which are directly under the control of Chinese central government. Therefore, their political statuses are higher than that of other kind of cities.

Prefecture-level cities are cities that are given prefecture status and the right to govern surrounding counties. To become a prefectural level city, a prefecture of China must meet the following criteria: (a) an urban center with a non-rural population over 250,000, (b) gross output value of industry of 200,000,000 yuan, (c) the output of tertiary industry supersedes that of primary industry, contributing over 35% of the GDP[20].

County-level cities are usually governed by prefecture-level divisions. The main purpose of creating country-level cities is to replace county.

In 2008, there are 4 municipalities (Beijing, Tianjing, Shanghai and Chongqing), 283 prefecture-level cities and 368 county-level cities in China. Given that county-level cities usually include rural areas many times the size of their urban, built-up area, the empirical analysis excludes these cities and restrict our attention on the urban area of municipalities and prefecture-level cities. In addition, due to missing values, La Sa City is also excluded so that our final empirical analysis uses a cross-sectional dataset of 286 cities in 2008.

(2) Control for urban infrastructure

Transport cost of bilateral trade on goods and idea are both determined by city's actual geographical locations, as well as infrastructure conditions. A dummy border variable, which equals 1 if the two cities share a common border (otherwise 0), is employed to control for the impact of geographical proximity on goods and ideas transportation. Besides, it has been recognized that urban infrastructure, in particular, the length of road connected the two cities, can affect trade costs. For given distance between cities, the better the road network system of one city, the lower the transport costs. The length of road is used to measure the condition of city's road network system. A road infrastructure variable, which is defined as the natural logarithm of the total length of road divided by the distance between two cities, is employed to control for the impact of urban infrastructure that reduces trade costs on goods.

On the other hand, transport cost of bilateral trade on ideas is affected by another type of infrastructure that facilitates knowledge spillovers or human capital formations. Two variables are used to proxy for such knowledge infrastructure. A telecommunication

[20] http://www.china.org.cn/english/Political/28842.htm.

infrastructure variable measures the condition of mobile phones and household phones between two cities. Similarly, an education infrastructure variable reflects the total number of universities and colleges. Both variables are divided by the distance between two cities. It is worth noting that the correlation coefficient between the two proxies for knowledge infrastructure is 0.885. To avoid the problem of multicollinearity, these variables are controlled to enter the following estimation models separately.

(3) Control for others

Regional industrial agglomeration is measured on the basis of Location Quotient (LQ_j) index:

$$LQ_j = \frac{x_j^M / \sum_{j=1}^{J} x_j^M}{x_j^{GDP} / \sum_{j=1}^{J} x_j^{GDP}}, \ j = 1, \ldots, J \tag{5.19}$$

Where x_j^M and x_j^{GDP} denotes output of manufacturing and GDP in region *j*, respectively.

For a country with *J* cites, LQ_j reflects the city *j*'s share of manufacture's productive activity in relative to its share of total productive activity. Then construct an agglomeration variable, which is defined as the differences of LQ_j indices to measure the disparity on industrial location between cities.

Regional income is directly related to regional wage level. Similar to the measurement for industrial agglomeration disparity, bilateral income disparity is measured by the differences of two city's wage share in national total wage of employed persons.

As discussed in section 3.1, taking the two cities as a whole economy entity, the empirical analysis focuses on their aggregate rather than individual economic growth. A growth rate variable, which is defined as the nature logarithm of the growth rate of the two cities' total real GDP per capita, is employed as a proxy for aggregate growth.

Four variables are constructed to account for city's capital endowments: material capital stock, human capital stock, knowledge capital stock and FDI stock. City's disparity of material capital stock is calculated using city's fixed-asset investment (I_t) with a depreciation rate (κ) of 5% as follows[21]:

$$MC_t = MC_{t-1}(1-\kappa) + I_t$$

$$MC_{ij} = \ln[abs(MC_i - MC_j) / \sum_{i=1}^{n} MC_i] \qquad (5.20)$$

City's disparity of human capital, knowledge capital and FDI are calculated in the same way. Human capital is measured by education level of the city's population, which is defined as the share of population who accepts at least 16 years of education (university, college and above) in city's total population, divided by the city's share in national total population. Knowledge capital variable is measured by output of innovation actives and is defined as the city's number of patents; FDI is measured by city's shares in national FDI flows.

The regression includes a labor force variable, which is defined as the nature logarithm of the share of two cities' employees in total manufacturing employees.

Finally, following Hering and Poncet (2010b), a mobile intensity variable, which is calculated as city's incoming population divided by city's total population, is constructed to measure the extent of labor mobility. City's incoming population indicates people do not have household registration in his current living city. The population data are from the 2000 population census, conducted by the Nation Bureau of Statistics of China. The definitions and descriptive statistics of each variable are summarized in Table 5.1.

5.3.3 Estimation Method: Instrumental Variables (IV) and Heteroskedasticity

The specification of simultaneous equations model violates the OLS assumption of zero covariance between the disturbance term and the independent variables. Therefore, estimation results obtained by OLS will be biased and inconsistent. Such simultaneous equations bias can be corrected by applying various instrumental variable (IV) estimation techniques. For example, following the theory behind IV estimation, Two Stage Least

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21 Following the common approach, 1990 is chosen as basic year, so that $MC_{1990} = I_{1990}$.

Squares (2SLS) crates an instrument that is correlated with the endogenous variable while uncorrelated with the disturbance term. And then, the latter can be used in place of the original endogenous variable to estimate the model equation by equation.

Table 5.1 Definitions and Statistics of Variables

	Definition	Mean	S.D.	Min.	Max.
Dependent variable					
Industrial agglomeration	Nature logarithm of the absolute value of the difference between city's LQ_j indices.	-0.749	0.886	-15.063	0.001
Income disparity	Nature logarithm of the absolute value of the difference between city's shares in national total wage of employed persons.	-0.717	0.665	-11.581	0.001
Growth	Nature logarithm of the growth rate of the two cities' total real GDP per capita	0.728	0.788	-6.535	2.882
Independent Variable					
Dummy border	Dummy border = 1, if the two cities share a common geographical border; Dummy border = 0, otherwise.	0.957	0.202	0.000	1.000
Road infrastructure	Nature logarithm of the sum of the length of road of two cities, divided by the distance between two cities.	0.659	1.100	-2.728	5.227
Material capital	Nature logarithm of the absolute value of the difference between city's share in national material capital stock MC_t.	-0.683	0.571	-4.390	-0.011
Human capital	Nature logarithm of the absolute value of the difference between city's shares in total population who accepts at least 16 years of education (university, college and above)	-0.909	-0.707	-7.468	-0.001
Knowledge capital	Nature logarithm of the absolute value of the difference between city's shares in national patents.	-0.777	0.802	-6.844	-0.001
FDI capital	Nature logarithm of the absolute value of the difference between cities' shares in national FDI flows.	-0.817	1.075	-8.541	0.000
Telecommunication infrastructure	Nature logarithm of the sum of the number of phones (mobile and household) of two cities, divided by the distance between two cities.	6.075	1.238	-0.214	11.374
Education infrastructure	Nature logarithm of the sum of the number of universities and colleges of two cities, divided by the distance between two cities.	6.123	1.185	0.806	11.563
Labor force	Nature logarithm of the share of two cities' employees in total employees in manufacturing sector	-0.704	0.721	-0.075	-0.001

However, the disturbance terms of these equations are likely to be contemporaneously correlated, because unconsidered factors that influence the disturbance term in one equation probably influence the disturbance terms in other equations, too. Ignoring this contemporaneous correlation and estimating these equations separately lead to inefficient estimates of the coefficients. In this sense, this section applies a Three Stage Least Squares (3SLS) method that estimates all equations simultaneously to obtain more efficient results. Specifically, 3SLS uses an IV approach to produce consistent estimates and generalized least squares (GLS) to account for the correlation structure in the disturbance terms across equations (Zellner and Theil, 1962). 3SLS produces estimates in three steps: (1) Create instrument variables for all endogenous variables, (2) Estimate the system equation by equation using 2SLS and obtain a consistent estimate for the covariance matrix of the equation disturbances, (3) Perform GLS-type estimation on the stacked system, using the covariance matrix estimated in the second stage.

In addition, as for the cross-sectional data set, the 286 cities may vary in their scale, population, capital stock and so on. This, in turn leads to a heteroskedasticity problem. The conventional IV estimator is consistent but inefficient in the presence of heteroskedasticity (Baum et al. 2003). To control for the potential heteroskedasticity, the empirical analysis applies the Generalized Method of Moments (GMM) introduced by Hansen (1982) and report the GMM results in the robustness analysis.

5.3.4 Estimation Results: Benchmark Results

Table 5.2 reports the estimation results of the system of simultaneous equations with 3SLS method. Focusing on the estimates of urban infrastructure variables in column (1) and (2), where the telecommunication variable and university variable enters the regressions separately, for both specifications, the coefficients of road infrastructure are positive and statistically significant at 1% level, supporting the important role of transport costs of goods in determining industrial location. In general, improving cities' road infrastructure facilitates the transaction on goods, and hence results in further industrial agglomeration. This result is consistent with the findings of Wen (2004) and Chen, *et al*. (1996), confirming that an improvement in regional transportation condition has a positive effect on industrial concentration.

Table 5.2 Benchmark Estimation Results: 3SLS Method

	3SLS			
	(1)	(2)	(3)	(4)
Location equation				
Income disparity	1.274***(0.004)	1.275***(0.004)	1.276***(0.004)	1.277***(0.004)
Border	0.144***(0.004)	0.145***(0.004)	0.146***(0.004)	0.147***(0.004)
Road	0.035***(0.002)	0.035***(0.002)	0.035***(0.002)	0.036***(0.002)
Adjusted R-squared	0.762	0.762	0.762	0.762
Income equation				
Growth rate	-0.114***(0.003)	-0.120***(0.003)	-0.124***(0.003)	-0.134***(0.003)
Material capital	0.450***(0.006)	0.448***(0.006)	0.431***(0.008)	0.423***(0.008)
Human capital	0.027***(0.002)	0.025***(0.002)	0.026***(0.002)	0.024***(0.002)
Knowledge capital	0.381***(0.005)	0.382***(0.005)	0.372***(0.005)	0.370***(0.005)
FDI	-	-	0.020***(0.004)	0.026***(0.004)
Adjusted R-squared	0.570	0.568	0.568	0.565
Growth equation				
Agglomeration	0.119***(0.006)	0.113***(0.006)	0.117***(0.006)	0.110***(0.006)
Border	0.460***(0.011)	0.469***(0.011)	0.458***(0.011)	0.495***(0.011)
Telecommunication	0.112***(0.002)	-	0.112***(0.002)	-
University	-	0.104***(0.002)	-	0.104***(0.002)
Labor force	0.429***(0.005)	0.428***(0.005)	0.431***(0.005)	0.432***(0.005)
Adjusted R-squared	0.215	0.203	0.215	0.204
Observations	40755	40755	40755	40755

Note: (1) The numbers in brackets are standard errors;
(2) *** denotes significance higher than 0.01.

Meanwhile, the estimation result shows that two proxies for knowledge infrastructures, telecommunication and university have positive and significant coefficients in both specifications. This result confirms the positive relationship between knowledge infrastructure and economic growth, as described in our theoretical model. That is, improving telecommunication conditions or establishing more universities will lower regional innovation cost and thus lead to higher growth rate.

The utilization of simultaneous equations approach allows us to explore the interaction among various variables of interest simultaneously. Table 5.3 reports the effects of different urban infrastructures on industrial agglomeration, income disparity and economic growth, using the estimation results obtained by 3SLS method. Column (1), (3) and (5) reports the effects which are calculated according to the coefficients provided in column (1) and (2) in Table 2; and column (2), (4) and (6) report the effects which are calculated according to the coefficients provided in column (3) and (4) in Table 5.2.

Table 5.3 Effects of Urban Infrastructure

		Industrial agglomeration		**Income disparity**		**Aggregate growth**	
		(1)	(2)	(3)	(4)	(5)	(6)
Road	Direct	0.035	0.036	-	-	-	-
	Indirect	-	-	-0.0005	-0.0005	0.004	0.004
Telecommunication	Direct	-	-	-	-	0.112	0.112
	Indirect	-0.016	-0.018	-0.013	-0.014	-	-
University	Direct	-	-	-	-	0.104	0.104
	Indirect	-0.016	-0.018	-0.012	-0.014	-	-
FDI	Direct	-	-	0.020	0.026	-	-
	Indirect	0.026	0.033	-	-	0.003	0.004

Note: Direct effects (e.g., Road on industrial agglomeration, Telecommunication or University on aggregate growth) are calculated using their coefficients in different equations. Indirect effects, for example, the indirect impact of road infrastructure on growth (0.004) is calculated by multiplying the coefficient of Road variable (0.035) by the coefficient of Agglomeration variable in growth equation (0.119), similarly, the indirect impact of road infrastructure on income disparity (-0.0005) is calculated by multiplying the effect of road on growth (0.004) by the coefficient of Growth variable in income disparity equation (-0.114). The indirect effects of other infrastructures are calculated in the same way.

The estimation of the system provides a significant correlation (0.004) between road infrastructure and aggregate growth, so that not only the improvement of knowledge infrastructure but also transportation infrastructure has a positive impact on economic growth. Our estimation result is in line with Démurger's finding (2001), which identify differences in infrastructure endowment have played an important role in per capita income growth in China[22]. Meanwhile, the indirect effect of road on income disparity (-0.0005) supports the negative relationship between transport costs and income disparity. Such negative but small effects are somewhat inconsistent with other studies related to the impact of road construction on income disparity, using city-level data (Hering and Pconcet, 2010a and 2010b). However, these papers are based on the well-known NEG wage equation which suggests a directly positive relationship between wages and market access. In addition to the differences in theoretical and empirical specifications, they use GDP per capita as a proxy for regional wages due to data limitations. Whereas this variable can also be interpreted as a proxy for economic growth, in this sense, the estimation results may not contradicts with them since it is also found an indirectly positive impact of road infrastructure on aggregate growth (0.004). To summarize, the above result confirms the existence of policy trade-off between spatial efficiency (higher growth rate) and spatial equality (lower income disparities and more even distribution of industries).

Estimation results also reveal that knowledge infrastructure, either telecommunication (-0.014 to -0.013) or university (-0.014 to -0.012), has a negative indirect impact on income disparity. These effects are quantitatively larger, comparing with the slightly negative impact of road infrastructure on income disparity. Furthermore, knowledge infrastructure also discourages industrial agglomeration through growth and income disparity equations (-0.018 to -0.016 for telecommunication and university). Therefore, the improvement in knowledge infrastructure not only enhances higher growth but also results in lower income disparity and more even industrial distribution.

The coefficients of other exogenous variables are consistent with most existing studies of the determinants of industrial location, income disparities and growth. The dummy border variable has a positive and significant coefficient in location equation and growth equation, respectively. In reality, the closer the two cities, the easier the transportation of goods and ideas between them. This positive relationship thus suggests an important role of geographical proximity in industrial agglomeration. Similarly, this border effect stimulates growth of two closer cites as knowledge spillovers become more costless.

[22] It should be pointed out that comparing to empirical analysis of this section, Démurger's (2001) finding is obtained by using single equation estimation and provincial level data.

The coefficients of three proxies for capital stock are all positive and significant at 1% level, which reveals a positive impact of capital stock on income disparity. As discussed in Baldwin and Martin (2003), regional income distribution is mainly determined by the "exogenous" initial distribution of capital endowments in the case of perfect capital mobility. This argument provides some explanations for income disparities between east and west in China during the transition period. On the one hand, eastern coastal regions accumulate more capital stocks by making full use of various national preferential policies since reform and opening in 1978. This advantage of capital endowments has been further reinforced through the home market effect. On the other hand, domestic market becomes more integrated as the large-scale construction of national highway networks over the past decades, which greatly facilitates capital mobility between regions. These two aspects work together, leading to industrial concentration in initial richer eastern regions and enlarging the income disparities between east and west.

In relation to labor force variable, the estimation results indicate a positive and significant impact of labor on economic growth. A larger labor force increases growth because of the usual scale effect (Martin, 1999).

5.3.5 Estimation Results: Extensions of FDI and Labor Mobility

To investigate the impact of urban infrastructure in an open economy, the FDI variable is introduced to the income disparity equation of the system and report the estimation results in column (3) and (4) in Table 5.2. Note that the impact of different urban infrastructures decreases slightly after controlling for FDI, indicating our benchmark estimation result is still robust when adding new explanatory variable to the system.

For each specification, the sign of estimated coefficients of FDI is the same as expected. The positive and significant impact indicates that income disparities between cities increase as their differences of FDI stock increases. In the case of an open Chinese economy, eastern coastal cities with better openness to foreign markets tend to attract more FDI flows and thereby enlarge their income differences with western inland cities.

The last two rows of Table 5.3 reports the direct and indirect impacts of FDI, calculated using the estimation results in column (3) and (4) in Table 2. The estimation of equations system reveals that FDI has a positive impact on industrial location. This result is consistent with the study of Ge (2008), who finds a close relation between trade and FDI and industry agglomeration in China. And export-oriented and foreign-invested industries have a higher degree of agglomeration than other industries. Meanwhile, estimation results reveal a positive correlation (0.003 to 0.004) between FDI and economic growth. However, this positive but slight effect is achieved at the expense of considerable increase in regional inequality between cities. In this sense, our paper, like many previous studies of the impacts of FDI (Fu, 2007; Ran *et al.*, 2007), suggests that policy makers should consider the gain and loss before implementing any FDI-attractive policies.

Another extension to our structural estimation is the role of labor mobility, which is usually ignored in most empirical studies based on the framework of NEG models. The 286 cities are divided into two sub-samples based on their mobile intensities: high-mobility cities, which have above-median mobile intensity, and low-mobility cities, which have below-median mobile intensity.

Table 5.4 reports the 3SLS estimates of two sub-samples. Note that the signs of three endogenous variables are as the same as which has been derived in the theoretical framework, so that our empirical study still supports the equilibrium relationship among industrial location, income distribution and growth. Nevertheless, the coefficients of road, telecommunication and university variables vary significantly in different sub-samples, implying the impacts of urban infrastructure depends on the heterogeneity of labor mobility across cities.

Table 5.5 and Table 5.6 reports the direct and indirect impacts of urban infrastructure, respectively, calculated using the estimation results of high labor mobility sub-sample and low labor mobility sub-sample. The estimation result provides a negative relationship (-0.009 to -0.008) between road and industrial agglomeration, so that building more roads between cities obstructs industrial agglomeration in the case of high labor mobility. Meanwhile, as industries become more dispersed, the cost of innovation increases and the growth rate decreases. Therefore, improved road infrastructure leads to lower growth rate and thereby larger income disparity between cities. When labor mobility is low, the impacts of road infrastructure are similar to that of the total sample. To summarize, the improvement of transportation infrastructure still faces the trade-off between spatial efficiency and equality irrespective of labor mobility.

Table 5.4 Extended Estimation Results: Labor Mobility

	High labor mobility		**Low labor mobility**	
	(1)	(2)	(3)	(4)
Location equation				
Income disparity	1.243***(0.007)	1.243***(0.007)	1.445***(0.009)	1.447***(0.009)
Border	0.104***(0.006)	0.106***(0.006)	0.188***(0.008)	0.190***(0.008)
Road	-0.008***(0.003)	-0.009***(0.003)	0.045***(0.003)	0.044***(0.003)
Adjusted R-squared	0.712	0.713	0.715	0.715
Income equation				
Growth rate	-0.118***(0.004)	-0.121***(0.004)	-0.136***(0.005)	-0.138***(0.005)
Material capital	0.297***(0.007)	0.296***(0.007)	0.395***(0.007)	0.397***(0.007)
Human capital	-0.005*(0.003)	-0.006**(0.003)	0.026***(0.003)	0.025***(0.003)
Knowledge capital	0.357***(0.005)	0.357***(0.005)	0.333***(0.006)	0.331***(0.006)
FDI	0.095***(0.003)	0.095***(0.003)	0.031***(0.004)	0.031***(0.004)
Adjusted R-squared	0.791	0.790	0.754	0.753
Growth equation				
Agglomeration	0.323***(0.016)	0.321***(0.016)	0.142***(0.011)	0.146***(0.011)
Border	0.246***(0.028)	0.260***(0.029)	0.435***(0.023)	0.472***(0.023)
Telecommunication	0.123***(0.004)	-	0.107***(0.003)	-
University	-	0.119***(0.005)	-	0.104***(0.004)
Labor force	0.142***(0.015)	0.138***(0.015)	0.270***(0.013)	0.271***(0.013)
Adjusted R-squared	0.189	0.180	0.242	0.235
Observations	10153	10153	10153	10153

Note: (1) The numbers in brackets are standard errors;

(2) ***, ** and * denotes significance higher than 0.01, 0.05 and 0.1, respectively.

By comparison, the effect of knowledge infrastructure measured by university variable becomes larger in high mobility cities sub-sample, supporting the close relationship of labor mobility in knowledge spillovers between cities. By contrast, the effects of university are smaller and nearly zero (-0.003 to -0.002) in the case of insufficient labor mobility.

Therefore, with growing labor mobility between cities, knowledge infrastructures tend to play a more important role in stimulating growth and decreasing regional inequalities in terms of industrial location and income disparities.

Table 5.5 Effects of Urban Infrastructure with High Labor Mobility

		Industrial agglomeration		**Income disparity**		**Aggregate growth**	
		(1)	(2)	(3)	(4)	(5)	(6)
Road	Direct	-0.008	-0.009	-	-	-	-
	Indirect	-	-	0.0003	0.0004	-0.003	-0.003
Telecommunication	Direct	-	-	-	-	0.123	-
	Indirect	-0.018	-	-0.015	-	-	-
University	Direct	-	-	-	-	-	0.119
	Indirect	-	-0.018	-	-0.014	-	-

Table 5.6 Effects of Urban Infrastructure with Low Labor Mobility

		Industrial agglomeration		**Income disparity**		**Aggregate growth**	
		(1)	(2)	(3)	(4)	(5)	(6)
Road	Direct	0.045	0.044	-	-	-	-
	Indirect	-	-	-0.001	-0.0001	0.006	0.001
Telecommunication	Direct	-	-	-	-	0.107	-
	Indirect	-0.021	-	-0.015	-	-	-
University	Direct	-	-	-	-	-	0.104
	Indirect	-	-0.003		-0.002	-	-

5.3.6 Robustness Analysis

In general, the main results of structural system are robust to the inclusion of additional variable (e.g., FDI) and variation of sample sizes (e.g., high labor mobility sub-sample and low labor mobility sub-sample).

In addition, to check the robustness of our estimation results and control for the potential heteroskedasticity problem, the system of equations are estimated with different specifications, using GMM method. The GMM results for our benchmark estimation are reported in column (1) to (2) in Table 5.7, results for the specification of including FDI variable are reported in column (3) to (4), where telecommunication and university variable enters the regression, respectively. The coefficients of all variables are all significant at 1% level. The Hansen's J-test does not reject the validity of the instruments and the overidentifying restrictions for all specifications.

Table 5.7 Robustness Check for Benchmark Results

	GMM			
	(1)	(2)	(3)	(4)
Location equation				
Income disparity	1.213***(0.006)	1.208***(0.006)	1.216***(0.006)	1.212***(0.006)
Border	0.128***(0.004)	0.124***(0.004)	0.130***(0.004)	0.127***(0.004)
Road	0.019***(0.002)	0.022***(0.002)	0.019***(0.002)	0.022***(0.002)
Adjusted R-squared	0.767	0.767	0.766	0.767
Income equation				
Growth rate	-0.101***(0.002)	-0.107***(0.002)	-0.108***(0.003)	-0.116***(0.002)
Material capital	0.477***(0.006)	0.471***(0.006)	0.454***(0.007)	0.441***(0.006)
Human capital	0.024***(0.002)	0.024***(0.002)	0.024***(0.002)	0.024***(0.002)
Knowledge capital	0.373***(0.005)	0.378***(0.005)	0.364***(0.005)	0.367***(0.005)
FDI	-	-	0.022***(0.004)	0.029***(0.004)
Adjusted R-squared	0.572	0.571	0.571	0.569
Growth equation				
Agglomeration	0.142***(0.004)	0.132***(0.004)	0.143***(0.004)	0.133***(0.004)
Border	0.440***(0.011)	0.472***(0.011)	0.439***(0.011)	0.471***(0.011)
Telecommunication	0.118***(0.002)	-	0.118***(0.002)	-
University	-	0.112***(0.003)	-	0.112***(0.003)
Labor force	0.441***(0.005)	0.445***(0.005)	0.440***(0.005)	0.443***(0.007)
Adjusted R-squared	0.211	0.200	0.210	0.200
J-statistic	0.067 (0.795)	0.070 (0.791)	0.066 (0.797)	0.068 (0.794)
Observations	40755	40755	40755	40755

Note: (1) The numbers in brackets are standard errors;

(2) *** denotes significance higher than 0.01 and 0.05, respectively.

Table 5.8 reports the GMM results for the specification of high and low labor mobility sub-samples, respectively. Note that in the case of high labor mobility, road infrastructure has negative and significant coefficients in both specifications (-0.015 and -0.019), which is consistent with those of 3SLS estimates. To summarize, by comparison with the results of 3SLS method, the signs and significance of coefficients do not change considerably, so that our main results are robust to the choice of different estimation techniques.

Table 5.8 Robustness Check for Extended Estimation Results

	High labor mobility		**Low labor mobility**	
	(1)	(2)	(3)	(4)
Location equation				
Income disparity	1.187***(0.010)	1.168***(0.010)	1.429***(0.012)	1.425***(0.012)
Border	0.091***(0.005)	0.083***(0.005)	0.194***(0.008)	0.191***(0.008)
Road	-0.015***(0.002)	-0.019***(0.002)	0.036***(0.003)	0.035***(0.003)
Adjusted R-squared	0.723	0.725	0.717	0.718
Income equation				
Growth rate	-0.100***(0.003)	-0.100***(0.003)	-0.136***(0.004)	-0.138***(0.004)
Material capital	0.299***(0.008)	0.290***(0.008)	0.355***(0.009)	0.356***(0.009)
Human capital	0.006**(0.003)	0.006**(0.003)	0.036***(0.003)	0.036***(0.003)
Knowledge capital	0.372***(0.006)	0.377***(0.006)	0.353***(0.008)	0.353***(0.008)
FDI	0.085***(0.003)	0.089***(0.003)	0.032***(0.005)	0.033***(0.005)
Adjusted R-squared	0.800	0.799	0.758	0.757
Growth equation				
Agglomeration	0.369***(0.015)	0.355***(0.015)	0.189***(0.008)	0.195***(0.008)
Border	0.236***(0.027)	0.253***(0.028)	0.428***(0.022)	0.488***(0.022)
Telecommunication	0.127***(0.004)	-	0.111***(0.003)	-
University	-	0.123***(0.004)	-	0.103***(0.003)
Labor force	0.132***(0.013)	0.140***(0.013)	0.244***(0.010)	0.241***(0.010)
Adjusted R-squared	0.181	0.178	0.234	0.226
J-statistic	0.103 (0.748)	0.110 (0.740)	0.109 (0.741)	0.103 (0.748)
Observations	10153	10153	10153	10153

Note: (1) The numbers in brackets are standard errors;

(2) *** and ** denotes significance higher than 0.01 and 0.05, respectively.

5.4 Summary

Using a cross-section data of 286 Chinese cities in 2008, this chapter estimates a structural system of simultaneous equations to examine the impact of two types of infrastructures on industrial location, income disparity and growth simultaneously.

It is found that an improvement in transportation infrastructure increases growth and decreases income gap at the expense of increasing industrial agglomeration between cities. This result confirms the existence of a trade-off between spatial equity i.e., more even spatial distribution of economic activities, and spatial efficiency, i.e., higher growth rate. However, an improvement in knowledge infrastructure escapes from this trade-off, as it increases growth but also decreases income gap and industrial agglomeration simultaneously.

This chapter can be viewed as a first attempt to empirically investigate the effects of public infrastructures by making clear distinction between transportation infrastructure and knowledge infrastructure. As discussed in Baldwin *et al*. (2003), in reality, the situation is complicated: facilitating trade in goods also facilitating trade in ideas and labor mobility between cities. In addition, improving road network decreases inter-regional transport cost but also intra-regional transport cost simultaneously. In particular, Martin (1999) shows that a reduction in intra-regional transport costs in the poor region will lower spatial concentration, decrease growth and increase income inequality between regions. Therefore, it is worthwhile to extend the current empirical analysis to investigate the interaction of different public infrastructures and to incorporate intra-regional trade costs in future studies.

Chapter 6 Conclusion

This dissertation empirically examines the impact of economic policies on regional inequalities and growth in China, focusing on the trade-off between spatial equality and spatial efficiency. With the utilization of data from individual-, industry-, and urban-level, the empirical analysis conducts a thorough investigation on the role of economic policies in determining the geographical distribution of industries, income disparity, and growth.

First, at the industrial-level, this dissertation focuses exclusively on China's high-tech industries, which has obtained great concern and support from central and local governments in recent decade. The dissimilarity indices are calculated to investigate trends and changes in high-tech industrial specialization and regional concentration during the period 1996 to 2005. It is found that both specialization and concentration increases significantly at nation-level. In particular, it is found that a widening gap of industrial structure between coastal and inland regions, while the whole high-tech industry sector has become more and more concentrated in coastal regions. Using static and dynamic panel approach, this dissertation empirically examines the impact of promotion policies on specialization and concentration while controlling for other driving forces proposed by theories. It is found that the implementation of high-tech oriented export policy and subsidy for science and high technology activities have positive effects, whereas local government's protection for local high-tech industries decreases the level of specialization and concentration. The empirical study also confirms the role of high-skilled labor in determining the location of high-tech industries.

To our knowledge, there have been very little empirical studies on the possible impact and significance of economic policy on industrial specialization and regional concentration of high-tech industries in China. Thus, this dissertation contributes to existing empirical literature through a complete investigation on the trends and extent of specialization and concentration of high-tech industries during the period of 1996 to 2005. As for econometric analysis, the adoption of dynamic panel data approach could introduce the historical factors (measured by the lagged specialization variable) and policy factors (measured by the lagged policy variables) into empirical models. Furthermore, by comparison of various estimation techniques, this chapter adopts system Generalized Method of Moments method (system GMM) to solve the endogenetiy of lagged variables and to obtain unbiased and consistent estimation results.

In addition, this dissertation provides some policy implications for both central and local governments of China. (1) Central government should further accelerate economic openness in inland regions with various macro-level preferential policies, facilitating the transfer of some export-oriented high-tech industries from eastern coastal region to inland regions. (2) Local governments of inland regions should pay more attention to promote local high-tech industries that already have a comparative advantage, such as A&S manufacturing. Third, the significant negative impact of local protectionism suggests that further reducing entrance barriers and encouraging domestic market unification would play a more important role in stimulating industrial specialization. However, the lagged effects of previous specialization pattern indicate that inland governments require more effort and time to catch up with their counterparts in eastern coastal regions.

Second, at the individual level, this dissertation investigates the relationship between urban infrastructure and wages in China and contributes to existing literatures in two aspects: (1) FA method is adopted for reducing the multi-dimensional aspects into a one-dimensional variable, i.e., a composite index to measure the extent of urban infrastructure across cities. (2) This dissertation examines the respective impacts of urban infrastructure on rents and wages and returns to returns to worker characteristics (e.g., education, experience, tenure). Using OLS and instrumental variable estimation method, the empirical analysis reveals evidence of compensating differentials in housing and labor markets for urban infrastructure in china. Moreover, the empirical analysis estimates an earning function including an interaction term of urban amenities and worker characteristics. It is found that returns to workers characteristics vary significantly across cities.

China has witnessed increasing wage inequality across regions in the past three decades. Unlike those time-invariant natural amenities (e.g., warm weather, deep-water port), urban infrastructure that could affect the quality of life of urban residences (e.g., theaters and shopping centers) or firms' profits can be produced and enhanced gradually. In this sense, improving urban infrastructure in relatively backward inland regions can be an effective way of reducing wage inequality across regions.

Lastly, at the region-level, this dissertation examines the role of two types of urban infrastructure in determining industrial geography, income disparity, and growth. The study of this dissertation contributes to existing literature on the role of urban infrastructure in the following aspects. (1) Previous studies primarily focus on the role of transport infrastructure and therefore ignore the comparison of impacts of different infrastructures (notable exception is Démurger, 2001). Given the significantly different role of urban infrastructure in stimulating growth and reducing regional inequality, this chapter makes a clear distinction between urban infrastructure that facilitates inter-regional transaction on goods (e.g., road network), which is defined as transportation infrastructure and urban infrastructure facilitates inter-regional transaction on ideas (e.g., telecommunication) or human capital formation (e.g., universities), which is defined as knowledge infrastructure here. (2) The empirical analysis follows a theoretical framework to guide empirical studies and estimate equations directly derived from the theoretical model. As Combes and Lafourcade (2002) argue, the adoption of specifications derived from a fully-specified model allows authors to provide much more precise statements. (3) While previous studies use single-equation estimation methodology, this dissertation adopts a simultaneous approach in the empirical analysis.

Broadly speaking, infrastructure policies facilitates trade in ideas, for example, developing inter-regional telecommunication, constructing internet connection, establishing universities and vocational training schools, would achieve a desired result for policy makers to escape from the trade-off between spatial equality and efficiency. Meanwhile, the findings also highlight the importance of labor mobility and its influence on the effects of public infrastructures. Over the past few decades, China has witnessed a large-scale of labor migration from inland to coast or from rural area to urban area. Considering the growing trends of domestic integration in China, labor mobility is predicted to continue to increase in future. This, in turn, enhances the effects of knowledge infrastructure policies on reducing regional inequality and stimulating growth. Nevertheless, in China, the special household registration system, known as “hukou”, strictly obstructs labor mobility by discriminating against migrant workers in their employment, healthy insurance, or even in their children’s education. In this regard, this dissertation suggests a policy to phase out the household registration system to encourage more inter-regional migration.

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