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Regional economic impacts of China's high-speed rail development and its institutional challenges

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REGIONAL ECONOMIC IMPACTS OF CHINA'S HIGH-SPEED RAIL DEVELOPMENT AND ITS INSTITUTIONAL CHALLENGES

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I hereby declare that this PhD dissertation is my original work
and it has been written by me in its entirety.
I have duly acknowledged all the sources of information
which have been used in this dissertation.

This PhD dissertation has also not been submitted for any degree
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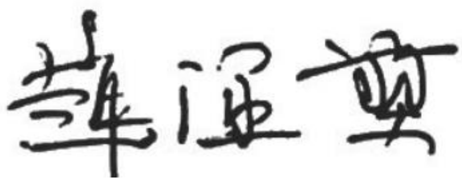

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Abstract

REGIONAL ECONOMIC IMPACTS OF CHINA'S HIGH-SPEED RAIL DEVELOPMENT AND ITS INSTITUTIONAL CHALLENGES

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This article studies the impact of connecting to high-speed rail (HSR) network on regional development and the replication and sustainability of China's GIUR system, aiming to summarize the experience of China's HSR, which can provide several policy references for developing countries. This article conducts two research: (1) explore the impact of connecting to HSR network on the urban industrial structure, urban creativity and urban-rural income gap of cities in different regions and cities with heterogeneous locations along the HSR lines in the long and short term; (2) explore the advantages and disadvantages of the Government-Industry-University-Research (GIUR) system in the process of introducing, absorbing and innovating technologies of HSR, as well as its adjustment in the technology-pioneering stage.

For the first research, HSR and urban development, I conduct the empirical research and descriptive statistics based on urban development theory, and the results indicate following conclusions. Firstly, connecting to HSR network can significantly increase the proportion of tertiary industry in eastern cities of China. Secondly, it can promote the creativity of urban primary and tertiary industries, and more developed cities and non-eastern cities benefit more. In addition, it has also significantly improved the creativity of the tertiary industry in major hub cities, the better accessibility (with more HSR lines passing through) major hub cities possess, the more improvement in creativity of tertiary industry they can benefit compared to those minor node or non-node cities. Thirdly, connecting to the HSR network will only widen the urban-rural income gap in economically underdeveloped regions, and this expansion effect is more significant in economically underdeveloped minor node cities.

For the second study, combining the existing research and case study, I find that in the early stage of technological development in which international advanced technology can be brought in, the government-dominated GIUR system is more conducive to promoting HSR technology accumulation and development. But in the technological pioneering stage, the system needs to transform into a market-oriented Industry-University-Research system. In addition, based on above research, I argue that the government GIUR system has a good sustainability for promoting scientific research innovation but has a high threshold when applied to other industry. This study increases people's awareness for reformation system of China's HSR research and development (R&D) and helps to propel the rapid development of similar emerging industries. Finally, I discuss the policy implications.

Key Words: Chinese HSR; regional development; GIUR system; innovation

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Acknowledgement

Since 2014, I have been working on China’s high-speed railway (HSR) development. During this period of time, I have gained a lot of experience and thoughts which I think might be beneficial to China’s HSR industry and help promote the HSR to contribute more to the world. The above motivates this thesis.

It is quite challenging to obtain the degree and write the thesis. It cannot be done without support from my supervisors, classmates, friends, and my family. Especially, I would like to show gratitude to my supervisors, i.e., Professor Gerard GEORG, Professor Bing XIANG and Professor Sock Yong PHANG. My thesis benefits a lot from their careful and patient guidance and insightful suggestions.

Chapter 1 Introduction

1.1 Background of China's high-speed rail

China's high-speed rail (HSR) has made remarkable achievements. Since 2008 when the Beijing-Tianjin high-speed rail (HSR), which is also the first HSR line in China, put into operation. Since then, China's HSR network has been rapidly expanded. According to China State Railway Group Co., Ltd. (CHINA RAILWAY), by the end of 2018, China's total length of HSR lines in operation amount to 29,000 KM, which takes around 2/3 of world total length of HSR lines. By the end of the decade in 2018, the HSR has transported more than 9 billion passengers. In 2019, according to the survey by *Railway Gazette International*, Beijing-Shanghai HSR line topped the world HSR lines by its average speed of over 300 KM per hour. Moreover, China's HSR industry has accumulated comprehensive technologies through the introduction of technology from Canada, Japan, Germany and France as well as R&D itself.

Despite its late start, China's HSR is growing rapidly. After many years of technology preparation and the introduction of advanced technology to quickly fill the technical gaps, China's HSR has now formed full-industrial chain with independent research and development (R&D) capability. The success of the government-industry-university-research (GIUR) system in China's HSR development during the last decade can be attributed to Chinese unique institutional environment and internal incentive mechanism (He, Lv, Huang &

Jiang, 2018).

The HSR in China mainly brings following welfare to the society. Firstly, it has not only brought great convenience to people’s travelling but also substantially promoted regional development. Secondly, it has greatly shortened the space-time distance that means the travelling costs and commuting time are drastically reduced, thus motivating people to travel more and enrich people’s life. It can be said that HSR shortens the psychological distance between people to a certain extent. Thirdly, it promotes the movement of labor, capital and other production factors within or even across regions, resulting in optimal allocation of resources and contributing to regional integration. In addition, the huge infrastructure investment brought by HSR construction has boosted local employment and economic development.

HSR has different impacts on different cities due to siphon effect, which means the labor in an inferior city will be attracted to a nearby advantageous city when transportation costs between the two cities are reduced. In addition, the following factors should be taken into account in the planning and development of high-speed rail, including the cost of HSR construction, different income levels and market demand in different regions, geological factors in various regions, different local government policies and heterogeneous local geopolitical factors.

1.2 Concerns on China's HSR development

The development of HSR has played a significant role in promoting Chinese economy development. However, I would like to propose several concerns and questions based on our observation and literature review.

- **1 Question** What is the actual impact of connecting to HSR network on a city's economic development? Connecting to HSR network will generate siphon effect and agglomeration effect at the same time. It has different impacts on cities of different development levels, regions and cities along the HSR lines. Moreover, it also has different impacts on different industries, and different impacts in the short term and in the long term. Existing literature does not systematically sort out those issues. Besides, few literature has systematically revealed the heterogeneous impacts of HSR on cities' industrial structure and creativity in the short and long term.

- **2 Concern** Existing literature ignores the impact of HSR on income gap between urban and rural populations in a city. But in practice, the income gap between rural and urban areas has always been a concern. The development of HSR promotes the productivity and incomes in the urban area, which gradually draw rural labor into the urban area. Will this lead to further decline in the rural sector? Does the development of HSR have the same impact on the urban-rural income gap in cities with different economic endowments? How could the government make rural areas enjoy the dividends brought by HSR?

- **3 Concern** China has established a government-industry-university-research system (GIUR) in the HSR industry, and the GIUR has achieved great success during the last decade. Dominated by the government, the technology bringing in and digestion in the early stage have done a good job, but I am still concerned about the innovation of HSR in the future. Few studies have discussed the possible improvement of the R&D system in China's HSR industry. How to adapt the initial GIUR system to the new role of pioneering technological development rather than digesting existing technologies?

1.3 Research objectives, research questions and findings

The research objective of this article is to explore the impact HSR on regional development from economic perspectives, to investigate the sustainability and reproducibility of China's GIUR system from institutional perspectives, and to summarize China's experience. The specific research questions are as follows**:**

- **Research Question 1:** How does connecting to HSR network affect industrial structure, creativity, and urban-rural income gap of cities, and how do the impacts vary across regions in the long and short term?
- **Research Question 2:** What are the pros and cons of the government-dominated GIUR system in the process of introducing, digesting and reinnovating HSR technology? How should this system be adjusted in the future?

For the first research question, I measure the impact of connecting to HSR network on urban development through the multi-period differences-in-differences method. The results are as follows: **Firstly**, it is found that connecting to HSR network only significantly increases the proportion of the tertiary industry among the eastern cities, which does not occur in non-eastern cities or other cities. The change of industrial structure takes time, but the observation period is too short to observe large-scale change of industrial structure caused by HSR across the whole country. Moreover, siphon effect also takes time and is more likely to happen in certain areas. **Secondly**, connecting to HSR network promotes the creativity of the HSR cities (which is measured by the increase in the number of patents registered each city each year) in the primary and tertiary industries, and the impacts are more significant for more developed cities and non-eastern city. **Thirdly**, connecting to HSR network only widens the urban-rural income gap in less developed regions. In addition, I also quantitatively explore the heterogeneous impact of HSR on major hub, minor node and non-node cities along the HSR lines through descriptive statistics, and find that connecting to HSR network has significantly improved the creativity of the tertiary industry of major hub cities in a local area. And the better accessibility major hub cities possess (with more HSR lines passing through), the more significant improvement they benefit compared to those minor node and non-node cities. What’s more, connecting to HSR network will only widen the urban-rural income gap in those economically underdeveloped minor node cities, which is consistent with the above empirical results.

For the second research question, this study finds that the GIUR system is more suitable for the early stage of HSR development. Comparing the competitive Industry-University-Research system to the current GIUR system, I believe that China will play a pioneering role in the current and future stages, rather than following the HSR technology development and need to adjust the initially GIUR system. In addition, I further demonstrate the importance of the GIUR system for promoting industrial scientific research innovation and the adjustment policies required for different technology development stage.

1.4 Significance and contribution

HSR development is one of China's most important national projects, and HSR now is China's gold name card towards the world. In this study, I try to answer two important research questions in terms of China's HSR development.

The third chapter has the following contributions. **Firstly,** it fills a gap in the current research on the impact of HSR on the urban-rural income gap in different regions and cities with different economic endowment. **Secondly**, the empirical results demonstrate that large-scale changes of industrial structural are difficult to occur in the short term. It could be seen that compared with the secondary industry in all regions, the number of patents in the tertiary industry has significantly increased, but the changes in the industrial structure caused by HSR can only be clearly observed in eastern China. The above phenomena can be attributed to the short history of HSR development in China, and industrial agglomeration and transfer takes a long time, so the more frequent commutes brought by HSR may occur quickly in the short term. **Thirdly**, the results of this article also indicate that the appearance of siphon effect takes time, and the existing literature ignores the fact that the siphon effect could not occur immediately, especially when it is across regions. **Finally**, this study increases people's understanding of the locational heterogeneous impact of HSR on different cities along the lines.

The fourth chapter combines theoretical experience and case studies to clarify the advantages and disadvantages of the GIUR system at different stages of the HSR technology development and how it should be adjusted, which increases people's awareness for R&D system reformation of China's HSR.

1.5 Structure of the study

The second chapter of this article is the literature review. The third chapter mainly studies the heterogeneous impact of HSR on urban industrial structure, creativity, urban-rural income gap in different regions, different development levels and different cities along the HSR lines. The fourth chapter discusses the advantages and disadvantages of the government-dominated GIUR system in different stages of technology development and proposes the adjustment direction in the future required for adapting to the role of technology leaders. The fifth chapter gives the conclusions and policy implication.

Chapter 2 Literature Review

2.1 Basic framework of urban economics: urban internal structure and equilibrium across cities

2.1.1 The formation of urban internal structure

From the perspective of urban spatial structure, urban development has two typical characteristics, including horizontal spread and multi-center agglomeration, which brings higher productivity within the city center (Ciccone & Hall, 1996; Chen, Yang & Shen, 2009; Wei, Chen & Lu, 2016; Liu & Li, 2017). However, regarding to the impacts of Chinese urban spatial structure on urban economic efficiency, there are two different views. Wei et al. (2016) argue that horizontal spread has no significant impact on urban productivity, but multi-center agglomeration significantly improves urban productivity. The productivity growth is mainly due to the interaction between the secondary center of the manufacturing industry and its production-service industry. On the contrary, Liu et al. (2017) believe that the spatial structure of single center can greatly improve the economic efficiency of cities on smaller geographical scales such as internal cities. At the same time, Wei et al (2016) also find that the multi-center agglomeration effect is different at different stages of development and urban types. And it is believed that strengthening multi-center agglomeration and moderate control of spread are the key to efficient operation of the economy in urban expansion.

The existing literature also explores the existence and causes of multi-centers within a city (Sasaki & Mun, 1996; Lucas & Rossi–Hansberg, 2002; Yang, Ji & Wang, 2019). Causes include trade (Cavailhes, Gaigne, Tabuchi & Thisse, 2007), development of transportation technology (Glaeser & Kahn, 2004) and so on. In the equilibrium model of urban land use, some spatial models focus on competition between firms for higher productivity sites (Lucas & Rossi-Hansberg, 2002), while others focus on competition among workers for housing closer to work (Mills, 1967). Mills's classical model assumes that the Central Business District (CBD) is surrounded by the surrounding homes, but it does not study the competition between enterprises and the residents. And some key features of the internal structure of the city are explained by assumptions rather than deriving from economic models. Fujita and Ogawa (1982) also study the formation of a multi-center or single-center city. According to Fujita and Ogawa (1982), in a linear city with a given population, businesses and households compete for space in different locations and the company's productivity is determined by the externalities of the company's distance. Enterprise production requires a fixed percentage of land and labor, and each worker (consumer) needs a fixed amount of residential land. It also assumes that residential land and employment density do not change with distance. In equilibrium, the research results are consistent with Mills' example which shows that low commuting costs result in specialized production sectors surrounded by specialized residential land. However, as the commuting costs increase, land use will be mixed during the equilibrium.

2.1.2 Equilibrium between cities

Rosen (1974) argue that, given the zero inter-city migration costs, manufacturers with the same scale returns earn zero profit at equilibrium, regardless of where they are. Moreover, workers with the same preferences have the same utility no matter where they live. Also, Desmet and Rossi-Hansberg (2013) theoretically find that for cities, the combined effect of productivity, facilities and excessive frictions would lead to changes in the size of urban employment and population. When labor mobility tends to be spatially balanced, eliminating the difference in productivity and convenience between cities will lead to labor migration between cities. Finally, individual utility will not change much, but it will bring an increase in the size of the population and employment to cities that were initially weak.

2.2 Transportation and urban development

2.2.1 Transportation and urban economic growth

The government's fiscal expenditure of infrastructure construction has multiplier effects in terms of driving economic development, and this is especially significant for the construction of HSR of large investment scale with long construction period (Song et al., 2015; Yoshino, Naoyuki, Abidhadjaev & Umid, 2016; Wang & Ni, 2016; Zhang, 2017; Liu & Li, 2017; Ahlfeldt &

Feddersen, 2018). From the perspective of new economic geography, geological factors are taken into consideration, and the development of regions and cities is no longer considered as isolated but interrelated. In this research framework, urban economic growth is studied from the perspective of spatial spillover effect. Connecting to HSR network has a significant economic spillover effect on cities. This economic spillover effect is mainly reflected in the improvement of urban industrial agglomeration and the improvement of regional economic division and cooperation, thereby further promoting the development of HSR cities.

In order to measure the impact of connecting to HSR network on urban economic growth, many studies often use the difference-in-difference (DID) method to treat connecting to HSR network as a dummy variable in a model to evaluate the impact of connecting to HSR network on the urban economy. In a specific research, Wang and Ni (2016) believe that the impact of connecting to HSR network on economic development can be divided into the growth effect caused by regional spillover mechanism and the structural effect characterized by economic pattern changes. From the perspective of direct effects, Jiang, Fan, Xia, Chen and Yao (2017) believe that the investment-driven effect of HSR not only promotes urban economic growth but also promotes urban employment. Through input-output analysis, Jiang et al. (2017) conclude that in 2012, every 100 million yuan of investment in China’s HSR leads to an increase of 372 million yuan in total output, a growth of 121 million yuan in GDP and an increase of 1084 jobs. From the perspective of indirect effects, HSR has an impact on economic development by improving location conditions and market accessibility and generating spatial spillover effect. For example, Liu and Li (2017) find that the average annual economic growth rate of cities which are connected to HSR (I call these cities as HSR cities) is 2.7 percentage points higher than that of other cities. The average annual economic growth rate of neighboring cities of the HSR cities is 2 percentage points higher than that of other non-HSR cities. The above findings confirm the existence of the economic spillover effect of connecting to HSR network.

Although the fast and efficient HSR will accelerate the movement of economic factors between regions and cities, the impact of HSR on urban economic development will be uneven due to the different concentration level of urban economies. For most small and medium-sized cities, HSR brings more (passive) siphon effect (Zhang & Tao, 2016; Qin 2017; Wang & Duan, 2018; Diao, 2018; Deng & Xu, 2019). That is to say, for large and medium-sized cities, HSR has brought about an expansion of market potential, but the siphon effect of HSR will bring significant negative growth to small cities and counties with poor economic resources (Qin, 2017). Preston and Wall (2008) and Hall and Peter (2009) find that small cities along the HSR lines are often neglected in improving traffic accessibility in large cities, making it easier to transfer resources along the way central cities and exacerbating imbalances in regional development. Zhang and Tao (2016) demonstrate the siphon effect of HSR on the economic development of non-regional central city along the way and find that the siphon effect mainly occurs in the eastern region, while prefecture-level cities that are closer to regional central city will be more negatively affected by connecting to HSR network. Deng and Xu (2019) find that while HSR promotes population concentration in certain regions, it also severe the population loss in cities that are losing population. It is further believed that the development of HSR has accelerated the polarization of regional economic development.

2.2.2 Transportation, accessibility, and urban location

The development of transportation infrastructure will enhance intercity connectivity and change a city's accessibility (Hou & Li, 2011; Cao, Liu, Wang & Li, 2013; Kim & Sultana, 2015; Shaw, Fang, Lu & Tao, 2014; Liu & Zhang, 2018), but this change in accessibility is uneven (Diao, 2018; Monzón, Ortega & López, 2013). From regional perspective, the uneven development of HSR network has widened the development gap between regions and even metropolitan areas. Wang and Ni (2016) believe that the reduction in space-time distance brought by rapid transportation networks such as HSR will accelerate the agglomeration, diffusion and differentiation of economic activities at the regional level and trigger the expansion of the central area in geography and the decline of peripheral areas in China. In practice, connecting to HSR network has made central areas expand and integrate into the eastern China, and has made traditionally peripheral areas such as the west and northeast regions lag behind and has increased the risk of economic recession in some remote areas. Wang and Duan (2018) divide the winners and the losers in the Yangtze River Delta region due to connecting to HSR network based on their net population inflows and different distances between their nearest urban HSR stations and their urban centers. Diao (2018) believes that the developed eastern regions will benefit more from the accessibility changes brought by HSR, and second-tier cities with large population bases will achieve higher GDP growth through higher fixed-asset investment growth driven by HSR development.

In addition, as far as HSR is concerned, connecting to HSR will also affect housing price (Hensher, Li & Mulley, 2012) by changing a city’s accessibility (Bowes & Ihlanfeld, 2001; Andersson, Shyr & Fu, 2010; Zheng & Kahn 2013; Geng, Bao & Liang, 2015; Ding & Ni, 2017) or public investment capitalization (Cohen & Brown, 2017), and also affect land price through land finance (Zhou, Yang, Huang & Geoffrey, 2018). Moreover, the impact of HSR on urban real estate has urban heterogeneity and regional heterogeneity. For example, through constructing market potential indicators under the influence of HSR, Zheng and Kahn (2013) find that connecting to HSR network makes it possible for some labor to flow into second-tier cities around large cities, and enjoy the urban agglomeration economy without bearing the huge housing cost and living cost there, which in turn increases the housing prices of the second-tier cities along the HSR.

2.2.3 Transportation, movement of factors and urban development

Connecting to HSR network, especially intercity railways, promotes the movement of economic factors such as labor (Sasaki, Ohashi & Ando, 1997; Desmet & Rossi-Handberg, 2013; Dong & Zhu, 2016), information (Huang, Liu & Ma, 2016; Long, Zhao, Zhang & Li, 2017; Inoue, Nakajima & Saito, 2017; Yang et al., 2019; Long, Li & Song, 2019) and capital, which further influence the business productivity (Zhang, Yu, Zhong & Lin, 2018) and urban labor productivity (Florida, Mellander & Stolarick, 2008; Fu & Gabriel, 2012) through spatial selection effect and spatial classify cation effect (Baldwin & Okubo, 2006; Venables, 2011; Forslid & Okubo, 2014; Behrens, Duranton & Robert-Nicoud, 2014).

From the perspective of labor, on the one hand, HSR will increase the labor demand of cities along the route. For example, some companies have moved to the surrounding areas of the central city in order to save rental costs and labor costs (Zheng & Kahn, 2013). On the other hand, HSR will also increase labor supply. For example, Dong and Zhu (2016) believe that the convenience of public facilities brought by HSR to the city will improve the living quality which will attract not only families in less developed areas to relocate to HSR cities, but also part of the labor to relocate from big cities to HSR cities for getting bigger living space and lower consumption cost.

From the perspective of information, connecting to HSR network reduces the transmission cost of labor and ideas, accelerating their movement between the HSR cities. For example, Huang et al. (2016) believe that the convenience of information communication brought by HSR makes up for the impact of geographic distance (reflecting the degree of information asymmetry between investors and the company) on IPO pricing, thus reducing the distortion of the IPO price relative to the real value. Long et al. (2017) find that HSR has reduced the information asymmetry between investors and entrepreneurs through improving accessibility, which in turn attracted more venture capital for HSR cities and eventually expanded investment radiation range of the central city of venture capital (VC). Therefore, the information flow brought by the improvement of accessibility helps to enhance the radiation range of the central city.

From the perspective of enterprises, Baldwin and Okubo (2006) argue that, in the new economic geography model proposed by Melitz (2003), it is not necessary to assume the enterprises are homogeneous. If this assumption is relaxed, the impacts of the HSR can be decomposed into the space selection effect (agglomeration effect, i.e., high-efficiency enterprises have stronger agglomeration effect than dispersion effect and thus further relocate to the central cities) and space classification effect (the low-efficiency enterprises relocate to peripheral cities). Zhang et al. (2018) use industrial enterprise data and find that HSR negatively affects the productivity of enterprises in peripheral cities, which is thought to be caused by the spatial selection effect, that is, the improvement of market access caused by the construction of transportation infrastructure such as HSR has generated siphon effect which makes the production factors such as capital and labor in the peripheral city flow to the central city and thus reduces the productivity of the peripheral city. Furthermore, from the perspective of urban endowments, connecting to HSR network has a more significant negative impact on cities with lower initial transportation endowments. From the perspective of industry heterogeneity, the increase in market access brought by HSR attracts high-level elements of capital or technology-intensive industries into central cities, which has a significant negative impact on the development of industries in peripheral cities.

Connecting to HSR network has accelerated the flow of production factors between cities, resulting in a more optimal allocation of production factors, which brings higher production benefits and will further promote the development of urban industry specialization and functional specialization (Duranton & Puga, 2000, 2005; Davis & Henderson, 2008; Su & Zhao, 2011; Zheng & Kahn, 2013; Lin, 2017).

2.2.4 Transportation and urban industry

The development of transportation infrastructure is closely related to the development of regional industries. Existing literature shows that connecting to HSR network has significantly promoted the development of some industries in HSR cities (Li, Linda & Hu, 2016; Li & Sun, 2017; Shao, Tian & Yang, 2017). For example, Li and Sun (2017) believe that HSR generally promotes the manufacturing agglomeration of HSR cities by affecting labor movement, and it weakens the agglomeration of manufacturing industry in the central cities while enhances the agglomeration of the manufacturing industry in the non-central cities. Shao et al. (2017) argue that connecting to HSR network has not weakened the agglomeration of service industry in small and medium-sized cities in the Yangtze River Delta region, and find that if HSR travels more frequently, it will significantly promote the accumulation of urban productive services, but the impact of HSR on the customer services and public services industries is not significant. However, the tourism industry is most affected by HSR . Gao, Su and Wang (2019) find that HSR has indeed brought about an increase in tourist population, especially for underdeveloped areas in the Midwest region of China. Wang and Duan (2018) analyze the tourism industry and find that HSR expand the radiation range of inland central cities such as Zhengzhou. Zhou et al. (2018) analyze the impact of HSR on micro-land prices from the perspective of local government incentives (land finance) and industry heterogeneity affected by HSR. They believe that HSR significantly increases the price of urban commercial service facilities and urban residential land but lowers the price of industrial land, which verifies that HSR promotes agglomeration of urban commercial and residential services.

In the new economic geographic model, the development and agglomeration of manufacturing industry are closely related to the cost of freight transportation. The improvement of transportation infrastructure has a great impact on the layout and location of start-ups, but this effect is significant in urban heterogeneity (Combes & Lafourcade, 2004; Fujita & Mori, 2005), that is, the reduction in transportation costs can reduce the concentration of central city and promote the spread of industries to surrounding cities.

With further improvement of the degree of urban industrial agglomeration and the level of economic cooperation between cities, the higher production efficiency will further promote the development of urban industry specialization and functional specialization (Duranton & Puga, 2000, 2005; Davis & Henderson, 2008; Su & Zhao, 2011; Zheng & Kahn, 2013; Lin, 2017). Zheng and Kahn (2013) believe that connecting to HSR network will accelerate the division of labor and cooperation among cities in the region and within the metropolitan area, enabling companies to relocate their headquarters and marketing departments in large cities with higher rents and place production departments in surrounding small cities with lower rents, and this will further promote the development of urban functional specialization (Su & Zhao, 2011). Lin (2017) explores the impact of connecting to HSR network on the specialization pattern of the city, and finds that connecting to HSR network and the improvement of market accessibility brought by it have significantly promoted the employment of creative and interactive industries such as IT, commerce and so on.

2.3 Government-dominated and technological development in HSR industry

China's HSR industry has undergone three stages of development and now has realized independent R&D of the whole industry chain (Ma & Zhen, 2017; He et al., 2018). The first stage is the technology accumulation period of independent R&D and exploration, which is from 1990 to 2004. In this stage, the former State Science and Technology Commission and the former Ministry of Railways launched more than 200 HSR technology-related projects and gathered the universities (such as Southwest Jiaotong University) and research institutes (such as Zhuzhou Institute, Qishuyan Institute) to make technological breakthroughs. At the same time, the China's railway industry achieved the accumulation of HSR technology and professionals in the early stage through some experimental projects, such as reconstructing new HSR and some experimental HSR locomotives. At this stage, the development of HSR technology formed a joint system of "government industry, university and research cooperation" (GIUR), which is still in the use in other industries today. The second stage is the introduction stage of technology oriented by independent innovation, which is from 2004 to 2009. At this stage, the former Ministry of Railways proposed to introduce, digest and absorb the latest scientific and technological achievements abroad, standing at a high starting point for independent innovation, to realize the leapfrog development of railway technology. The third stage started in 2009, which aimed to form the independent innovation capability of railway technology and to realize the whole industrial chain of railway technology catch-up and pioneer the world. National Ministry of Science and Technology and the Ministry of Railways have formulated the "Two Joint Action Plans", integrated the five sectors of science and technology innovation entities, including transportation service sector, investigation and design sector, equipment manufacturing and construction enterprises, communication signal system production and efficient and scientific research institutions, to promote independent intellectual property rights innovation in the HSR industry. Not only that, the railway industry has formed China’s own unified standard system, and most of the system components can be interchanged.

The GIUR system has gone through the three stages of China’s railway technology development. A large number of traditional theories argue that state-owned enterprises dominating the industry and long-term government’s strong intervention hinder independent innovation. However, China’s HSR industry has done well during the last decade, which is an abnormal phenomenon that occurs under certain conditions. Some studies have tried to explain this abnormal phenomenon. For example, Lin, Zhang and Hao (2017) use the "Innovative Triple Helix" theory to explain the collaboration of the government (the administrative chain in theory), the enterprise (the production chain in theory) and the scientific research institutions (the technology and science chain in theory) in the HSR technology innovation. Specifically, in the process of collaboration between the three major entities, the government carries out policy guidance, the university and other research institutions carry out basic research, the enterprises carry out the application of research outcomes, and integrating different entities into organizations for resource coordination. However, this article does not explain why the collaboration of the three major entities can be successful in the development of HSR in China while not successful in other economic development activities.

He et al. (2018) explains the abnormal phenomenon that the GIUR system has succeeded in China’s HSR development based on the characteristics of Chinese institution and the differences between China’s HSR industry and other industries. According to this study, the following characteristics enable the GIUR to promote innovation in China’s HSR development, and such successful experience cannot be repeated in other industries or countries.

Firstly, China’s HSR industry has stable innovation entities, which makes these entities have the capability to carry out specialized research and development. These innovative entities come from within the railway system, including the very early major players of the railway sector and new foreign enterprises, universities, and research institutes after the "Two Joint Action Plans" between the Ministry of Science and Technology and the former Ministry of Railways in 2008. The scientific research entities within this part of the railway system have remained stable for a long time. They have good expectations for railway construction, so they are willing to expand investment in technology research and development.

Secondly, after market-oriented reform, the railway industry has built a railway research and development system with stable internal technology development entities and specialized vertical division of labor, supplemented by other market players. There are many unique incentive mechanisms within the system to promote independent research and development: (1) In order to maintain the legitimacy of their monopoly railway department, the former Ministry of Railways and China State Railway Group Co., Ltd(CR) always have a strong willingness to innovate independently, and the main leaders of the former Ministry of Railways have technical backgrounds and can fully understand the process and needs of R&D and provide specialized services; (2) the internal scientific research entities of the railway system are stable and the former Ministry of Railways and CR always monopolize the buyer whose needs can be directly transmitted to the scientific research subjects which strengthens the innovation incentives of these subjects; (3) market-oriented reforms combined with a highly specialized vertical division of labor system, are conducive to the entry of new subjects outside the railway system and improve the railway innovation system.

Thirdly, the railway industry has a stable innovational entity and three incentive mechanisms, which enable the relational supply chain system within the railway system to effectively convey government's (the former Ministry of Railways, etc.) requirements and aspirations for technological development.

Most of the existing literature have carried out analysis on the success of China's HSR technology development, especially the success of the GIUR system in the development of HSR. Most literature just explains the reasons for the success of China's HSR development from the perspective of the whole institution and few studies explore that whether China's HSR technology could continue to develop in the new technology development stage.

2.4 Conclusion

When discussing the role of HSR or transportation construction in urban development, the existing literature either discusses from the perspective of the impact of HSR development on urban internal structure or the perspective of the relative development of HSR to cities. Overall, the existing literature ignores the impact of HSR on the income gap in a city and it has not used proper measures to directly measure a city's creativity. While HSR is promoting the development of HSR cities, it also leads to the change of industrial structure and functional specialization in HSR cities, which have a great impact on the employment of labor in a city. A typical Chinese city includes urban (urban sector) and town (rural sector). The development of HSR improves the productivity and income in the urban sector and further encourages rural people to move into cities. Will this lead to a further decline in the rural sector? How to let the rural sector enjoy the benefits brought by the development of HSR while not impair the labor force there? These are the points that the policymakers should pay attention to. Also, few literature directly proves the occurrence of siphon effect between different cities or differentiates the impacts of siphon effect in the short term and in the long term.

With regard to the study of GIUR system in China, especially the research on the development of HSR technology, most of the studies explain the reasons for the success of China's HSR development from the perspective of the whole system but few studies focus on the possible improvement of China's HSR technology development from a micro perspective. Moreover, the current stage of the development of HSR, as well as the domestic and international economic and political environment are all different from the past. So, how should China's initial GIUR system could be adjusted under the new background? Few researches raised concerns on this topic.

Chapter 3 HSR and urban development

3.1 Introduction

The development of transportation technology has shaped urban forms. Since 2008, China has started to be connected to HSR network, which has largely promoted cities' development. HSR promotes productivity and economic growth by improving accessibility, using location advantage of the HSR cities (cities which are connected to the HSR network), promoting resource optimal allocation and enhancing spatial knowledge spillover among the HSR cities (Wang & Ni, 2016; Liu & Li, 2017). In the meantime, HSR stimulates the movements of resources from less developed cities (small cities, rural areas or less developed cities) to more developed cities, which enlarges economic growth gap among HSR cities (Dong & Zhu, 2016; Qin, 2017; Deng & Xu, 2019). Therefore, the relationship between HSR and cities' development can hardly be generalized. It is of great significance to understand the impacts of HSR on cities of different development levels.

This study aims to answer the following four research questions: (1) How does connecting to HSR network change the industrial structure of a city? (2) How does connecting to HSR network improve the creativity of the HSR cities? (3) Does connecting to HSR network affect a city's urban-rural income gap? (4) How do the above impacts vary across cities of different development levels, and what are the differences in cities with different endowments of location along the HSR lines?

I conduct the empirical research using the multi-period difference-in-difference method and descriptive statistics in this chapter. The empirical results **firstly** indicate that connecting to HSR network only significantly increases the proportion of the tertiary industry among the eastern cities. **Secondly**, connecting to HSR network promotes the creativity of the HSR cities (which is measured as the annually increase in number of registered patents in each city) in the primary and tertiary industries, and more developed cities and non-eastern cities benefit more. **Thirdly**, connecting to HSR network will only widen the urban-rural income gap in less developed regions. Robustness analysis is provided to eliminate the concerns on empirical design. In addition, I also quantitatively explore the heterogeneous impact of connecting to HSR network on major hub, minor node and non-node cities along the HSR line through descriptive statistics. The results are as follows. Firstly, connecting to HSR network has significantly improved the creativity of the tertiary industry of major hub cities. The better accessibility the major hub cities have (with more HSR lines passing through), the more significant improvement in creativity they benefit compared to minor node and non-node cities; secondly, connecting to HSR network will only expand the urban-rural income gap in minor node cities with underdeveloped economies, which is consistent with the empirical results above.

This study makes the following contributions. **Firstly**, the empirical research using multi-period difference-in-difference method directly demonstrates the impact of the siphon effect, in terms of the impacts of HSR on changing urban industrial structure and functional specialization. **Secondly**, it fills the current research gap of the impact of HSR on the urban-rural income gap in different regions. **Thirdly**, this study provides new understanding for the impacts of transportation across cities. Theoretically, the current literature predicts two sources of knowledge spillover caused by improved transportation. One is caused by agglomeration of industry and the other is caused by more frequent commutes (Fujita, Krugman & Venables, 1999; Desmet & Rossi-Hansberg, 2013; Dong & Zhu, 2016). The findings in this study imply the second one is the major source of knowledge spillover caused by the HSR in the short term. There is more substantial increase in patents in the tertiary industry compared to the secondary industry in all regions, but the industrial structure change associated with HSR can only be clearly observed in the eastern China. Because HSR has only been in China for more than ten years, though the occurrence of industrial agglomeration needs longer time, more frequent commutes through HSR can make it happen quickly in the short term. **Finally**, it increases the understanding for the heterogeneous impacts of HSR on different cities along the HSR lines.

The following structure of the chapter is as follows. The second part is the theoretical framework and research hypotheses. The third part summarizes the information on HSR stations and introduces the data and variable definitions. The fourth part is empirical research of the impacts of HSR on the urban industry structure, creativity and urban-rural income gap. The fifth part is the analysis of the heterogeneous impacts of HSR on different cities along the lines; The sixth part is the conclusion.

3.2 Theoretical framework

In the two-city endogenous model, the friction of labor movement and other factors across cities hinder the optimal resource allocation and knowledge spillover (Fujita el al. 1999). Connecting to HSR helps reduce the friction and promotes innovation and productivity of HSR cities. Despite this, endowments of different cities are heterogenous, which generates siphon effect. This section will draw three research hypotheses and one concern by reviewing the existing literature.

Hypothesis 1: Connecting to the HSR network raises a city's proportion of tertiary industry, and the effect is stronger in more developed cities.

Connecting to HSR network has significantly promoted the development of industries in HSR cities (Li et al., 2016; Li & Sun, 2017; Shao et al., 2017). Shao et al. (2017) find that connecting to HSR network with more frequent HSR service can more significantly promote the agglomeration of urban production service industries in the Yangtze River Delta region. Zhou et al. (2018) find that

HSR significantly increases the prices of lands for urban commercial service facilities and urban residential lands but lowers the prices of industrial lands, which implies that HSR promotes agglomeration of urban commercial services. The above studies have demonstrated that connecting to HSR network promotes the agglomeration of the tertiary industry and thus raises the proportion of the tertiary industry in a city's industrial structure. On the other hand, connecting to HSR network promotes the movement of economic factors such as labor (Desmet & Rossi-Hansberg, 2013; Dong & Zhu, 2016) and information (Huang et al., 2016; Long et al., 2017; Yang et al., 2019; Long et al., 2019) between cities, which facilitates knowledge dissemination and spillover, and these impacts are especially beneficial for the development of the tertiary industry.

Many studies have studied the siphon effect and they focus on the heterogeneity of the impacts of HSR on cities of different scales or economic development stages (Zhang & Tao, 2016; Qin, 2017; Wang & Duan, 2018). For the large and medium-sized cities, the HSR enlarges their market potential (Qin, 2017). The population, resources and other factors of the non-regional centers along the HSR will be more inclined to shift to node cities with higher levels of economic development, which makes the agglomeration effect of the tertiary industry in the node cities more significant.

Hypothesis 2: Connecting to HSR promotes the creativity of the HSR cities.

The improvement of urban industrial agglomeration and inter-city economic collaboration further promote urban industrial specialization and functional specialization as well as productivity (Duranton & Puga, 2000, 2005; Davis & Henderson, 2008; Su & Zhao, 2011; Zheng and Kahn, 2013; Lin, 2017). Zheng and Kahn (2013) believe that connecting to HSR network will accelerate the division of labors in industrial chain in a city, enabling companies to relocate their headquarters and marketing departments in large and central city with higher land rents, and to place production departments in surrounding small cities with lower land prices, which further promotes functional specialization and productivity (Su & Zhao, 2011). Lin (2017) explores the impact of connecting to HSR network on urban specialization. It is found that the higher market accessibility created by HSR has significantly increased the employment in creative and interactive industries such as IT and commerce in HSR cities, which has also greatly increased the proportion of labor force with related professional skills.

The improvement of urban functional specialization and productivity is largely caused by the optimal allocation of economic factors such as labor and capital among cities. The large-scale constructions of HSR with huge investments and the acceleration of the speed of China's traditional railways have facilitated the movement of factors such as labor (Desmet & Rossi-Hansberg, 2013; Dong & Zhu, 2016), information (Huang et al., 2016; Yang, et al. 2019; Long, et al, 2019) and capital, which further improves enterprises' productivity (Forslid & Okubo, 2014; Behrens et al., 2014; Zhang et al., 2018) and urban labor productivity (Florida et al., 2008; Forslid & Okubo, 2014; Behrens et al., 2014; Fu & Gabriel, 2012).

Although HSR will accelerate the movement of economic factors between regions and cities, it has uneven impacts on the development of different cities. Preston and Wall (2008) and Hall (2009) find that when connecting to HSR network, resources of the smaller cities along the way are transferred to the central node cities. This results in a higher agglomeration of professional talents in the central node cities with better endowments of economy, and these cities are more likely to attract the high-skilled workers from the small and medium-sized cities along the HSR network, so as to better improve the professional level of the cities' internal functions as well as their creativity.

Concern: Connecting to HSR will expand urban-rural income gap.

HSR promotes economic growth of the HSR cities by improving their location advantages and accessibility, and ultimately enhances spatial spillover effect (Wang & Ni, 2016; Liu & Li, 2017). Therefore, HSR can promote income growth of the urban and rural areas of a city, but whether it will narrow the urban-rural income gap depends on the relative intensity of the impact of HSR on urban and rural areas in a city. It is a concern that the economic development brought by the HSR will widen the rural-urban income gap because higher productivity in the urban area will draw labors from the rural area, which will worsen the productivity in rural areas.

Hypothesis 3: Compared with minor nodes or non-nodes cities, HSR improves the creativity of major hub cities more significantly, and the better accessibility they have (with more HSR lines passing through), the more significant improvement in urban creativity they benefit; and the same as previous concern, connecting to HSR network may widen the urban-rural income gap of those minor nodes with underdeveloped economy.

The previous literature shows that the impact of HSR on urban creativity is mainly achieved by promoting the functional specialization of urban areas and accelerating the movement of labor, information, capital and other factors, while this influence mechanism essentially benefits from the rapid intercity rail transit such as HSR, which greatly improves the accessibility of inter-city traffic. As we all know, major hub cities often have more HSR lines passing by, that is, they enjoy better accessibility compared to other cities, so the impact brought by HSR will be more significant, and the improvement of urban creativity will be more obvious. In addition, as concerned about before, less developed minor nodes have weaker capability to balance urban and rural development, resulting that the rural areas in these cities cannot enjoy the benefit brought by connecting to HSR network, which is even negative for their development. Therefore, the development of the rural sector is likely to lag behind urban after connecting to

HSR network or even cause the decline of these rural areas.

3.3 Data and variable

Using data disclosed by the Ministry of Railways and city-level data from *China City Statistical Yearbook*, this study constructs a panel data with 248[1] prefecture-level cities during the period between 2007 to 2016, and the definitions of the variables are listed in Table 1. The HSR stations refer to the stations where there are trains whose numbers start with G-, C- or D- passing by. The time when a railway station (no matter it is an existing one or a newly constructed one) starts to operate HSR is taken as the time when the HSR station is put into operation in a city. Table 2 summarizes the time when the cities' HSR stations are put into operation. Cities with HSR stations opened in the earlier years are mostly in the eastern region. For cities of different regions in China, the different times they connect to HSR network reflect the imbalance in regional development. In addition, using China Patent Database, I calculate the numbers of invention patents registered annually in each city to measure the creativity of each industry in a city.

[1] There are 287 prefecture-level cities in the "China City Statistical Yearbook", but we remove some cities due to their very poor data quality.

Table 1 Variables and definitions

Variables	Definitions
IndStr	The urban industrial structure is defined as the ratio of the output value of tertiary industry in a city to the output value of secondary industry in the same city.
URIncGap	The urban-rural income gap is defined as the ratio of the actual disposable income per capita of residents in the urban area to the actual income per capita of rural residents.
Ln(Pri_Patents)	The natural logarithm of number of invention patents classified in the primary industry registered in each city year.
Ln(Sec_Patents)	The natural logarithm of number of invention patents classified in the secondary industry registered in each city year.
Ln(Ter_Patents)	The natural logarithm of number of invention patents classified in the tertiary industry registered in each city year.
Dev	GDP Per capita in the urban area of a city.
HDL	A dummy variable, if the development level (Dev) of a city in 2005 is higher than or equal to the median of the development level across all cities, HDL=1, otherwise HDL=0.
WagePC	It is the average wage of employed persons, in RMB.
FiscalPC	It is defined as the fiscal expenditure per capita in a particular city, in 10,000 RMB.
RatioSciEdu	Proportion of science and education expenditure in total fiscal expenditure in a city year.
DoctorPC	Number of medical doctors per capita in a city year.
YouthRate	It is defined as the proportion of primary and secondary school students in total population of a city in each year.
Reg	All cities are divided into eastern and non-eastern cities. The eastern region includes cities in Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong and Hainan; cities in other provinces are grouped into non-eastern cities.
HSRyear	Cities with HSR stations put into operation in the particular year. It is a vector of dummy variables, year=[2008, 2009,...,2016]. For example, if a city has at least one HSR station put into operation in 2008, HSR2008=1, otherwise HSR2008=0.
OPEyear	Years when a HSR station is put into operation. It is a vector of dummy variables, year=[2008,2009,...,2016]. For example, OPE2008=1 indicates a year of or after 2008, and OPE2008=0 indicates a year before 2008.

Table 2 The proportion of HSR stations opened in each year across the three regions

	All		Opened in 2008		Opened in 2009		Opened in 2010		Opened in 2011		Opened in 2012	
	Number of cities	Proportion (%)	Number of cities	Proportion (%)	Number of cities	Proportion (%)	Number of cities	Proportion (%)	Number of cities	Proportion (%)	Number of cities	Proportion (%)
East	98	34.88	9	75.00	10	34.48	9	50.00	9	75.00	13	50.00
Central	99	35.23	2	16.67	13	44.83	7	38.89	2	16.67	13	50.00
West	84	29.89	1	8.33	6	20.69	2	11.11	1	8.33		
ALL	281		12		29		18		12		26	

	Opened in 2013		Opened in 2014		Opened in 2015		Opened in 2016		Opened in 2017 and beyond		No recent opening plan	
	Number of cities	Proportion (%)	Number of cities	Proportion (%)	Number of cities	Proportion (%)	Number of cities	Proportion (%)	Number of cities	Proportion (%)	Number of cities	Proportion (%)
East	10	45.45	6	17.14	4	20.00	3	27.27	6	54.55	19	22.35
Central	4	18.18	14	40.00	11	55.00	1	9.09	2	18.181	30	35.29
West	8	36.36	15	42.86	5	25.00	7	63.64	3	27.27	36	42.35
All	22		35		20		11		11		85	

Data source: I collect and summarize the data disclosed by the Ministry of Railways.

3.4 Empirical analysis of the impact of HSR on industrial structure, creativity, and urban-rural income gap

In Section 3.4, I develop a multi-period difference-in-difference model to estimate the impacts of HSR on city development. The first part aims to estimate the heterogeneous impacts of HSR on industrial structure of cities with different development levels (measured by Dev); the second part aims to estimate the heterogeneous impacts of HSR on creativity of cities with different development levels; and the third part is to estimate the heterogeneous impacts of HSR on urban-rural income gaps in cities with different development levels.

3.4.1 Empirical design

(1) Estimating impacts of HSR on urban industrial structure

As HSR stations in different cities are opened in different years, this study uses multi-period difference-in-difference model to estimate the impacts of opening HSR stations (i.e., connecting to the HSR network) on changing the industrial structure of a city. The empirical model is set up as in Model-1.

$$IndStr_{it} = \alpha + \boldsymbol{\theta} * \boldsymbol{HSRyear_i} * \boldsymbol{OPEyear_t} + \boldsymbol{\rho X_{it}} + \boldsymbol{\gamma_t} + \boldsymbol{\mu_i} + \varepsilon_{it}$$

（Formula-1）

$IndStr_{it}$ is the industrial structure of city i in year t. $\boldsymbol{HSRyear_i}$ is a vector of dummy variables including $HSR2008_i$, $HSR2009_i$, $HSR2010_i \ldots HSR2015_i$, indicating whether a city has a HSR station and the station is put into operation in the particular year. $\boldsymbol{OPEyear_t}$ is a vector of year when a HSR station is put into operation. $\boldsymbol{X}$ is a vector of control variables. $\boldsymbol{\gamma_t}$ represents the year fixed effect, $\boldsymbol{\mu_i}$ represents the city fixed effect, ε_{it} is the residual. α is the constant term, $\boldsymbol{\theta}$ is a vector of coefficients measuring the impact of connecting to HSR network on the city's industrial structure in a city since a particular year.

In this model, our control variables only include the per capita financial expenditure of the government ($FiscalPC$), reflecting the amount of basic public service expenditure, financial pension and social welfare assistance expenditure and social security subsidy expenditure of the city government. Local financial expenditure plays a decisive role in the industrial structure of the city. On the one hand, the financial expenditure will improve the production efficiency of the primary industry and reduce the labor demand of the primary industry, so as to shift the labor force to the secondary and tertiary industries (Yan & Gong, 2014). On the other hand, the improvement of the financial expenditure efficiency will increase the residents' income, increase residents' demand for non-agricultural products, so as to promote the upgrading of the industrial structure (Zhang et al., 2017). I also control the proportion of fiscal expenditure on science and education ($RatioSciEdu$) and monthly wage per capita ($WagePC$), to control the fundamental factors of a city.

I use the complete sample to estimate model-1 for 5 times, and use 4 sub samples of cities with different development levels and from different regions.

The sub samples include samples of high Dev cities ($HDL = 1$), samples of low Dev cities ($HDL = 0$), samples of eastern cities ($regions = eastern$), and samples of non-eastern cities ($regions = non - eastern$).

(2) Estimating impacts of HSR on urban creativity

This part discusses the heterogeneous influence of HSR development on creativity of HSR cities. Multi-period difference-in-difference model is set up to measure the impacts of HSR (i.e., access to HSR network) on the specialization of urban functions. The empirical model is specified in Model 2.

$$Ln(Patents)_{it}^{k} = \alpha + \boldsymbol{\theta} * \boldsymbol{HSRyear_i} * \boldsymbol{OPEyear_t} + \boldsymbol{\rho X_{it}} + \boldsymbol{\gamma_t} + \boldsymbol{\mu_i} + \varepsilon_{it} \quad \text{(Formula-2)}$$

$Ln(Patents)_{it}^{k}$ represents the natural logarithm of numbers of patents in industry k of city i in year t. $k = Pri, Sec\ and\ Ter$ represents the primary industry, secondary industry and tertiary industry. The definition of other variables is consistent with those in Model-1. In addition to the control variables used in Model-1, I also include industrial structure (IndStr), number of doctors per capita ($DoctorPC$) and the proportion of the youth in total population of a city ($YouthRate$).

For each of the three industries, I estimate Model-2 using full sample, and 4 sub samples of cities of different development levels and from different regions, respectively. The sub samples include samples of high Dev cities ($HDL = 1$), samples of low Dev cities ($HDL = 0$), samples of eastern cities

($regions = eastern$), and samples of non-eastern cities ($regions = non-eastern$).

(3) Estimating impacts of HSR on urban-rural income gap

This part discusses the impacts of HSR on the urban-rural income gap of a city. I also set up a multi-period difference-in-difference model which is specified in Model 3.

$$URIncGap_{it} = \alpha + \boldsymbol{\theta} * \boldsymbol{HSRyear_i} * \boldsymbol{OPEyear_t} + \boldsymbol{\rho X_{it}} + \boldsymbol{\gamma_t} + \boldsymbol{\mu_i} + \varepsilon_{it} \quad \text{(Formula-3)}$$

$URIncGap_{it}$ represents the income gap between urban and rural areas of city i in year t. The setting of other variables is consistent with the variables in Model-1, but the model introduces the city industrial structure ($IndStr$) and ratio of fiscal expenditure on science and education ($RatioSciEdu$) as control variables. I estimate Model-3 using full sample, and 4 sub samples of cities of different development levels and regions, respectively. The sub samples include samples of high Dev cities (HDL=1), samples of low Dev cities (HDL=0), samples of eastern cities (regions=eastern), and samples of non-eastern cities (regions=non-eastern).

3.4.2 Empirical results

This section discusses the empirical results and provides the robustness tests.

(1) Results for impacts of HSR on urban industrial structure

Table 3 reports the results of Model-1 about the impacts of HSR on the industrial structure of cities connected to HSR network. The samples include all cities, relatively less economically developed cities, relatively more economically developed cities, eastern cities and non-eastern cities. The results are in accordance with expectation, R^2 ranges between 0.193 and 0.36, indicating that the explanatory power of the model is acceptable.

Column (1) gives the results of all cities samples. The coefficient of "$HSR2013 * OPE2013$" is -0.232, and its significance level is 1%, which shows that the ratio of tertiary industry to secondary industry in cities whose HSR stations opened in 2013 was reduced by 0.232 due to the connection to HSR network. The coefficient of "$HSR2014 * OPE2014$" is 0.134, and its significance level is 1%, which shows that the ratio of tertiary industry to secondary industry in cities with HSR stations opened in 2014 was increased by 0.134 due to the connection to HSR network. The coefficients of the rest of $\boldsymbol{HSRyear_i * OPEyear_t}$ are not significant. Overall, connecting to HSR network does not significantly raise the proportion of the tertiary industry. This finding is quite different from what have been predicted from the literature. This is probably caused by the fact that the observation period is too short to see the changes in industrial structure of all the cities, but later we will see immediate increase in creativity of the cities.

Column (2) and (3) present the results for sub samples of relatively economically less economically developed cities and relatively more economically developed cities, respectively. We can see that most of the coefficients of "$\boldsymbol{HSR}\mathbf{year} * \boldsymbol{OPE}\mathbf{year}$" for two samples are either insignificant or inconsistent. Therefore, I neither observe clear evidence of industrial structure change nor see any siphon effect in the two sub samples.

Column (4) and (5) present the results for sub samples of eastern cities and non-eastern cities, respectively. In Column (4), the coefficients of " $HSR2008 * OPE2008$ ", " $HSR2010 * OPE2010$ ", " $HSR2012 * OPE2012$ ", " $HSR2015 * OPE2015$" are 0.162, 0.105, 0.0777 and 0.369, respectively. They are positive and significant at 5% or 1% level, indicating that the ratio of tertiary industry to secondary industry in the eastern cities with HSR stations opened in 2008, 2010, 2012 and 2015 are substantially increased due to the connection to HSR network, despite that we observe the industrial structure in cities with HSR stations opened in 2013 is substantially reduced. By comparing the results of the eastern cities (Column 4) and results of the non-eastern cities (Column 5), we observe substantial siphon effect which is demonstrated by the negative or insignificant coefficients of "$\boldsymbol{HSR}\mathbf{year} * \boldsymbol{OPE}\mathbf{year}$" for the non-eastern cities.

The results in Table 3 show that connecting to HSR only raises the ratio of tertiary industry to the secondary industry among the eastern cities. This finding has several implications. Firstly, the change of industrial structure takes time, the observation period is too short to observe substantial industrial structure change caused by HSR across the country. Secondly, siphon effect also takes time and it happens easier within a certain region. The results observed for the eastern cities are the results of both the direct impacts of the HSR as well as the siphon effect.

Table 3 Impacts of HSR on industrial structure of different HSR cities

	(1)	(2)	(3)	(4)	(5)
Dependent Variable: IndStr					
	All Cities	Less Developed Cities	More Develope d Cities	Eastern Cities	Non-Eastern Cities
HSR2008*OPE2008	0.0688	-0.247	0.0927*	0.162***	-0.284**
	(0.061)	(0.166)	(0.049)	(0.051)	(0.126)
HSR2009*OPE2009	-0.054	-0.139**	-0.00022	-0.0157	-0.0746
	(0.034)	(0.059)	(0.033)	(0.040)	(0.046)
HSR2010*OPE2010	0.0382	0.0291	-0.00426	0.105***	-0.0563
	(0.040)	(0.133)	(0.031)	(0.040)	(0.062)
HSR2011*OPE2011	-0.0156	-0.00237	-0.0466	0.0129	-0.0703
	(0.048)	(0.109)	(0.041)	(0.039)	(0.123)
HSR2012*OPE2012	0.0115	0.0222	-0.0216	0.0777**	-0.0326
	(0.034)	(0.064)	(0.032)	(0.035)	(0.053)
HSR2013*OPE2013	-0.232***	-0.300***	-0.206***	-0.154***	-0.287***
	(0.040)	(0.074)	(0.037)	(0.040)	(0.061)
HSR2014*OPE2014	0.134***	0.192***	0.0525	-0.0486	0.155***
	(0.038)	(0.061)	(0.040)	(0.061)	(0.047)
HSR2015*OPE2015	-0.0719	-0.151	0.0583	0.396***	-0.149*
	(0.064)	(0.097)	(0.075)	(0.126)	(0.077)
Observations	2,437	1,204	1,225	836	1,601
R-squared	0.213	0.193	0.36	0.337	0.221
Number of cities	249	123	125	86	163

Note: Fixed effect model, standard deviations of the coefficients are clustered at city level, and are provided in the parenthesis; IndStr, WagePC, FiscalPC, RatioSciEdu, DoctorPC, YouthRate, Year Fixed Effect, City Fixed Effect are control variables whose results are not reported in this table, detailed results is available upon request; *** p<0.01, ** p<0.05, * p<0.1.

(2) Results for impacts of HSR on creativity

Table 4, Table 5 and Table 6 report the results of Model-2 about the impacts of connecting to HSR network on creativity of a city in terms of its primary industry, secondary industry and tertiary industry, respectively.

Column (1) to (5) of Table 4 present the impacts of HSR on creativity of the primary industry for all cities samples, relatively less economically developed cities, relatively more economically developed cities, eastern cities and non-eastern cities, respectively. The results are in accordance with expectation, R^2 ranges between 0.601 and 0.803, indicating that the explanatory power of the model is acceptable.

Column (1) of Table 4 gives the results of all cities samples. The coefficients of "$HSR2008 * OPE2008$" and "$HSR2011 * OPE2011$" are 0.381 and 0.323, and are significant at 5% level and 10% level, respectively. The results indicate that the number of patents registered in cities with HSR stations which are opened in 2008 and in 2011 are increased by 38.1% and 32.3% due to the connection to the HSR network. The coefficients for the rest of "$\boldsymbol{HSR}\textbf{year} * \boldsymbol{OPE}\textbf{year}$" are insignificant. Across the five sub samples, we observe consistent results that connecting to HSR network raises the creativity of the primary industry of HSR cities as a whole.

Table 5 presents the impacts of HSR on creativity of the secondary industry for all cities samples, relatively less economically developed cities, relatively more economically developed cities, eastern cities and non-eastern cities, respectively. The results are in accordance with expectation, R^2 ranges between 0.735 and 0.837, indicating that the explanatory power of the model is acceptable.

The results show that connecting to HSR network does not raise the creativity of the secondary industry. In Column (1) for all cities, the coefficients for "$\boldsymbol{HSR}\mathbf{year} * \boldsymbol{OPE}\mathbf{year}$" are not significant except "$HSR2012 * OPE2012$" which is -0.265 and significant at 1% level. The result indicates that connecting to HSR network reduces the creativity (measured by number of patents registered) of the secondary industry of cities with HSR stations opened in 2012 by 26%. The coefficients of "$\boldsymbol{HSR}\mathbf{year} * \boldsymbol{OPE}\mathbf{year}$" for other sub samples are either inconsistent or insignificant.

Table 6 presents the impacts of HSR on creativity of the tertiary industry for all cities samples, relatively less economically developed cities, relatively more economically developed cities, eastern cities and non-eastern cities, respectively. The results are in accordance with expectation, R^2 ranges between 0.322 and 0.661, indicating that the explanatory power of the model is acceptable.

The results show that connecting to HSR network raises the creativity of the tertiary industry. In Column (1) for the sample of all cities, the coefficients of "$HSR2008 * OPE2008$", "$HSR2010 * OPE2010$", "$HSR2012 * OPE2012$" and "$HSR2013 * OPE2013$" are 0.794 significant at 1% level, 0.324 significant at 10% level, 0.315 significant at 5% level and 0.384 at 5% significance level, which show that the number of patents in tertiary industry of cities with HSR stations opened in 2008, 2010, 2012 and 2013 are boosted by

79.4%, 32.4%, 31.5% and 38.4%. Despite that the coefficient for " $HSR2013 * OPE2013$" is significantly negative and those for "$HSR2009 * OPE2009$", "$HSR2011 * OPE2011$", are insignificant, I can say that overall, connecting to HSR raises the creativity of the tertiary industry of the HSR cities.

By comparing the results of Column (2) and Column (3), we can see that creativity of the tertiary industry in the relatively more economically developed cities and relatively less economically developed cities benefit from the HSR. By comparing the results of Column (4) and Column (5), the tertiary industry of the non-eastern cities benefits more from the HSR compared to the eastern cities, which is probably due to that the creativity of the non-eastern cities were initially low and thus have more potential to improve.

Overall, the results show that connecting to HSR does not raise creativity of the secondary industry of the HSR cities, but slightly raises the creativity of the primary industry. Moreover, connecting to HSR network substantially raises the creativity of the tertiary industry, and the non-eastern cities benefit more.

(3) Results for impacts of HSR on urban-rural income gap

Table 7 reports the results of Model-3 of the impacts of HSR on the urban-rural income gap. The samples include all cities, relatively less economically developed cities and relatively more economically developed cities, eastern cities and non-eastern cities. The results are in line with expectations, R^2 ranges between 0.318 and 0.474, which indicates that the explanation power of the model is acceptable.

The results indicate that connecting to HSR only raises the urban-rural income gap of the less developed cities. The coefficients of "$\boldsymbol{HSR}\mathbf{year} * \boldsymbol{OPE}\mathbf{year}$" for all cities (Column 1), the more developed cities (Column 3), the eastern cities (Column 4) and the non-eastern cities (Column 5) are either inconsistent or insignificant, but those for the less developed cities are positive and significant (Column 2). For Column 2, the coefficients of "$HSR2009 * OPE2009$", "$HSR2012 * OPE2012$" and "$HSR2015 * OPE2015$" are 0.109, 0.125 and 0.216, respectively, and all are significant at 5% level. The coefficients of the rest of "$\boldsymbol{HSR}\mathbf{year} * \boldsymbol{OPE}\mathbf{year}$" are not significant. The results show that connecting to HSR in recent years has raised the urban-rural income gap of the relatively less developed cities. One possible explanation to why HSR raises the urban-rural income gap of the less developed cities can be that the less developed cities have less capability to balance the development of urban and rural areas.

Table 4 Impacts of HSR on creativity of primary industry in different HSR cities

	(1)	(2)	(3)	(4)	(5)
Dependent Variable: Ln(Pri_Patents)					
	All Cities	Less Developed Cities	More Developed Cities	Eastern Cities	Non-Eastern Cities
HSR2008*OPE2008	0.381**	0.418***	0.384**	0.293	0.669**
	(0.156)	(0.141)	(0.173)	(0.189)	(0.278)
HSR2009*OPE2009	0.138	0.0525	0.188	0.425***	0.0642
	(0.193)	(0.341)	(0.202)	(0.155)	(0.266)
HSR2010*OPE2010	0.0261	-0.380***	0.127	0.575**	-0.219
	(0.172)	(0.122)	(0.220)	(0.272)	(0.159)
HSR2011*OPE2011	0.323*	0.841***	0.189	0.312	0.843*
	(0.192)	(0.286)	(0.234)	(0.194)	(0.461)
HSR2012*OPE2012	-0.132	-0.154	-0.117	0.0754	-0.335
	(0.157)	(0.198)	(0.240)	(0.191)	(0.210)
HSR2013*OPE2013	0.226	0.299	0.176	-0.0785	0.432
	(0.205)	(0.281)	(0.257)	(0.130)	(0.327)
HSR2014*OPE2014	0.0444	0.198	-0.281	-0.169*	0.0912
	(0.247)	(0.367)	(0.225)	(0.102)	(0.297)
Observations	1,158	591	564	367	791
R-squared	0.646	0.605	0.709	0.803	0.601
Number of cities	245	120	124	86	159

Note: Fixed effect model, standard deviations of the coefficients are clustered at city level, and are provided in the parenthesis; IndStr, WagePC, FiscalPC, RatioSciEdu, DoctorPC, YouthRate, Year Fixed Effect, City Fixed Effect are control variables whose results are not reported in this table, detailed results is available upon request; *** p<0.01, ** p<0.05, * p<0.1.

Table 5 Impacts of HSR on creativity of secondary industry in different HSR cities

	(1)	(2)	(3)	(4)	(5)
Dependent Variable: Ln(Sec_Patents)					
	All Cities	Less Developed Cities	More Developed Cities	Eastern Cities	Non-Eastern Cities
HSR2008*OPE2008	0.202	0.776**	0.0491	-0.043	0.740***
	(0.151)	(0.385)	(0.116)	(0.098)	(0.256)
HSR2009*OPE2009	0.000203	0.0901	-0.0607	0.148	-0.0727
	(0.077)	(0.123)	(0.080)	(0.113)	(0.096)
HSR2010*OPE2010	-0.083	-0.289	0.00209	0.161	-0.344***
	(0.098)	(0.176)	(0.114)	(0.134)	(0.103)
HSR2011*OPE2011	-0.207	0.207	-0.297*	-0.202	0.542
	(0.186)	(0.385)	(0.155)	(0.142)	(0.373)
HSR2012*OPE2012	-0.265***	-0.323*	-0.149	-0.088	-0.324**
	(0.098)	(0.179)	(0.102)	(0.104)	(0.153)
HSR2013*OPE2013	0.0742	-0.204	0.289	-0.0824	0.333
	(0.170)	(0.301)	(0.188)	(0.163)	(0.257)
HSR2014*OPE2014	0.0779	0.0577	-0.0154	-0.118	0.119
	(0.128)	(0.204)	(0.110)	(0.113)	(0.155)
Observations	2,171	1,060	1,104	757	1,414
R-squared	0.753	0.735	0.806	0.837	0.742
Number of cities	246	120	125	86	160

Note: Fixed effect model, standard deviations of the coefficients are clustered at city level, and are provided in the parenthesis; IndStr, WagePC, FiscalPC, RatioSciEdu, DoctorPC, YouthRate, Year Fixed Effect, City Fixed Effect are control variables whose results are not reported in this table, detailed results is available upon request; *** p<0.01, ** p<0.05, * p<0.1.

Table 6 Impacts of HSR on creativity of tertiary industry in different HSR cities

	(1)	(2)	(3)	(4)	(5)
Dependent Variable: Ln(Ter_Patents)					
	All Cities	Less Developed Cities	More Developed Cities	Eastern Cities	Non-Eastern Cities
HSR2008*OPE2008	0.794***	1.215***	0.575***	0.590***	0.918***
	(0.156)	(0.235)	(0.160)	(0.203)	(0.159)
HSR2009*OPE2009	0.0274	0.0111	0.0151	-0.0613	0.0681
	(0.146)	(0.183)	(0.186)	(0.252)	(0.151)
HSR2010*OPE2010	0.324*	-0.399	0.229	0.334*	0.197
	(0.167)	(0.529)	(0.141)	(0.174)	(0.277)
HSR2011*OPE2011	-0.0719	0.26	-0.257	-0.175	0.550***
	(0.174)	(0.324)	(0.191)	(0.190)	(0.073)
HSR2012*OPE2012	0.315**	0.376	0.251*	0.205	0.490*
	(0.149)	(0.305)	(0.142)	(0.139)	(0.272)
HSR2013*OPE2013	0.384**	0.107	0.414**	-0.0115	0.720**
	(0.177)	(0.291)	(0.194)	(0.183)	(0.283)
HSR2014*OPE2014	-0.314*	-0.438*	-0.241	-0.614	-0.194
	(0.174)	(0.248)	(0.256)	(0.417)	(0.186)
Observations	1,579	643	932	667	912
R-squared	0.508	0.322	0.661	0.618	0.46
Number of cities	242	117	124	86	156

Note: Fixed effect model, standard deviations of the coefficients are clustered at city level, and are provided in the parenthesis; IndStr, WagePC, FiscalPC, RatioSciEdu, DoctorPC, YouthRate, Year Fixed Effect, City Fixed Effect are control variables whose results are not reported in this table, detailed results is available upon request; *** p<0.01, ** p<0.05, * p<0.1.

Table 7 Impacts of HSR on urban-rural income gaps of HSR cities in different regions

	(1)	(2)	(3)	(4)	(5)
Dependent Variable: URIncGap					
	All Cities	Less Develope d Cities	More Develope d Cities	Eastern Cities	Non-Eastern Cities
HSR2008*OPE2008	0.0655**	-0.0464	0.0765**	0.0781**	-0.0341
	(0.031)	(0.030)	(0.034)	(0.034)	(0.023)
HSR2009*OPE2009	-0.0326	0.109**	-0.153*	-0.143*	0.0217
	(0.054)	(0.051)	(0.080)	(0.077)	(0.070)
HSR2010*OPE2010	0.0626*	-0.043	0.0750**	0.0913***	0.0324
	(0.033)	(0.047)	(0.037)	(0.029)	(0.043)
HSR2011*OPE2011	0.0248	-0.187	0.118***	0.0186	-0.252
	(0.066)	(0.145)	(0.043)	(0.039)	(0.159)
HSR2012*OPE2012	0.172**	0.125***	0.223*	0.178	0.108***
	(0.068)	(0.045)	(0.117)	(0.125)	(0.033)
HSR2013*OPE2013	-0.178***	-0.127	-0.231***	-0.388***	-0.0528
	(0.058)	(0.083)	(0.083)	(0.104)	(0.058)
HSR2014*OPE2014	-0.107***	-0.0571	-0.164***	-0.224**	-0.0673*
	(0.037)	(0.051)	(0.051)	(0.088)	(0.040)
HSR2015*OPE2015	0.000434	0.216**	-0.38	0.309***	-0.157
	(0.205)	(0.097)	(0.502)	(0.095)	(0.248)
Observations	1,951	977	969	662	1,289
R-squared	0.402	0.452	0.399	0.318	0.474
Number of cities	248	123	124	85	163

Note: Fixed effect model, standard deviations of the coefficients are clustered at city level, and are provided in the parenthesis; IndStr, WagePC, FiscalPC, RatioSciEdu, DoctorPC, YouthRate, Year Fixed Effect, City Fixed Effec are control variables whose results are not reported in this table, detailed results is available upon request; *** p<0.01, ** p<0.05, * p<0.1.

(4) Robustness tests[1]

The robustness analysis includes two parts. In order to exclude alternative explanations for the raised creativity of the HSR cities, I carry on the placebo tests in the first part by adopting alternative measures of the creativity for the cities. In the placebo tests, I adopt another type of patent that is utility model patent, which are easier to be registered and whose property right is protected by law for only 10 years. As a result, the utility model patents are often abused by people who need to register some patents to enrich their resumes.

As expected, the results are inconsistent, and we cannot see systematically improvement in registered number of utility model patent of HSR cities due to the connection to HSR network.

In the second part, in order to eliminate some of the differences in estimation results between the treatment and control groups due to unobservable factors, e.g., some observable factors in a city cause the city's creativity to increase faster or its industrial structure to change faster. I adopt a propensity score matching difference-in-difference (PSM-DID) method to make the treatment group and control group comparable. So, I develop Model-4 to re-estimate the impacts of connecting to HSR network on industrial structure change, creativity of the three industries and urban-rural income gaps.

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[1] The detailed results and content for robustness tests are available upon request.

$$A_{it} = \alpha + \theta * HSRyear_i * OPEyear_t + \boldsymbol{\rho X_{it}} + \boldsymbol{\gamma_t} + \boldsymbol{\mu_i} + \varepsilon_{it}$$

（Formula-4）

Different from the previous models which are multi-period DID models, Model-4 is single period DID model with propensity score matching (PSM-DID). I also find the consistent results[1]. Overall, it can be concluded that connecting to HSR network does not systematically raise the proportion of the tertiary industry or expand the rural income gaps but raises the creativity of the primary industry and tertiary industry of the HSR cities.

[1] The detailed results and content for robustness tests are available upon request.

3.5 Research on the locational heterogenous impacts of HSR on cities along the HSR lines

In the above, the multi-period difference-in-difference method is used to estimate the heterogeneous impact of connecting to HSR network on the industrial structure, urban creativity, and urban-rural income gap in the sample groups of eastern and non-eastern cities, more developed cities and underdeveloped cities. In order to further explore the heterogenous impact of HSR on cities with different endowment of location along the HSR lines, the following mainly uses descriptive statistical method to quantitatively test whether there are significant differences in economic growth, industrial structure, urban creativity, or urban-rural income gap between cities with different endowment of location along the HSR lines before and after connecting to HSR network.

3.5.1 Research design

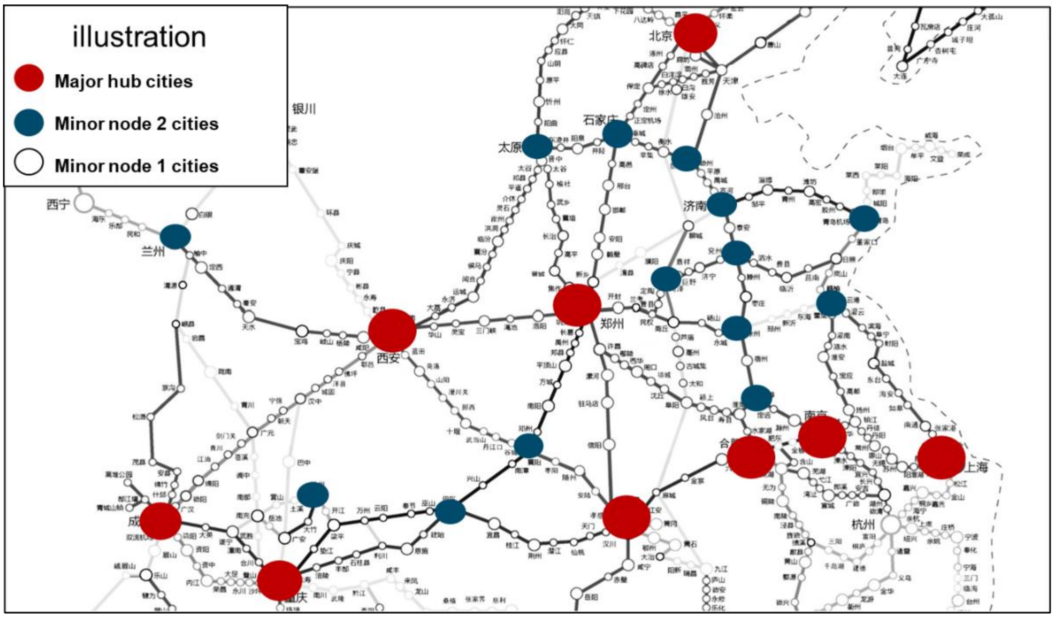
(1) Comparison of differences between major hub, minor node and non-node cities along the HSR lines.

Major hub cities are often the junction of multiple HSR lines and play a role of regional transportation hubs, so I take the cities with 3 or more HSR lines passing by as major hub cities, take the cities without HSR lines passing by or those with several passing line but whose opening time is later than the observation period of the experimental sample as non-node cites, and take the cities with 2 and 1 HSR lines passing by as minor nodes(named minor node2 city and minor node1 city in the experiment respectively). On the basis of the above grouping (shown in Figure 1), the HSR cities whose opening time between 2008-2010 and 2011-2013 are regarded as the two experimental group (shown in Table 8). Then I compare the differences of the growth rate change of the observed indicators before and after the median year of HSR operation in these cities of one group.

Table 8 Different groups of cities

Group	Trait	Group1		Group2	
		Obs	Open Time	Obs	Open Time
Major hub city	With 3 or over 3 HSR lines	14	2008-2010	0	2011-2013
Minor node2 city	With 2 HSR lines	20	2008-2010	15	2011-2013
Minor node1 city	With 2 HSR lines	21	2008-2010	39	2011-2013
Non-node city	no HSR lines in the sample period	88	No open /open year>2016	88	No open / open year>2016

Figure 1 Distribution of major hub, minor node and non-node cities (drawn by the author)



Note: The distribution of HSR lines and cities in this picture are intercepted from the China's HSR diagram http://crh.gaotie.cn. On this basis, I divide part of major hub cities and minor node cities by the number of HSR lines, draw the distribution diagram of major hub cities and minor node cities shown in the figure above, in order to help readers to understand the above-mentioned concept of major hub cities and minor node cities in terms of geography and space. The blank areas on the map are all regarded as non-node cities in the absolute sense, the cities marked in red are regarded as major hub cities, and the rest are minor node cities in the relative sense.

In order to explore the heterogenous impact of connecting to HSR network on different groups of cities, I adopt the T-test method to quantitatively verify whether the impact of the HSR on each sub-sample is significant. **Firstly**, I use the number of registered patents per unit of GDP($GDP\_PerPat_i, i = Pri, Sec, Ter$) to reflect the creativity of each city before and after connecting to HSR network, and calculate the difference between the arithmetic mean of the indicator before and after connecting to HSR network to reflect the impact of the HSR on the sample cities. Considering the sample interval and the validity of the data, I use the difference in the average number of registered patents per unit GDP between 3 years before and 3 years after operation to quantitatively reflect the changes in urban creativity. The calculation is as follows:

Experiment 1: $\Delta GDP\_PerPat_{ij} = \frac{\sum_{2010}^{2012}(GDP\_PerPat_{ij})_t}{3} - \frac{\sum_{2007}^{2009}(GDP\_PerPat_{ij})_t}{3}$ (Foluma-5)

Experiment 2: $\Delta GDP\_PerPat_{ij} = \frac{\sum_{2013}^{2015}(GDP\_PerPat_{ij})_t}{3} - \frac{\sum_{2010}^{2012}(GDP\_PerPat_{ij})_t}{3}$ (Foluma-6)

GDP_PerPat_{ij} represents the number of registered patents per unit GDP of a certain industry in a certain city, j represents the city, $i = Pri\_, Sec\_, Ter\_, t = 2007,2008, \dots ,2012$. For urban gross product (GDP), urban-rural income gap ($URIncGap$), and urban industrial structure ($IndStr$), I adopt the geometric mean of the growth rate to reflect the impact of connecting to HSR network on the sample, and the ratio of the average growth rate before and after operation is used to reflect the growth rate change before and after operation. The calculation formula is as follows:

Experiment 1: $\Delta\gamma_{ij}\_growth = \sqrt[3]{\prod_{2010}^{2012}\frac{(\gamma_{ij})_t}{(\gamma_{ij})_{t+1}}} / \sqrt[3]{\prod_{2007}^{2009}\frac{(\gamma_{ij})_t}{(\gamma_{ij})_{t+1}}}$ $(i = 1,2,3)$ (Foluma-7)

Experiment 2: $\Delta\gamma_{ij}\_growth = \sqrt[3]{\prod_{2013}^{2015}\frac{(\gamma_{ij})_t}{(\gamma_{ij})_{t+1}}} / \sqrt[3]{\prod_{2010}^{2012}\frac{(\gamma_{ij})_t}{(\gamma_{ij})_{t+1}}}$ $(i = 1,2,3)$ (Foluma-8)

$\Delta\gamma_{1j}\_growth, \Delta\gamma_{2j}\_growth, \Delta\gamma_{3j}\_growth$ respectively represent the ratio of growth rate of a city's GDP, the urban industrial structure, and the urban-rural income gap before and after connecting to HSR network; $\gamma_{1j}, \gamma_{2j}, \gamma_{3j}$ are indicators that respectively indicate the urban gross product (GDP), urban industrial structure ($IndStr$) and urban-rural income gap ($URIncGap$), $(\gamma_{ij})_t$ represents the observed value of the indicator γ_{ij} of city j in year t,

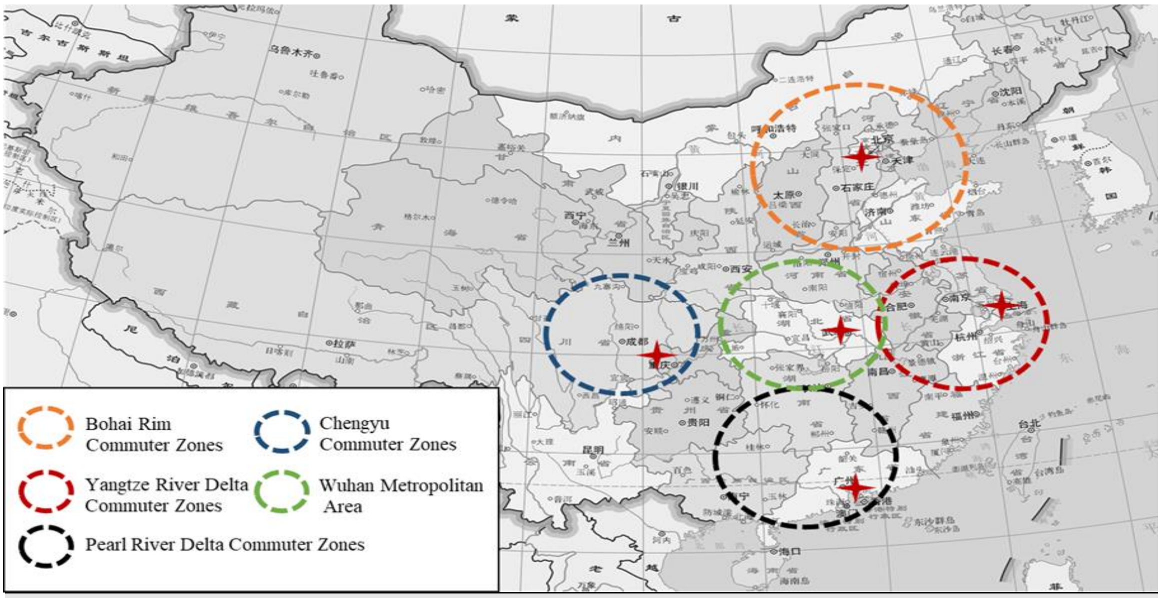
i represents the observed indicators, j represents the city, $t = 2007, 2008 \ldots \ldots 2015$.

Then, I use T-test method to verify whether connecting to HSR has heterogeneous impact on different groups of cities in terms of urban creativity, economic growth, industrial structure, and urban-rural income gap. Therefore, in experiment 1, I conduct T-test analysis on major hub cities and other sub-sample cities. And in experiment 2, I conduct T-test analysis on minor node cities and other sub-sample cities, thereby exploring the location heterogenous impact of HSR on cities along the HSR lines.

(2) Differences between HSR central city and peripheral city

With the improvement of inter-regional transportation infrastructure, the effect of urban agglomeration is increasingly significant. The concepts of "metropolitan area" or "commuter zones" are gradually being introduced into the macroeconomic field as the main body of research to explore the mechanism of regional development and the radiative effect of urban economy. The "one-hour commuter zones" is widely used to observe the effect of regional agglomeration. At present, China has formed three major commuter zones (metropolitan areas), the Yangtze River Delta commuter zone, the Pearl River Delta commuter zone and the Bohai Rim commuter zone. In order to ensure the integrity of the experimental region, I also incorporate the Chengdu-Chongqing commuter zone and the Wuhan metropolitan area that have developed rapidly in recent years due to rapid intercity traffic methods like HSR. On this basis, according to the economic scale of the major cities of the commuter zones, I respectively set Shanghai, Guangzhou, Beijing, Chongqing, and Wuhan as the core cities of the above five commuter zones, and use the commuting time from core cities to other cities by HSR as the dividing basis, successively divide the cities outside the core cities into one-hour commuter zones cities and three-hour commuter zones cities, or two-hour commuter zones cities and four-hour commuter zones cities. Then, I also use the average HSR opening time of sample group as a cross-sectional year to analyze the heterogeneous impacts of connecting to HSR network on central cities and peripheral cities.

Figure 2 Distribution of China's main commuter zones and the core cities (drawn by the author)



Commuter Zones	Yangtze River Delta	Pearl River Delta	Wuhan Metropolitan Area	Bohai Rim	Chengyu
Core city	Shanghai	Guangzhou	Wuhan	Beijing	Chongqing

3.5.2 Descriptive statistics

Table 9 shows the descriptive statistics results of major hub, minor node and non-node cities during the observation period. The results show that major hub cities are ahead of minor node and non-node cities in terms of economic scale, urban creativity and industrial structure, and have a smaller urban-rural income gap. And the better accessibility a city possesses (with more HSR lines passing through), the greater competitive advantage and the better endowment of location it achieves in regional economic development.

Table 9 Descriptive statistics of major hub, minor node and non-node cities

	Major hub city	Minor node2 city	Minor node1 city	Non-node City
GDP	54100,000.000	20400,000.000	6938,790.000	4441,817.000
GDP_PerPat_Pri	164.475	84.975	24.119	8.962
GDP_PerPat_Sec	7,197.988	2,750.510	923.319	272.830
GDP_PerPat_Ter	785.462	153.690	43.262	3.406
IndStr	1.199	1.080	.962	1.010
URIncGap	2.364	2.491	2.569	2.776

Note: Major hub city indicates the city who has more than 3 HSR lines passing through; Minor node2 city indicates the city who has 2 HSR lines passing through; Minor node1 city indicates the city who has 1 HSR line passing through; Non-node city indicates the city who has no HSR line passing or the opening time of HSR outside the observation period.

Table 10 summarizes the opening time of the HSR of the central city and peripheral city in the five major commuter zones (shown above Figure 1). We can clearly observe the HSR opening time of central city in each commuter zones (1hour/2 hours commuting distance from core city) is often earlier than 2010, while the opening time of HSR of most peripheral city (3 hours/4 hours commuting distance from core city) is later than 2014 or even later, which has caused the following two major estimation limitations: (1) connecting to HSR network has an effect on the central city much earlier than the peripheral city. The estimation results made by using the same cross-sectional to define the overall opening time of the sample have a large bias; (2) due to the limitations and lag in the update of relevant data in HSR cities, this article only collects 10 years data from 2007 to 2016, which means that the date cannot accurately reflect the changes of various indicators after connecting to HSR network in most peripheral city. Therefore, at present, it is difficult to analyze the heterogeneous impact of connecting to HSR network in the central and peripheral city in China's major commuter zones.

Table 10 Descriptive statistics of central and peripheral city in China's major commuter zones

Commuter Zones -Core City	Economic Radiation Group	Average starting year of HSR	Diff. in Year of start
Yangtze River Delta Commuter Zones-Shanghai （Opened in 2010）	One-hour commuting-distance cities	2010	4
	Three-hour commuting-distance cities	2014	
Pearl River Delta Commuter Zones -Guangzhou （Opened in 2008）	One-hour commuting-distance cities	2011	>3
	Three-hour commuting-distance cities	2014*	
Chengdu-Chongqing Commuter Zones-Chongqing （Opened in 2008）	Two-hour commuting-distance cities	2011*	>=3
	Four-hour commuting-distance cities	2014*	
Wuhan Metropolitan Area -Wuhan （Opened in 2009）	One-hour commuting-distance cities	2010	>4
	Three-hour commuting-distance cities	2014*	
Bohai Rim Commuter Zones -Beijing （Opened in 2008）	One-hour commuting-distance cities	2010	2
	Three-hour commuting-distance cities	2012	

Note: 1. I choose the two and four commuter zone to cover most cities within Chengdu-Chongqing commuter zone because the adjacent HSR stations are relatively far due to the topography factor; 2. Some cities in the commuter zones have not yet connected to HSR network, so I regard 2021 as its earliest opening time.

3.5.3 T-test statistical results

Table 11 shows the T-test results of the major hub, minor node and non-node cities with the opening time between 2008-2010. The results are as follows: (1) in terms of economic growth, it is difficult to observe that there are significant differences between major hub cities, minor node cities or non-node cities after connecting to HSR network. The economic growth of relatively developed major hub cities tends to decrease marginally, while relatively underdeveloped minor node cities and non-node cities may show positive marginal growth after connecting to HSR network. Therefore, it is difficult to observe a significant difference in GDP growth between the treatment group and the control group; (2) in terms of urban creativity, connecting to HSR network has significantly increased the number of registered patents per unit GDP of the tertiary industry of major hub cities compared with minor node and non-node cities. And the better accessibility it possesses (with more HSR lines passing through), the more improvement it benefits. On the one hand, this may be attributed to the fact that connecting to HSR network has greatly improved intercity rapid transit accessibility and promoted the movement and concentration of knowledge, information, labor and other factors (Desmet & Rossi-Hansberg, 2013; Huang et al., 2016; Yang et al., 2019), making the spatial knowledge spillover effect more significant in major hub cities, thus driving the improvement of the local scientific research and innovation level. And the better the traffic accessibility of the city, the easier it is to attract high-skilled talents or industries from surrounding cities to gather here, so the improvement of creativity is more obvious. On the other hand, higher-intensity HSR services have significantly promoted the agglomeration of urban productive service industries (Shao et al., 2017), thereby increasing local demand for tertiary industry-related production activities and R&D investment. Therefore, the improvement of tertiary industry in major hub cities is more significant than that of minor node or non-node cities; (3) because the observation period is too short and changes in the industrial structure are difficult to occur in the short term, I cannot observe that there is a significant change in the industrial structure between different samples after connecting to HSR network; (4) the urban-rural income gap in major hub cities has not changed significantly after connecting to HSR network, indicating that connecting to HSR network has no significant impact on the urban-rural income gap in economically developed cities.

Table 12 shows the T-test results of the major hub, minor node and non-node cities with the opening time between 2011-2013. The results are basically consistent with the Table 11. The only difference is that we can see a significant increase in the urban-rural income gap in minor node2 cities due to connecting to HSR network compared to minor node1 cities and non-node cities. Minor nodes2 cities are relatively less developed regional hubs compared to major hub cities. Therefore, it is believed that connecting to HSR network will only expand the urban-rural income gap in such relatively underdeveloped cities to a certain extent.

Table 11 T-test for different city groups connecting to HSR network between 2008-2010

	Major hub city	Minor node2 city	Minor node1 city	Non-node city
ΔGDP_growth	0.980	0.983	0.994	0.972
		（0.814）	（0.378）	（0.684）
ΔGDP_PerPat_Pri	2,163.560	2,234.411	595.542	1,086.094
		（0.948）	**（0.075*）**	（0.206）
ΔGDP_PerPat_Sec	39,837.390	40,304.020	20,030.810	16,835.780
		(0.978)	（0.131）	**（0.077*）**
ΔGDP_PerPat_Ter	3712.749	1122.716	622.996	38.199
		(0.012)**	**（0.000***）**	**（0.000***）**
ΔIndStr_growth	1.005	0.989	0.985	1.026
		(0.637)	(0.524)	(0.562)
ΔURIncGap_growth	0.987	0.990	0.991	0.994
		(0.773)	(0.757)	(0.486)

Note: In parentheses are the p-value of major hub cities and other subsample city groups by T-test, *** p<0.01, ** p<0.05, * p<0.1.

Table 12 T-test for different city groups connecting to HSR network between 2011-2013

	Minor node2 city	Minor node1 city	Non-node city
ΔGDP_growth	0.939	0.923	0.932
		(0.648)	(0.777)
ΔGDP_PerPat_Pri	92.671	907.564	1,086.094
		(0.190)	(0.114)
ΔGDP_PerPat_Sec	25,925.04	15,815.38	16,835.78
		(0.548)	(0.636)
ΔGDP_PerPat_Ter	1,052.564	578.99	38.199
		(0.354)	**(0.026**)**
ΔIndStr_growth	1.054	1.099	1.106
		(0.180)	0.144
ΔURIncGap_growth	1.031	0.982	0.982
		(0.054*)	**(0.033**)**

Note: In parentheses are the significant coefficients of minor nodes2 cities and other subsample city groups by T-test, *** p<0.01, ** p<0.05, * p<0.1.

3.5.4 Robustness tests[1]

In the following part, I adopt a robustness test to further verify whether the above estimation results are robust, to remove the concern that there would be significant differences in endowment of economy in different cities along the HSR lines and the endogenous problems of the urban economic level (GDP) on observation results of the sample. The experimental design is as follows: firstly, I group all cities into more developed cities and less developed cities based on the average GDP in different groups. Then, I carry out the T-test between the major hub cities (or minor node2 cities) and the more developed cities in minor node and non-node cities in turn, to reduce the estimation bias brought by the difference in endowment of economy between the different groups of cities.

The results are as follows: (1) connecting to HSR network has robustly improved the urban creativity of tertiary industry in major hub cities, and the better accessibility major hub cities possess(with more HSR lines passing through), the more improvement in creativity they benefit compared to those minor nodes and non-nodes cities; (2) it is difficult to observe the major industrial structure changes caused by connecting to HSR network in experimental results, which is consistent with the previous empirical results; (3) when I carry out the T-test on minor nodes cities with better endowment of

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[1] The detailed results for robustness test are available upon request.

economy and major hub cities, the coefficient of urban-rural income gap is no longer significant. It can be concluded that connecting to HSR network will only expand the urban-rural income gap in the relatively less developed major hub cities, therefore among those cities with relatively developed economies, we cannot see a significant difference in urban-rural income gap between two groups after connecting to HSR network. For those rural areas in less developed minor nodes, they cannot enjoy the economy spillover effect after connecting to the HSR network due to its poor radiative effect. Therefore, the movement of labor and other resources between cities and rural areas become more unidirectional (from rural to urban areas), which leads to the decline of the rural production sector.

3.5.5 Summary

In this section, I mainly uses descriptive statistics and robustness test to conduct the following two research: (1) analyzing the heterogeneity of the impact of connecting to HSR network on major hub cities, minor node cities and non-node cities through the comparison of accessibility (the number of HSR passing lines); (2) introducing the concept of "commuter zones" (the commuting distance from HSR to core city) to analyze the heterogenous impact of connecting to HSR network on central city and peripheral city.

The statistics results are as follows: (1) Compared with minor node and non-node cities, the creativity of the tertiary industry in major hub cities has been significantly improved after connecting to HSR network. The previous empirical results show that HSR improves the creativity of the primary and tertiary industries in the more developed and non-eastern cities, but if only from a partial perspective, it can be observed that connecting to HSR network could significantly improve the creativity of the tertiary industry in major hub cities along the HSR lines; (2) the change of industrial structures takes time, and the observation period of the sample is too short, so it is hard to observe the significant changes in the industrial structure of major hub cities or minor node cities compared with non-node cities; (3) connecting to HSR network may only widen the urban-rural income gap in minor node cities with underdeveloped economy. Although connecting to HSR network can promote urban economic development, rural areas in these cities may not be able to enjoy the economic spillover effect brought about by HSR, that is, the less developed minor node cities lack the capability to coordinate the development of urban and rural areas and will easily lead to the decline of the rural production sector. This part of the conclusion is consistent with the above.

Regarding to the second research, since the opening time of HSR stations in most of the peripheral cities lags behind that of central city by 3-4 years or even longer, this article cannot accurately estimate the heterogeneous effects of central city and peripheral city due to the connection to HSR network. Moreover, the opening time of most HSR stations in peripheral city is out of the observation period of data coverage, resulting that the data in this article cannot accurately reflect the economic spillover effect caused by the radiation effect of the central city after connecting to HSR network.

3.6 Conclusions and implications

This study has four parts of findings. **Firstly,** the results in terms of impacts of HSR on industrial structure change are generally not consistent with Hypothesis 1. This study finds that connecting to HSR network only significantly increases the proportion of the tertiary industry in the eastern cities in China, while the same phenomenon does not happen in non-eastern cities. The change of industrial structure takes time, and the observation period is too short to observe substantial industrial structure change caused by HSR across the whole country. Moreover, the significant results observed within the eastern cities are the results of both the direct impacts of the HSR and the siphon effect. Siphon effect takes time and it is more difficult to happen across regions than that within a certain region. Because, there are diverse social cultures includes dialects across different regions in China, which makes people difficult to adapt to life in nonlocal regions and hinders people from migrating across regions. **Secondly,** connecting to HSR network promotes the creativity of the HSR cities in the primary and tertiary industries, and more developed cities and non-eastern cities benefit more. These results are consistent with Hypothesis 2. **Thirdly**, it only widens the urban-rural income gap in economically less developed regions and this trend of expansion is more significant for those minor node cities, but the capability to balance the urban-rural development and economy spillover effect is poor. This part of the results demonstrates the concerns raised in 3.2. **Fourthly**, from the perspective of accessibility, the better accessibility major hub cities possess (with more HSR lines passing through), the more significant improvement in creativity of the tertiary industry they benefit compared to those minor node and non-node cities. The results of this article suggest that China should vigorously support the development of HSR network and play an active role in the process of promoting urban development. In particular, the government needs to pay more attention to those minor node cities that have been connected to HSR network but are relatively economically underdeveloped, because connecting to HSR network may widen the urban-rural income gap in these areas.

Chapter 4 Government-dominated GIUR system and innovation

China's high-speed rail (HSR) construction has made remarkable achievements, and HSR has become a golden card for China. It not only reflects achievements in mileage and scale, but also in technical breakthrough. Large-scale technology introduction is the starting point for China's HSR construction. In just two decades, China has made great progress in HSR technology, and today it is recognized as world's leading country in the development of HSR, whose HSR technology is one of the very few high-tech complex industries that can reach the world-class level and even lead the development of global HSR technology in certain fields. The success of China's HSR has attracted widespread attention for studying and explaining the reasons for success of China's HSR (Cheng, Liu, Chen & He, 2011; He et al., 2018). Despite the different perspectives of above studies, there is a basic consensus that the cooperation between the central and local governments has played a very important role in the China's HSR development, especially the government leadership and policy guidance. The government-dominated government-industry-university-research cooperation (GIUR) system has greatly promoted the development and construction of HSR in China. This chapter focuses on the following research questions:

- What are the advantages and disadvantages of Chinese government-dominated GIUR system for scientific research and innovation in a context of new development period, and new political and economic environment at home and abroad?

- What should China do to adjust the initial GIUR system in the future?

To answer these questions, this chapter mainly adopts research methods of theoretical analysis and case study, and finally gets the following conclusions: under the application of GIUR system, in the early stages of industrial (technical) development, government needs to play a leading role; while in the technology-pioneering stage (with industrial maturity), government-dominated GIUR system should be transformed into a market-oriented industry-university-research system.

The contribution of this chapter is to explain the institutional advantages and adjustment directions of the GIUR system at different stages of industrial development in combination with theoretical study and practical cases, and to raise the understanding of the reform of China's HSR research and development (R&D) system.

The structure of this chapter is as follows: 4.1 provides the background, mainly summarizes the successful experience of the application of GIUR system in China's HSR construction, and reviews the application of the GIUR system in the development of China's automobile industries (CAI) and new energy automobile industries(NEAI); 4.2 explains the advantages and disadvantages of government-dominated GIUR system in different stages of HSR technology development, and proposes preliminary policy implications;

4.3 takes the CAI and NEAI as case objects to further demonstrate the advantages of the GIUR system at different stages of technology development and the effectiveness of the solutions; 4.4 is the conclusion and implication of this chapter.

4.1 Background introduction

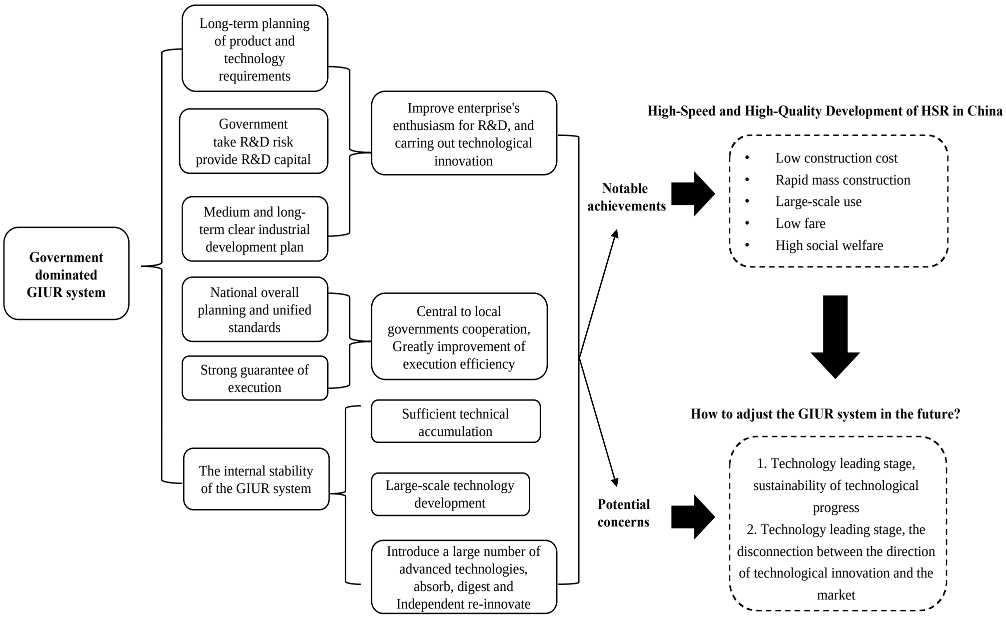
4.1.1 China's HSR development experience and the contribution of government-dominated GIUR system

Over the past decade, China has put about 25,000 kilometres of HSR lines into operation, far more than the rest of the world combined. Not only that, but the ticket is also cheap and the HSR service is punctual, stable and comfortable. Passengers can arrive and leave in time, which greatly saves their traveling time. Meanwhile, the unit cost of China's HSR construction is about 2/3 of that of other countries, and the fare per mile is about 1/4 of that of European countries.

The latest World Bank report attributes the success of China's HSR to government-dominated GIUR System, as shown in Figure 3 (left side). It provides following favorable conditions[1] for the development of HSR.

[1] The detailed content for this is available upon request

Figure 3 Development, construction experience and potential improvement of HSR in China



Note: Part of the figure refers to the World Bank report "China's HSR Development" in 2019.

First of all, this system guarantees the scale of market demand. Schmookler (1966) points out that enterprises innovate in pursuit of market profit, and market demand is the main reason for enterprise innovation. Therefore, the scale of market demand in the initial stage of the industry determines the enterprise's intention to carry out independent R&D and innovation. **Secondly**, the government's long-term plan for HSR has greatly reduced the R&D risks and increased R&D enthusiasm of enterprises. Innovation is a risky activity. Acemoglu and Zilibotti (1997) point out that enterprises at an early stage of development can only finance a limited number of intermediate industries or products so that R&D entities inclined to choose inferior technologies under limited economic conditions. But the GIUR system not only provides the capital needed for enterprise R&D at low cost, but also bears most risks of enterprise R&D failure, which can encourage R&D entities to boldly choose cutting-edge technologies for technological innovation. **Thirdly**, it reduces the uncertainty of enterprises R&D. Bloom, Eifert, Mahajan, McKenzie and Roberts (2007) points out that when the uncertainty is high, the redistribution process of production factors from low-productivity companies to high-productivity companies would also slow down, leading to a slowdown in industry or social productivity growth and innovation processes. However, under the application of government-dominated GIUR system, central government has formulated a clear long-term plan for the construction of HSR, which passes clear investment prospective to the market. In addition, Chinese government has extraordinarily strong execution power for long-term plans which greatly reduces the uncertainty of the entire R&D and application system, including market uncertainty, expected uncertainty and profit uncertainty. **Fourthly**, this system establishes a cooperative network which strengthens the close cooperation within the HSR innovation entities and improves the execution efficiency of R&D tasks. Under the application of government-dominated GIUR system, China's HSR technology has achieved unified standards early in the development of technology, thereby prompting diverse innovative entities to form a close and effective cooperative relationship. Ultimately, China's HSR has achieved the improvement of the entire industrial chain in terms of basic research, technology application, equipment assembly to core components. **Fifthly**, the government-dominated GIUR system is relatively gated, and the main entities inside the system are stable, providing a "pool" for technology accumulation and reducing the cost of technology introduction. Therefore, the R&D entities within the railway system can efficiently implement the government's requirements for scientific research and technology development and are willing to make high-risk and long-term R&D investments, which have enabled China's HSR industry to achieve considerable technology accumulation at an early stage. **Last but not the least**, it guarantees that the mid-and-long-term development plan for HSR can be implemented. As a senior government department, the Ministry of Railways dominates the GIUR system and major innovation entities within the system, which establishes following unique advantages for HSR construction. On the one hand, the interests of the entities in the system are consistent and concentric, local government officials at all levels can complete the HSR construction targets with quality and quantity, which ensures the mid- and-long-term planning for HSR can be powerfully implemented from top to bottom, central to local. On the other hand, as a monopoly buyer for foreign counties, Chinese GIUR system has strong bargaining power which could help the domestic R&D entities to learn and accumulate international advanced knowledge in terms of product, design and manufacturing on a large scale at a lower cost (Lu, 2020), and on this basis, R&D entities could carry out a large amount of independent innovation activities to catch up technologically in a short term.

4.1.2 Application of the GIUR system in other industries: taking CAI and the NEAI as examples

Before the development of HSR, many studies pay attention to the CAI in the field of transportation. Both industries were led by the central government in the early stages of development, and experienced the introduction and absorption of international advanced technologies during the development process. However, after more than ten years of development of China's HSR, both the technical level and the industrial scale have been at the forefront of the world, but the CAI has always lagged behind the world level. Until 2009, after the state readjusted the automobile industry strategy, the development of CAI has gradually caught up with the world level in recent years. However, it is worried that the key technologies and independent brands of the automobile industry still have a certain gap with developed countries at present. China's HSR and automobile industries seem to have the same development history but have quite different results. The reason for it has also attracted the attention of some scholars (Zong, Li & Deng, 2016).

Comparing the development history of CAI and HSR, I find that the CAI lacks a unified force dominated by government in the development process. Under the large-scale policy guidelines issued by the central government, local governments did not provide sufficient financial support for R&D and dominate the R&D direction of state-owned automobile companies in order to pursue short-term performance and profits, resulting in the trend of "market for technology", the consciousness of independent innovation was gradually diminished, and the CAI embarked on the road of dependent development. In the end, the level of technology continued to lag behind and fell into a vicious circle of "introduction-backward-re-introduction". On the contrary, under the strong leadership of the Ministry of Railways in the early stage of the construction of China's HSR, a stable research and innovation entity has formed within the HSR industry. Facts also prove that it is the GUIR system formed under the government domination that helped the "latecomer" China's HSR to overtake the developed countries in the world in just over ten years. However, the lack of such scientific research, innovation system and effective government planning during the initial development of the CAI causes the technology level of the CAI to lag far behind the developed countries after decades of development.

On the other hand, the energy saving and new energy vehicles industry (NEV) which also belongs to the automobile industry, began in the early 21st century. Different from the early development of CAI, the central government incorporated it into major national science and technology subjects in the early stages of the development of new energy automobile research projects and put forward the strategy of energy saving and new energy vehicles (NEV), paying great attention to the R&D and industrialization of NEV. Therefore, at the early stage of the development of NEAI, the Chinses government actively supported and led the innovation of domestic NEV independent brands and key technologies through formulating the strong industrial policies and strategic plans, which promoted the research and formulation of related policies, regulations and standards for the NEAI. Chinses government also took the enterprise as the main entity to establish an independent R&D innovation system, which combines industry, university and research. With sufficient independent innovation capabilities and the government's leadership for key R&D direction, it is different from the "market for technology" in the early development of the CAI. China continuously carried out independent R&D and innovation while introducing and absorbing the internationally advanced technologies such as power batteries and electric drive systems, so that the technological level of China's NEAI has gradually reached the world advanced level. But government financial subsidies are difficult to support the continuous growth of the industrial market, and it is difficult for the government-dominated GIUR system to further promote the improvement of scientific research and innovation capabilities at the stage of industrial maturity. Therefore, in recent years, the government's subsidies and support for NEAI have shown a downward trend, aiming to make the NEAI change from "government-dominated" to "market-dominated" (Zhao, 2018) and to give full play to the market competition and resource allocation mechanism to promote the continuous innovation of NEAI and eliminate backward enterprises, so as to achieve the sustainable development of NEV in China.

Both the CAI and the NEAI have the epitome of the application of the government-dominated GIUR system in the early development process. Although the two industries have an inclusive relationship, the difference in factors such as technology policy orientation, technical capability, and the application level of the GIUR system has led to a different development situation for the two industries. Excluding domestic and foreign environmental impact factors, I believe that the application strategy of the GIUR system plays a key role in this process. The early CAI blindly implemented government-dominated GIUR system without the support of the corresponding technical foundation, and finally the erroneous policy of "market for technology" weakened the independent innovation capabilities of most China's automobile companies, which has kept technological innovation capability of China's automobile industries at a low level in the global value chain for a long time. But the development of the NEAI could take a lesson drawn from past mistakes. Compared with the early development of the automobile industry, NEAI has a more stable innovation body and stronger technological capability, and the central decision maker had provided more powerful and clear technical guidance and financial support for the development of the industry, so that the NEAI can continue to achieve technological breakthroughs since its early development, and has gradually been in line with the world's leading level. However, there is still a major concern in the NEAI and HSR industries that after the lack of guidance from advanced technology, government-dominated GIUR system gradually begins to show weakness in promoting technological innovation, making the technological development speed of the two industries show a downward trend compared with the initial stage.

In summary, I initially believe that the government-dominated GIUR system has good applicability and institutional advantages in the early stage of industrial development, but it needs to be applied conditionally and strategically, otherwise it will negatively affect the technical development of the industry, weakening the momentum of innovation within the system; after the industry (technology) gradually matures, it is necessary for the government-dominated GIUR system to make some adjustments, so that the technological innovation within the system can have sustained development momentum.

4.2 The problems and solutions faced by government-dominated GIUR system

4.2.1 Problems existing in the GIUR system of the HSR industry

GIUR system runs through the three stages of China's railway technology development, from the initial independent exploratory R&D to the introduction of foreign advanced technology to quickly complement the technical shortcomings, and to the current independent development of the entire industry chain which pioneers the world. The classic marketization theory believes that under the condition of state-owned enterprises as the main body and long-term strong government intervention, independent innovation is often costly and inefficient, and the market is the source of independent innovation. The achievements of China's HSR have triggered people's reflection on traditional economic theories and stimulated people's interest in explaining the mechanism behind the GIUR system and refining the theory. As discussed in the literature review of this article, most of the above literature explain the reasons for the success of China's HSR development from the perspective of the entire system. Few studies have explored the possible improvement of China's HSR technology development from a micro perspective. China's HSR technology has successfully transformed from a lagger into a leader, and entered a new stage of development. At different stages of development, the problems and challenges it encountered are different. Therefore, under the new development stage and the international background, how should the original GIUR system adapt to and face the challenges? This section will focus on the details, aiming to raise some concerns about the current and future technology development of the HSR industry, and propose solutions. As mentioned above, government-dominated GIUR system conforms to the characteristics of China's HSR internal system during the early development stages. Combined with practical work experience, I raise two concerns about the future development of China's HSR technology, as shown in Figure 4.1 (bottom right).

Concern 1: The role of China's HSR industry in HSR technology development has changed from follower to leader. Can the previous government-dominated GIUR system maintain the sustainable development of HSR technology?

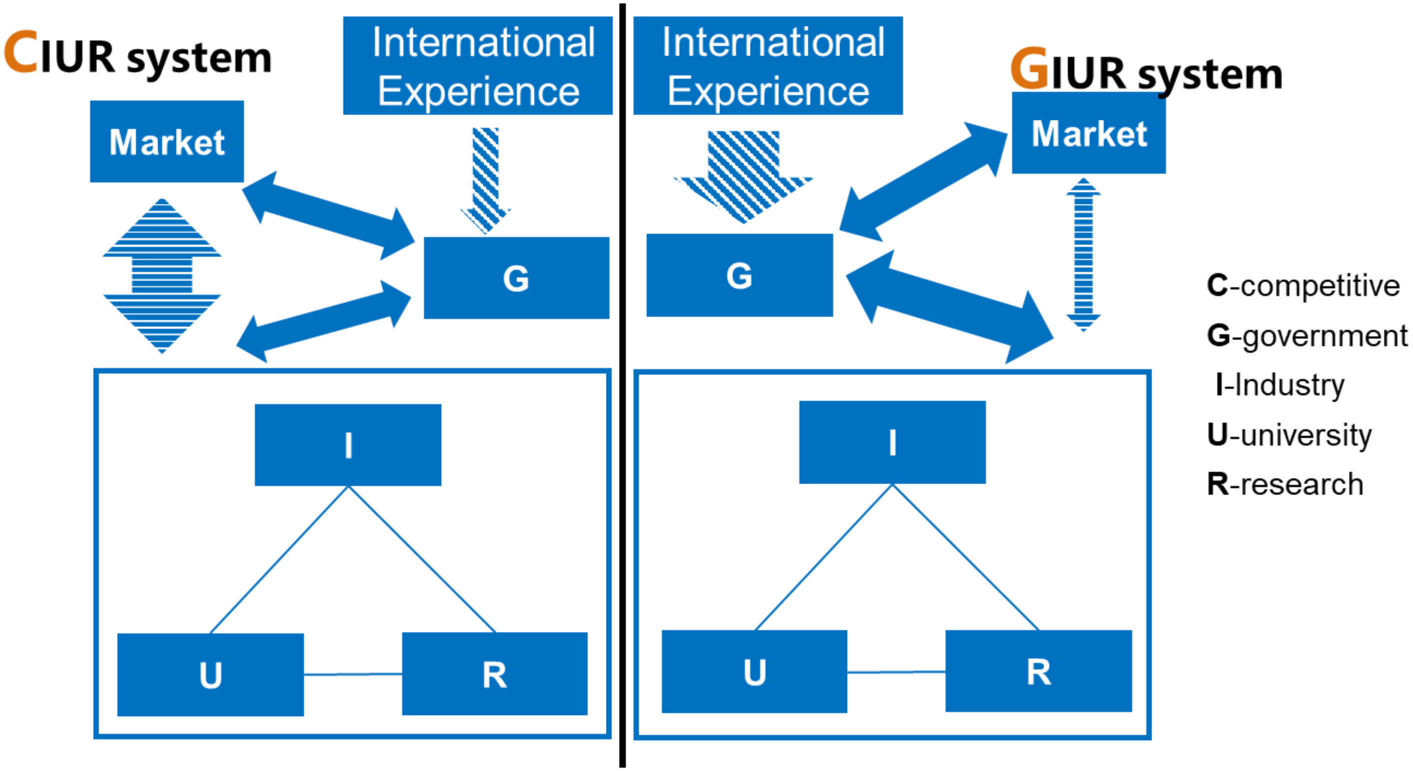
Concern 2: Can the government-dominated GIUR system set the right direction and adapt to changes in market demand even make forward-looking research and development?

As a kind of public product, HSR needs to be promoted by the government for its construction and investment. On the one hand, HSR technology itself is not a pure public product, and technology R&D requires coordination between the government and the market. HSR construction has a huge positive externality to economic development, but the direct economic benefits are limited. Therefore, it is difficult for the private sector to provide sufficient public goods such as HSR. Private public goods providers are always motivated to be free riders (refuse to provide public goods while using the goods provided by others) (Falkinger, Fehr, Gachter & Winter-Ebmer, 2000). So, the government needs to actively participate in the provision of such public goods and fully utilize the externality of HSR as a public product to maximize social welfare (Isaac, Mccue & Plott, 1985). On the other hand, the output of HSR technology mainly comes from basic R&D and applied R&D activities, and the positive externalities of basic R&D are very high. However, basic R&D, such as new materials and new theories, are characterized by long investment cycles, poor short-term liquidity and high risks. Most companies do not have enough motivation to engage in basic R&D. Therefore, it also requires strong government support and assistance, such as subsidies and policy interventions, or directly borne by state-owned enterprises (Ye, Lin, Zhang & Cao, 2019).

In the R&D of HSR technology, the government should cooperate with the market operation, and the role of the government should depend on whether the market forces are enough to promote the development of technology. In other words, the government-dominated GIUR system needs to be adjusted in the new stage of HSR technology development, new market environment, and economic endowment. The framework of development economics of "New Structural Economics" (Lin, 2010) holds that developing countries need to play a synergistic role between market and government to achieve long-term economic development, and narrow the gap between themselves and developed countries. Moreover, the government's policies and institutional arrangements must take into account the factor endowments and market forces at different levels of development. That is to say, in the process of cooperation between market and government, the government plays different roles with the changes of market power and economic factor endowment. When the market is weak and the endowment of economy is insufficient, the government needs to mobilize resources to promote development, at that point, the leading role of the government is greater. When the market matures gradually and the endowment of economy is sufficient, the leading role of the government is returned to the market. The government cooperates with the change of market power to promote the healthy development of the economy and society. This transformation of dominance between government and market is also reflected in the development of financial markets in some developing countries (Zhang, 2010), including China and Singapore. In the early stage of economic growth, capital accumulation is small and the government dominates the development of financial markets, which is conducive to mobilizing resources, quickly breaking the financial bottleneck and promoting financial markets to serve the real economy. With the maturity of the financial market and the sufficient accumulation of capital, the dominant position of the government should give way to the market.

Figure 4 summarizes the mechanism of market competitive Industry-University-Research system (left) and GIUR system (right) in the early stage of HSR technology introduction, absorption and redevelopment (referred to as early-stage), and pioneering and independent R&D stage (referred to as the pioneering stage). I believe that GIUR System is more suitable for the early stage of HSR development where China is a follower, while in the current stage when China is a leader, the GIUR System needs to be improved.

Figure 4 The difference between competitive Industry-University-Research system and GIUR system of HSR industry in China



Note：The arrows in the figure represent the information transmission.

In the early stage, compared with the competitive Industry-University-Research system, GIUR system is more conducive to the rapid development of HSR technology. The reason is that in the early stage, China's HSR technology development can introduce, absorb and digest advanced foreign technology, and even make some independent research and development on this basis. In this case, the direction of technology development is clear, and the uncertainty of technology introduction, absorption and R&D is small. The shortcoming of government dominance does not exist at this stage. Generally, under the government-dominated model, state-owned enterprises will have many inefficiency problems. For example, state-owned enterprises are more reluctant to invest in R&D than private enterprises. This is because state-owned executives lack the incentive to invest in R&D on a large scale. Executives of state-owned enterprises play an important role in promoting enterprise innovation because they are decision-makers and execution promoters of enterprises. They prefer to reflect R&D output by improving management efficiency (Zhou & Zhang, 2016). Executives of state-owned enterprises have dual identities. They are both managers and officials. So, they are motivated not only by salary incentives but also by political promotion. More importantly, they serve shorter terms than normal managers, often less than five years. Salary and political promotion incentives are based on enterprises performance, while

R&D investment will affect the short-term performance of enterprises and has the characteristics of high short-term risk and long investment cycle (Holmstrom, 1989). This leads to the reluctance of state-owned enterprise executives to invest in large-scale R&D. In the early stage, through the introduction and absorption of international technology to achieve technological progress, it has high certainty and clear benefits, the above problems of state-owned enterprises no longer exist.

In the early stage, the advantages of government dominance are particularly prominent. Because the government-dominated GIUR system can promote the process of introduction, absorption and digestion from the following aspects: 1) a clear long-term plan has been formulated for the construction of HSR, and the government strongly supports the implementation of the long-term plan, which conveys clear market operation and investment expectations, so the HSR enterprises dare to expand investment; 2) under the leadership of the government, in the stage of technology introduction and absorption, the standardization will be unified, the components of HSR will be exchanged, the cooperation and competition among R&D entities will be promoted, and the internal friction will be reduced; 3) the Ministry of Railways, as a high-level government dominating the GIUR system, enables R&D entities to have strong bargaining power in the process of introducing foreign technology and market-for-technology, so that they could quickly and massively introduce advanced foreign technologies. The process of technology introduction, absorption and digestion is consistent with Lin's (2003) view that developing countries can introduce and absorb advanced technology from abroad at lower cost to achieve rapid capital accumulation and technological catch-up.

However, in the pioneering stage (Figure 4.2), the direction of foreign advanced technology no longer exists, and the problem of government-dominated GIUR system is highlighted. For example, under GIUR system, state-owned enterprises are the major players. The theory holds that state-owned enterprises are the tools for the government to solve market failure, especially in basic R&D. Ye et al. (2019) argue that state-owned enterprises undertake more basic research tasks than private enterprises because the government invests more in basic research, and these investments go to state-owned enterprises. However, the R&D input and output of state-owned enterprises are more than that of private enterprises, because some of the resources needed for R&D innovation are occupied by state-owned enterprises (Li & Song,2010). If these basic research investments go into private enterprises, will there be more basic R&D output? After all, private enterprises are more efficient.

Moreover, it is difficult for the government to do a good job in the information channel of the market and Industry-University-Research system. In the pioneering stage, without the guidance of international advanced technology and experience, Industry-University-Research system needs to find the direction of technology development in the continuous interaction with market demand. The government should assist this interaction and promote market demand to transform into scientific research results, as shown in Figure 4.2 on the left of the market competitive Industry-University-Research system institute. If China continues to adopt GIUR system (on the right side of Figure 4.2), the following four problems will arise:

- R&D is out of line with the market: the government cannot effectively pinpoint the direction of market demand and transmit the market demand information to Industry-University-Research system, which will lead to the disconnection between R&D and the market of HSR technology;
- The disconnect between R&D and the market affects the process of applying R&D results to meet market needs;
- The internal imbalance of Industry-University-Research system: the government dominates the choice of research and development technology, resulting in a disconnect from manufacturers;
- Weakening the independent innovation momentum of the Industry-

University-Research system.

The government's intervention will hinder the information interaction between the market and the Industry-University-Research system. The government itself is a multi-level organization. Market information is easily distorted when it is transmitted to the Industry-University-Research system through the government. In hierarchical tier organizations, especially government agencies, the transmission of information is always distorted. On the one hand, when information is aggregated from low level to high level, it will lose details (Arya, Glover & Mittendorf, 2010). On the other hand, because of risk aversion, each level tends to adopt information transmitted directly from lower level (Slezak & Khanna, 2000), which leads to information cascades. The existence of these two problems makes high-level decision-makers have to add their views when judging information. This puts forward high professional and technical requirements for government decision-makers. When the professional skills of government leaders do not match those of the fields under their control, they often interpret market information unilaterally or even make impulsive decision in such hierarchical organizations. The same is true in the R&D process of HSR. For example, sometimes leaders will require good appearance like the "aesthetics" details of the parts, which will greatly improve the technical requirements and manufacturing costs of the parts but do not improve the service performance of the parts in the HSR system. It not only did not meet the market demand but also made it more difficult to produce the parts.

Government-dominated GIUR system not only affects the effective reception and interpretation of market information in Industry-University-Research system but also affects the process of applying R&D results to meet market demand. Although Industry-University-Research system is a more competitive system, different domestic R&D institutions and even international participants put forward different technical solutions for users to choose. Under the leadership of the government, the best technological scheme should have been chosen (the lowest cost and the best benefit). However, because of the conflict of interests between the government and the state-owned enterprises, it is not always the best technological scheme that is finally chosen. This is caused by two mechanisms. On the one hand, there may be agent problems in government departments and state-owned enterprises. The official in charge of technical audit and selection is the agent, while the railway department, the government and all the nationals are the principals. HSR is a public product, and the client is more concerned about the externality of public goods to social and economic development, considering the speed, stability, and safety of HSR construction, rather than the financial performance of HSR construction and operation. The number of clients is large and scattered, and the lack of clear monitoring indicators makes it difficult for the client to effectively supervise the agent (Jiang, 1994). At the same time, collusion can easily develop between the vertical levels of government and state-owned enterprises in the absence of effective regulation and the existence of principal-agent problems (Bac & Kucuksenel, 2006). Therefore, we will see that when railway officials choose to adopt technical solutions, it is likely that the difficulty and cost of technology applications (production) will increase due to the departmental interests rather than the optimal technology solutions.

In the process of application and technological innovation, government-dominated GIUR system may weaken the independent innovation momentum of the Industry-University-Research system. People argue that late-developing countries have a "latecomer disadvantages", that is, technology imitation is relatively simple and will be implemented first, which will accelerate economic development in the short term. But this process will promote the emergence of national opportunism, promote the inertia of institutional reform, and leave a hidden danger to long-term development. Lin (2003) questions this "latecomer disadvantages", believing that institutional change is endogenous to economic growth and does not need to take the initiative to reform. However, Lin (2010) further believes that although institutional change is endogenous, the government’s policies and institutional arrangements must take into account the factor endowments and market forces at different levels of development. That is to say, in the process of cooperation between market and government, the government plays different roles with the changes of market power and economic factor endowment. In other words, at the pioneering stage of HSR technology, the original GIUR system may cause the internal scientific research system of the HSR industry to lose the momentum of independent innovation.

4.2.2 How to respond?

The framework of development economics of "New Structural Economics" (Lin, 2010) provides reform ideas for the development system of HSR technology. According to the framework, there is a need to build up synergy between the market and the government, and the government should adjust its roles following changes in market forces and the factor endowments of the economy. Given the possible problems of the HSR GIUR system, the government needs to change in the following directions. **Firstly,** in the pioneering stage of technology development, the government should give way to the market properly on the premise of maintaining leading position, let the market interact more with the Industry-University-Research system, and let the interaction between the two play a greater role in R&D decision-making. **Secondly**, government-dominated model is still effective, but the premise is that government officials and managers of state-owned enterprises have more

HSR technology-related skills and more experience, then they can be more sensitive to the market and can grasp the direction of technology development. **Finally**, government officials should be more open to the opinions of academic researchers.

4.3 Further case study

4.3.1 Literature review

CAI has been developed for nearly 70 years. Although the annual sales of Chinese brand cars have ranked first in the world for many years, there are still existing the problems of low domestic car brand share, low enterprise efficiency, backward technology, and lacking competitiveness in the international market. Many studies have researched on the roots of problems and failure. For example, Zhao (2013) believes that the failure of CAI's independent innovation mainly comes from that the government failed to coordinate and organize the development of industrial innovation in the early stage and the CAI lacks an internal and stable innovation system. Zong, Li and Deng (2018) compare the development of China's HSR and automobile industry and argue that the CAI lacks independence in the development process and innovation in the process of introducing and absorbing international advanced technologies. Professor Lu Feng is commissioned by the Ministry of Science and Technology to investigate the automobile industry, and he concludes that: CAI did not embark on the path of independent development at least before 2005. Overall, the main reason for the backward development of CAI in the early stage is that the government has not provided long-term effective leadership and support for the development of the CAI, lacked emphasis on establishing a stable R&D and innovation system and carrying out independent R&D and innovation activities. On the other hand, China's NEAI has been included in the ranks of strategic emerging industries after its rise in the early 21st century and has been highly valued by the central government. Since 2009, Chinese government has successively issued a series of policies for NEAI, which have comprehensively promoted the rapid development of China's NEAI (Ma et al., 2018). However, some scholars (Zhou, Chu, Fu, Xu & Zhou, 2019; He & Zhou, 2016), through empirical research, find that the level of Industry-University-Research cooperation in China's NEAI is not high, which to some extent leads to the gap between the core technology level of China's NEAI and that of developed countries. Hou, Chen, Lin and Duan (2015) proposes that China's NEAI innovation system is in a fast-growing stage, the government's leading force and various measures play an active guiding role in the industrial development process, but problems such as incomplete infrastructure facilities, lack of uniform technical standards (Zhao, 2018), and imperfect private consumption market for NEAI are still bottlenecks in the current development of NEAI.

4.3.2 Design of the case study

In order to explore the applicability of the GIUR system dominated by the government to industrial development, and the adjustments required for different technology development stages, I choose the CAI and the NEAI as the case objects to carry on the comparative research. The reasons are as follows.

(1) The successful GUIR system has few application cases, so it is difficult to positively prove the universal advantages of the system from the existing cases, and I can only prove the importance of the system for the initial development of the industry from the adverse consequences caused by the lack of the system. Therefore, I compare the development of the automobile industry in the early period with the HSR industry to qualitatively discuss the importance of the GIUR system for promoting the scientific research innovation in early stage of industry development.

(2) The China's HSR industry, as a latecomer, spends just a decade catching up with the world's advanced technology. Its development process has two external characteristics. First, it is directly dominated by the government in the early stage of industrial development; secondly, in the history of development, it brings in and absorbs international advanced technology to make up for the weakness in HSR technology. Therefore, I choose the automobile industry and its sub-industries with the same two characteristics for

case comparative research.

(3) Although the NEAI belongs to the category of the automobile industry, compared with the early CAI, the government's role played in it is not exactly the same, and the degree of application of the Industry-University-Research system is different. Compared with China's HSR, the development stage of the NEAI has a high degree of matching with HSR industry, and it can support the conclusion that the GIUR system needs to be adjusted at different stages.

In conclusion, due to the particularity of the development process of the HSR industry and the less extensive application of the GIUR system in China's other industries, I measure the results of similar industry development through case analysis to summarize the problems that the industry will appear at different stages and the advantages of the GIUR system in solving these problems, which is used to qualitatively infer the importance of GIUR system at different industrial development stages and implicate the appropriate adjustment policy required for different stages.

Combining the existing researches, I expect to obtain the following empirical conclusions through the above case studies: in the early industrial developing stage, the government needs to formulate long-term strategic planning, propel the establishment of industry demand market, lead and support the industry core technology research and the independent brand innovation in the process of introducing and absorbing the international advanced technology, and actively promote the establishment of the alliance like GIUR system so as to give full play to the advantages of latecomers to quickly fill up the technological gap with developed countries and achieve rapid development. In the industrial growth stage, the government needs to change roles, expands the industrial market through macroeconomic regulation such as industrial policies and subsidies, and gradually makes the GIUR system transit to the market-dominated Industry-University-Research system so as to play the role of market competition mechanism and resource allocation to lead the continuous innovation of technology and eliminate backward production capacity, thereby promoting the sustainable development of the industry. At that time, government's investment should be shifted more from key technology to basic R&D so as to improve the construction of supporting facilities for industrial development, and take measures such as strengthening market supervision, encouraging business model innovation and international cooperation to support the sustainable development of the industry.

4.3.3 Case background[1]

4.3.3.1 Review of China's automobile industry development

[1] The detailed content for this is available upon request.

At the beginning of 1950, the Chinese government regarded the construction of automobile factory as the first major projects aided by the Soviet Union during the first five-year plan. In April of the same year, the Ministry of Heavy Industry set up a preparatory group for the automobile industry and started intense preparations. In June 1953, the government issued instructions: "strive to build Changchun automobile factory in three years". The establishment of Changchun FAW Automobile Factory in 1956 marked the birth of China's first automobile company which meant the CAI achieved a breakthrough and this process was inseparable from the strong support and guidance of the government. However, at that time, due to the lack of a stable and independent scientific research and innovation system, the government-dominated CAI developed slowly and could only accumulate technology with the help of the Soviet Union. After the 1960s, CAI entered a closed independent innovation stage due to some factors such as the deterioration of Sino-Soviet relations, economic blockade from western countries. After the reform and opening up in China, the overall technological level of the CAI was still about 20-25 years behind the international level, which forced the Chinese government and domestic enterprises to embark on the dependent development path of joint venture development and large-scale technology introduction. However, due to the improper intervention of government, the process of introducing technology through joint ventures instead hindered the improvement of CAI’s ability to innovate independently. The most energetic and active private auto companies were not supported and developed well, and it was difficult for auto companies in various regions to carry out independent innovation, eventually the independent innovation capability of CAI has stagnated.

In addition, the *Automobile Industry Policy* issued in 1994 proposed that the state encourages automobile industry enterprises to use foreign capital to develop Chinese automobile industry, establishing the basic pattern of "market for technology" in the CIA industry. However, prematurely allowing multinational companies to invest in the domestic market under the background of weak competitiveness of state-owned car brands and backward R&D capabilities severely squeezed state-owned car brands from internationally dominant auto brands. In the process of introducing technology from foreign companies, due to the lack of strong government leadership in technology negotiations and the disparity in strength between the two parties in the joint venture, leading to technical control and share capital is generally controlled by multinational automobile companies. Therefore, although the Chinese government’s policy orientation of “market for technology” stimulated China’s economic growth at that time, it limited the development of state-owned brand cars, and severely depressed the willingness and weakened the ability of R&D and innovation in China's auto companies. Since then, CAI has been at the low end of the value chain for a long time.

4.3.3.2 Review of China's new energy automobile industry development

China's NEAI started in the early 21st century. In 2001, the NEV research project was included in the "863" major scientific and technological subjects during the "10th Five-Year Plan" period. Since the "11th Five-Year Plan" period, China has proposed the strategy of "energy saving and NEV" strategy, the government has paid close attention to the R&D and industrialization of NEV. In 2006, the government actively promoted the implementation of industrial policies on energy conservation and NEV, established China's energy conservation and NEAI innovation alliance and developed an independent R&D and innovation system combining industry, university and research institutes with the enterprise as the main subject. With the high emphasis of central government on energy saving and NEV, the expert group on major projects of energy saving and NEV was formally established in December 2006. The members of the expert group were mainly from enterprises, universities and scientific research institutions, mainly responsible for implementing the overall integration and technical coordination of major projects of energy saving and NEV, which showed that the GIUR system taken shape in the early stage of the NEAI. At the same time, local governments also increased their support for the NEAI. During the 10-year period from 2001 to 2010, China has invested nearly 9 billion yuan into the electric vehicle research. From 2006 to 2008, China's NEAI made significant progress. Several China's automobile companies represented by BYD, Chery, BAIC, and Geely have independently developed NEV products based on pure electric, hybrid and fuel, and some of state-owned NEV key technologies have begun to enter the forefront of the world. After 2009, in order to promote the scale and industrialization of NEV, the government carried out demonstration and extension of NEV in pilot cities across the country. In addition, it also provided fixed subsidies to enterprises of NEV aiming to reduce the costs of production and the R&D. These measures greatly promoted the initial formation of China's NEV market and increased the enthusiasm of enterprises for NEV production and R&D. In recent years, China's annual sales of NEV have ranked first in the world for many years, and many China's independent brands have entered the top 20 of global NEV sales rank.

In general, the development of China's NEAI has achieved tremendous progress and brilliant grades compared with the early development of CAI. However, there are still some practical problems that require the government to attach great importance to systematical thinking and practical solutions (Zhao, 2018). The distribution of the NEAI is relatively scattered which is difficult to play the scale effect and regional cooperation mechanisms of Industry-University-Research, hindering the reduction of NEA costs and breakthroughs in key technology R&D. Insufficient infrastructure construction in each city further hinders promotion of the NEA market. In addition, the existing market has a strong dependence on government subsidies, which makes the market fails to give full play to the competition mechanism, resulting in the stagnation of technological R&D of individual enterprises. For these concerns, Chinese government began to gradually guide the transition of NEAI to market-oriented type. For example, it has adopted a sequence of declining subsidy policies and reduced fiscal and tax subsidies for NEV year by year, aiming to weaken the leading power of the government and make transition preparations for market mechanism to take over industrial development.

4.3.4 Case analysis

4.3.4.1 The significance of government-dominated GIUR system in the early stage of the industry

(1) Sufficient market demand scale is needed to promote independent innovation of enterprises in the early stage of industrial development. Schmookler (1966) pointed out that enterprises carry out innovation activities in order to pursue market profit, and market demand is the main reason for enterprise innovation. If the company expects that market demand will rise in the future, it will actively engage in innovation activities. The GIUR system guarantees the market scale of the HSR industry to a certain extent. Since January 2004, the State Council of the Communist Party of China considered and approved the "Medium- and-Long-Term Railway Network Plan" and formulated the HSR development plan from 2008 to 2016, which clarified the Chinese government's large-scale demand for HSR, including technical and product requirements, which makes the enterprises have a clear direction and sufficient motivation when carrying out independent innovation.

However, the development of the CAI in the early stage lacked the application of the GIUR system so that the government did not provide scientific guidance and planning for the technology and market needs of the automobile industry. On the contrary, excessive intervention in the development of the market caused the innovation of automobile enterprises to be restricted to varying degrees, which has led to the inability of the automobile industry to improve its independent innovation capabilities.

(2) High R&D risks and uncertainty exist in the early stages of industrial development. Innovation is a kind of risky activity, especially in the initial stage of an enterprise. As a result, companies tend to adopt low-level technologies and even delay or slow down innovation activities. The government-dominated GIUR system relatively reduced the R&D risks and uncertainty of the main body of research and innovation. On the one hand, the government provides the capital required for technological innovation to the R&D entities in the system at a low cost, and bears most of the risks of R&D failure. On the other hand, the long-term plan formulated by the government effectively implemented for a long time, thereby stimulating the innovation activities of the R&D entities. Technological R&D companies were more proactive in terms of technological investment and technological innovation, which eventually enable China’s HSR technology to successfully overtake developed countries at the forefront of technology and become a leader of global HSR technology.

In contrast to the CAI, the early development of the CAI was mainly dominated by local governments whose performance assessments were mainly based on the level of local economic development. Independent innovation means high risk, unstable returns, and great uncertainty. Some local governments are unwilling to take risks of innovation activities. Therefore, they restrain scientific research and innovation activities, and actively force enterprises to expand production scale and introduce foreign capital and advanced automobile brands to expand local market sales and stimulate economic development. As a result, companies gradually lost their motivation and determination for innovation and development. The weak awareness of competition and adversity led China's automobile companies to rely on the introduction and absorption of foreign technologies for joint venture production but lack of digestion and independent innovation of imported technologies, causing the CAI to gradually embark on the road of dependent development.

(3) A more comprehensive cooperation network is needed in the early stages of industrial development. The development of any industry is inseparable from the close and effective cooperative relationship between the various industrial subsystems. Only by promoting and developing each other's subsystems can we promote the further innovation and development of the entire industry. Under the guidance of GIUR system, China's HSR technology development achieved unified standards in the early stages, which has formed a close and effective cooperative relationship among the various innovation entities and improved implementation efficiency. In the end, China's HSR established a relatively complete cooperation network in basic research, technology application, equipment assembly and key components, which promoted the rapid improvement of the entire industry chain technology.

In the early stage of the development of the CAI, the government did not pay attention to the establishment of an industrial cooperation network and the unification of production technology standards and failed to effectively link and cooperate in the production of basic parts, vehicle assembly, and technological innovation. Without an effective cooperation network, the scattered innovation subjects could not play the synergistic effect that they should have on the overall promotion of the industrial chain, resulting in an imbalance in the dispersion and development of the various innovation subjects in the CAI.

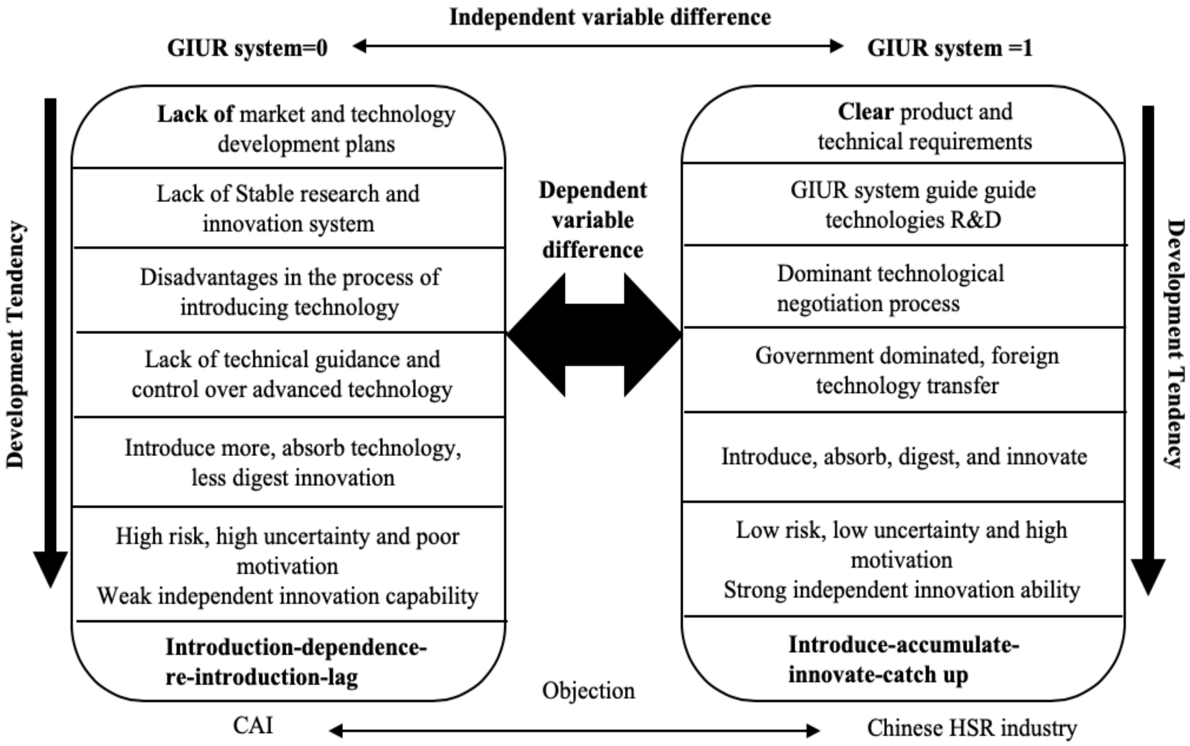
(4) Industrial policies that support industrial development require the powerful implementation of the state "from the central to the local, top to bottom". Industrial policies are often promulgated under the leadership of the central government of the country, and then notifications and requirements are issued from the central to the local and from the top to the bottom. However, in this process, it is easy for inconsistencies in policy guidance and support from the local and lower levels. Inconsistency and uneven support for industrial development in different places give rise to the phenomenon of local protectionism. But the government-dominated GIUR system promotes the implementation of industrial policies with a strong administrative nature and has administrative imperative requirements for R&D tasks, management systems, construction scope, and other aspects. Government employees at each level pressured by "promotion incentives" and "task accountability" pressures will pay special attention to their responsibilities and transfer the pressure step by step, thereby ensuring the synchronization and strong support for HSR construction from the central to the local and from top to bottom, making the early development of the HSR industry fully supported and guided by government and industrial policies. Although the CAI was guided by the central government's policy, the top-down policy requirements had not been well implemented due to the lack of guidance from the GIUR system. R&D tasks and management systems were not included in the work of local government who actually paid more attention to performance development and industrial expansion, and only focused on short-term benefits and ignored the importance of R&D innovation. It caused the stagnation of the CAI's technological level and the development of independent auto brands.

(5) Initial technological innovation in the industry requires a certain technological accumulation and a stable innovation body. The government-dominated GIUR system is relatively closed, and the internal body of the system is stable and unified, which provides a favorable research environment for the effective accumulation of technology and reduces the cost of technology introduction. The GIUR system enables the R&D entities within China's HSR industry to efficiently implement the government's requirements for R&D, and China's HSR companies can occupy a dominant position in the negotiation of technology introduction and technology transfer so that they can continuously carry out technical accumulation and innovation while introducing and absorbing international advanced technologies. Therefore, China’s HSR technology can quickly bridge the gap with advanced international countries.

However, in the early stage of the CAI, local governments and enterprises didn’t effectively and uniformly implemented the central government’s requirements for independent innovation in the automobile industry due to the lack of the application of the GIUR system. In the absence of technological accumulation and a mature scientific research and innovation system, the premature implementation of “market for technology” severely squeezed the development of domestic automobile companies, and their enthusiasm for independent scientific research and innovation was greatly frustrated. The government failed to play a role of forcing self-transformation and leading innovation in the process of introducing advanced technology, which caused CAI to blindly introduce and absorb the advanced technologies but lack independent innovation that ultimately results in the lack of independent innovation capabilities of the CAI.

In summary (shown in the Figure5), comparing with China’s HSR and automobile industries, the government-dominated GIUR system helps China’s HSR industry to quickly establish a stable scientific research and innovation system and helps the R&D entities to large-scale carry out the accumulation and independent innovation of the HSR technology in the process of bringing in and absorbing international advanced technology at low cost so as to achieve rapid breakthroughs in HSR key technologies. However, in the early stage of industrial development, the CAI did not pay attention to the combination of government domination and Industry-University-Research systems and misguided the technology development strategy of the automobile industry. As a result, the independent innovation capability of CAI had been at a low level before the 21st century and most domestic markets is monopolized by foreign brand cars. It can be seen that the application of the GIUR system is one of the key factors that cause the current development of the HSR industry and the automobile industry to be far apart. It has huge institutional advantages and significance in solving the problems faced by the early development of the industry.

Figure 5 Comparative analysis of the lack of GIUR system



4.3.4.2 Adjustment of government-dominated GIUR system at different stages

The previous paper explained the necessity and sufficiency of the government-dominated GIUR system to promote the rapid development of the industry in the early stages. At different stages of industrial development, the GIUR system needs to be adjusted to take full advantage of the system itself. The following will take NEAI as an example to analyze the characteristics of strategic emerging industries such as NEV and HSR at different stages and the need for adjustment of the GIUR system at corresponding stages.

(1) In the early stage of the industry, the government needs to play a leading role in promoting market formation and scientific research and innovation. At this stage, the industry is in the formative stage, the market size is small, and the technology level is low (Zhao, 2018). Emerging industries usually face some urgent issues at this stage.

On the one hand, when the product market is immature, most consumers have the characteristics of risk aversion, path dependence and lack of sufficient knowledge of new products. Therefore, market cultivation and expansion will face many obstacles, one of which is the insufficient demand that will seriously hinder the vertical advancement of emerging industries. Therefore, the initial market of emerging industries needs to be promoted and cultivated by the government through policy guidance. The Chinese government implemented a pioneering policy early in the development of the NEAI, for example, requiring local governments to publicly procure NEV, setting nationwide pilot cities to promote NEV, and setting requirements for the performance evaluation of the number of NEV promoted by local governments. These inductive and compulsory policies promoted the formation of the early NEV consumer market, and at the same time, increased the enthusiasm of domestic auto companies for NEV technology R&D.

On the other hand, the lack of technology reserves leads to the lack of commonality and key technologies in the early development of the industry. It is difficult for enterprises to fill the key technology gap through independent R&D in a short time. Therefore, the government needs to take the lead in promoting the formation of industrial innovation alliances and Industry-University-Research system and provide financial and technical support. It will promote the rapid accumulation of common technologies in emerging industries and breakthroughs in key technologies, which also helps to promote the development of industrial technologies to a high level. In the early years, the NEAI was highly valued by the government and was listed as a major national science and technology project. China quickly established an expert group composed of personnel from enterprises, scientific research institutions and universities to lead the direction of industrial technology R&D and promote the formation of industrial innovation alliances. It also provided a large amount of special R&D funds to support scientific research and innovation breakthroughs in the NEAI so that China's NEAI continue to accumulate technology during the early development, establish independent brands, and conduct market-based applications and promotion.

For strategic emerging industries such as NEAI, industrial policy, industrial technology and domestic market demand are the decisive factors to promote innovation and rapid development of such industries. The government-dominated GIUR system has provided tremendous help for the NEAI in terms of policy support, technology guidance, and promotion of market formation. Firstly, proactive government initiatives such as industrial development planning, pilot city promotion and government procurement and financial subsidies greatly promote the formation of the NEV market. Secondly, the government issued a number of industrial policies in the early stages of industrial development to support and guide the technological innovation of the NEAI (shown in the table13), so that R&D entities within China's NEAI have a clear direction for innovation and can boldly carry out technological accumulation and innovation activities with low cost, uncertainty and risks. Therefore, the cooperation mechanism of the GIUR system greatly improves the independent innovation capability and R&D enthusiasm of companies, thereby promoting the rapid development of the industry's initial technological level.

Table 13 Government measures related to the development of the NEAI in the early stage (Hou et al., 2015)

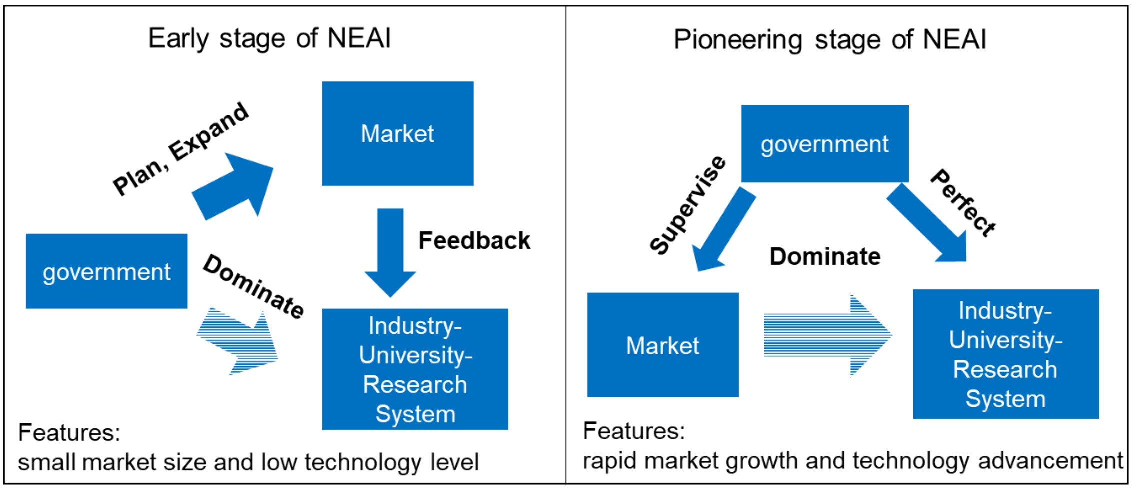
Time	Measures	Main Body	Category	Objective
2001.4	Major Projects Of "863" Plan for Electric Vehicle	Ministry of Science and Technology	Technology plan	Improve technical capabilities
2004.5	Automobile Industry Development Policy	Development and Reform Commission	Industrial policy	Cultivate a healthy consumer market; Improve enterprises R&D capabilities and industry concentration
2005.12	Guidance Catalog for Industrial Structure Adjustment	Ministry of Science and Technology, Development and Reform Commission, Ministry of Finance	Industrial policy	Guide the direction of industrial investment and promote industrial structure adjustment and optimization
2006.2	Outline of National Medium- and Long-Term Scientific and Technological Development Planning and Supporting Policies	State Council	Science and Technology Development Plan	Strengthen independent innovation capabilities and achieve technological breakthroughs
2006	Major Projects of "863" Plan for Energy Conservation and NEV	Ministry of Science and Technology	Technology plan	Improve technological innovation capabilities

(2) During the rapid growth of the industry, the government needs to weaken its leading role and guide the system to market-oriented transformation. At this stage, the industry has developed rapidly, the market size has initially formed, and the technology level has gradually matured (Zhao, 2018). In the early stage of industrial development, the government's compulsory forced the technical development of NEV onto the “fast track”. However, long-term government formulation and industrial policy guidance will instead break through the independent innovation momentum within the Industry-University-Research system. It is mainly reflected in: 1) the government’s long-term financial subsidies and industrial policy dominance can easily cause enterprises to have greater dependence on R&D, which is not conducive to play the subjective initiative of enterprises under the role of market mechanisms; In addition, with the withdrawal of government’s guidance and subsidies in R&D, the lack of NEV technology innovation direction and the increase in innovation costs become a major hidden concern for industrial development (Hou, Chen, Li & Duan, 2015); 2) the necessary condition for the sustainable development of the industry is a sufficient market demand scale, and the government’s promotion of the market through financial means is ultimately limited. Therefore, the government needs to actively cultivate the market during the period of rapid industrial development, so that the market can advance the industry continuously. On the one hand, the market can play a competitive mechanism to promote the scientific research and innovation of leading enterprises, which will help improve the overall innovation capacity of the industry, eliminate backward production capacity, and achieve optimal allocation of resources. On the other hand, the market-dominated Industry-

University-Research system can promote the connection between the market demand and Industry-University-Research system and make products more in line with consumer preferences and guide continuous industrial technology innovation while expanding the market size; 3)in the process of implementing financial subsidies and public procurement for emerging industries, the government will have local protectionism, which will damage the enthusiasm of non-local enterprises for development and is not conducive to regional cooperation and industrial integration of the NEAI. Therefore, in the mature stage of the industry, the GIUR system needs to be adjusted. The government should weaken its leading role and shift to the role of supervisor, establish a more complete market order, industry-related regulations and standardize the implementation of government preferential policies to assist the market to better promote the development of emerging industries.

China’s NEAI has developed rapidly in recent years, but the government has begun to reduce its subsidies for NEV and adopted mechanisms such as regressive subsidies policy to guide the NEAI to a market-oriented transformation and allow the market to play a leading role in resource allocation, so that enterprises can strengthen research and innovation and improve their own competitiveness. At present, the Chinese government is gradually reducing direct intervention in the NEV market and taking responsible for improving the policy system and industry standards, strengthening cooperation between upstream and downstream industries, and supporting the construction of supporting industrial facilities.

Figure 6 Adjustment of the GIUR system at different development stages of NEAI



Note：The direction and size of the arrows in the figure represent the direction and intensity of information transmission.

4.3.5 Case summary

Through the above case analysis of the CAI and NEAI, I can draw the following two obvious empirical conclusions: 1) the comparative results of the early development of the CAI and the NEAI prove that the government-dominated GIUR system has a significant promotion effect and institutional advantage for the early industrial development. In the early stage of industrial development, the GIUR system can greatly increase the willingness of enterprises to research and develop independently, promote the formation of regional innovation alliances and the Industry-University-Research. In addition, this system effectively guarantee the policy's support and correct guidance from the central to the local so as to better exert the latecomer advantages that through the introduction, absorption and digestion of a large number of international advanced technology to quickly shorten the technological gap, change from lagging behind to leading in a short period of time, and promote the rapid development and growth of the industry; 2) the government-dominated GIUR system needs to be adjusted to a market-oriented Industry-University-Research system after the industry entering a rapid growth and even mature period in order to give full play to the leading role of the market in scientific research innovation and resource allocation. The government-dominated GIUR system is conducive to the rapid development of the industry in the early stage, but long-term government domination or intervention in the market is not conducive to the sustainable development of the industry. Instead, it may cause problems such as excessive reliance on enterprises, imbalance of the Industry-University-Research system, and weakness of industrial research and innovation momentum. Therefore, the government needs to weaken its leading role and transform the Industry-University-Research system from a government-led market to a market-led one.

4.4 Conclusion and policy implication

(1) The government-dominated GIUR system is difficult to replicate

and promote on a large scale[1]

Through the combing of existing researches, the comparative analysis of cases between the CAI and HSR industry, and our investigation and research on the relevant departments and units of HSR, this study believes that the government-dominated GIUR system has a high promotion threshold, that is, it does not have the features of large-scale promotion. The great success of the GIUR system alone in the HSR industry is mainly attribute to several special features and I make the following summary. **Firstly,** the multifactorial technical opportunity. 1) Developed countries with advanced HSR technology often lack large-scale market applications while China has large-scale market application, leading to the fact that enterprises in technologically advanced countries possess technology but are unable to realize all-round development of technology. Therefore, China can obtain advanced technology at low cost, or even get full support from advanced technology companies, eventually achieving technical overtaking; 2) the innovation capabilities of China's HSR are produced to continuously meet the higher technical requirements put forward by the government as an industry management agency and railway operating unit, and are improved in the process of constantly solving practical

[1] The detailed content for this is available upon request

scientific, technical and engineering problems. In particular, China's geological and climatic conditions are complex and diverse, and high-speed EMUs that are put into operation in China must be able to adapt to various extreme natural conditions, but the imported prototypes totally cannot meet these technical requirements, which forces Chinese companies to make independent innovations and technological breakthroughs in response to China's special geological conditions; 3) during the period of introducing the international advanced HSR technology, some companies that mastered advanced HSR technology happened to have an operating crisis and were on the verge of bankruptcy. Therefore, it is so fortunate for China that can be able to introduce full-vehicle and full-vehicle manufacturing technologies at low prices. Above three factors have provided the necessary "stairs" for the process of introducing, absorbing and re-innovating advanced HSR technology. However, these are too difficult to easily happen to other industry in reality. Therefore, extensively replicating the GIUR system to other industry is not easy.

Secondly, long-term accumulated technical capability foundation. In the mid-to-late 1990s, the China's railway system began to decentralize power to various road bureaus, and each road bureau began to actively initiate independent R&D and innovation. Although the R&D of various EMUs such as "China Star" failed, they have tempered the company's R&D capabilities, accumulated human capital, and also accumulated a certain technical foundation, such as breakthrough technical progress in internal combustion EMUs, power decentralized electric EMUs, power concentrated EMUs and so on. It is precisely because of this technological foundation that China can achieve innovative breakthroughs in the fields of HSR plateau alpine railways, and heavy-load railways.

Third, China is experienced in digesting, absorbing and re-innovating models after technology introduction. It is very difficult for technologically backward countries to directly carry out technological R&D due to the existence of risks and uncertainties. Therefore, most developing countries welcome foreign investment very much, hoping that they will invest in domestic industries with relatively high technological complexity. In this way, technology and knowledge will spill over to the domestic economy. And the degree of China's foreign investment opening is almost ahead of the entire developing countries. More importantly, China has extensively used the reverse technology imitation model in the process of opening up, which means that China's enterprises not only rely on technology imitation, but also build their own competitive advantages by studying and understanding the design concepts behind the products, and systematically integrating and innovating introduced technologies. For most developing countries, they seem to be able to form unique competitive advantages by selecting advanced technologies and combining them with their own endowment of economy and factor advantages but it's still difficult for them to land the introduced advanced technology even if the cost of technology introduction is not high. So, the application of GIUR in these countries is difficult to achieve the same huge benefits as China's HSR industry.

(2) The promotion and application of the GUIR system needs to actively create "preconditions"

Although I have concluded that the GIUR system is unlikely to be replicated on a large scale, some aspects of application of the GIUR system in the construction of China's HSR are still worthy of reference by other international or regional governments. At the aspect of industry policy formulation, there are also certain policy implications.

Firstly, the capital and technology-intensive public goods industry with a large positive externality need a powerful push from central government. The pure Tiebout club-style public goods supply method is unable to complete this task. Even in the United States, it was privatized only after the construction of the entire North American continent railway network. **Secondly**, seize technical opportunities. Advanced technology means greater profit margins, so it is not uncommon for advanced technology companies to fall into a business crisis, but if such technological opportunities arise, the government and enterprises must possess such ability and enthusiasm for technology introduction or transfer, and actively absorb and digest the design and manufacturing information of advanced products, so as to supplement knowledge and accumulate technical capabilities for independent innovation (Lu, 2020). **Thirdly**, the government needs to actively create technological opportunities. Market opportunities do not necessarily lead to innovation and technological independence, such as CAI. Market opportunities without technological opportunities can only lead to technological imitation and productive investment. If the government builds strategic technological opportunities based on forming competitive advantages and taking advantage of the situation, it can lead to higher-intensity technology learning for enterprises to achieve independent technological innovation.

(3) The GIUR system needs to make appropriate adjustments in different development of technology.

The foregoing theoretical and empirical analysis shows that the original government-dominated GIUR system has two limitations when it is applied to promote technological innovation in the “latecomer industry”. On the one hand, the GIUR system is difficult to be replicated on a large scale, and there is a high promotion threshold for it. On the other hand, the government-dominated GIUR system cannot further promote technological innovation. However, China's HSR has achieved great achievements and is inextricably linked to the application of government-dominated GIUR system. To give full play to its institutional advantages and be able to be effectively applied to other industries, it needs to adopt necessary adjustment strategies at the appropriate stage of technological development. **In the early stages of industrial (technology) development, the government should play a leading role,** scientifically plan the direction of technology R&D, vigorously support and encourage enterprises to conduct basic R&D and then actively carry out the introduction, absorption and digestion of the international advanced technology, so as to fully utilize the "backward advantages" to achieve the catch-up of key technology. **In the technology pioneering stage (industry maturity stage), the government should appropriately weaken its leading role, let the market play a more leading role in technological innovation, and transform the government-dominated Industry-University-Research system into a market-oriented Industry-University-Research system.**

More specifically, the policy implication are as follows. **First of all**, the leading role of the government in early stage needs to be played specifically in guiding scientific research and innovation, expanding market size, unifying technical standards, and strengthening cooperation among R&D entities. And it is necessary to strengthen the close coordination from the central to the local and from top to bottom in order to implement the relevant industrial support policies formulated by the state simultaneously and consistently instead of letting the government leadership and industrial support policies flow into the form or giving birth to the phenomenon of inequality on policy support. **Secondly**, the government needs to prevent local protectionism from hindering the large-scale development of regional industries through strengthening market supervision and perfect relevant laws and regulations in the process of leading market promotion in the initial stage. **Thirdly**, the GIUR system should not only promote cooperation between different R&D entities, but also promote industrial cooperation between upstream and downstream industries and the regional agglomeration of industries, so as to bring about economies of scale and collaborative innovation mechanisms. **Finally**, when the government-dominated GIUR system is transformed to be a market-dominated Industry-University-Research system, the government should gradually weaken its leading role and appropriately adjust the policy support intensity and direction according to the development of market size and industrial development, so as to enable all kinds of enterprises in the industry can smoothly transit to the industrial development stage dominated by market.

Chapter 5 Conclusions and policy implications

This article investigates the experience and outcomes of HSR development in China. HSR plays an important role in China's economic and social development. HSR mainly affects the urban economy, industrial development, labor and other social factors by changing the connectivity and accessibility between cities (Hou & Li, 2011; Cao et al., 2013; Monzón et al., 2013; Kim and Sultana, 2015; Shaw et al., 2014; Diao, 2018; Liu & Zhang, 2018). As a large-scale infrastructure investment, HSR brings new growth opportunities to urban economic development and promotes economic growth (Song et al., 2015; Ding & Ni, 2017; Zhang, 2017; Liu & Li, 2017; Ahlfeldt & Feddersen, 2017).

The research findings have several important policy implications. **Firstly**, I find that siphon effect takes time and it happens easier only within a certain region. Therefore, the siphon effect should not be a big concern for those less developed countries if they plan to build HSR to connect their neighboring relatively developed countries, the Kuala Lumpur–Singapore HSR project, for example. It can boost the commuting and knowledge exchange between the two countries which benefit Malaysia a lot. Despite this, it is not easy for social economic resources like labor and capital (factories) to migrate across the border from Malaysia to Singapore.

Secondly, I find that connecting to HSR network is more beneficial for the less developed economies but it will only widen the urban-rural income gap in less developed regions, especially in minor nodes with poor endowment of economy and economic spillover effect. Therefore, the Chinese government should pay more attention to rural development in such areas and provide economic support when the HSR network is connected, such as actively improving the infrastructure services in these areas and strengthening the planning of talent introduction and industrial development policies in these areas.

Finally, this study finds that the system of GIUR is more suitable for the early stage of HSR development, while in the advanced stage of technology, the GIUR system needs to be adjusted. Our analysis implies that at the current and future stage where China plays a leading role rather than following the world HSR technology development, the initial GIUR system should be adjusted to be more competitive and market-oriented. In addition, through a horizontal comparison of the application of the GUIR system in the HSR industry and other industries (CAI and NEAI), I argue that the GUIR system has good sustainability in promoting industrial scientific research and innovation, but the promotion of the system has a higher threshold, which means that it does not have good replicability.

Reference

Acemoglu, D., & Zilibotti, F. (1997). Was Prometheus Unbound by Chance? Risk, Diversification, and Growth. *Journal of political economy, 105* (4), 709-751.

Ahlfeldt, G. M., & Feddersen, A. (2018). From periphery to core: measuring agglomeration effects using high-speed rail. *Journal of Economic Geography, 18* (2), 355-390. doi:10.1093/jeg/lbx005

Andersson, D. E., Shyr, O. F., & Fu, J. (2010). Does high-speed rail ac cessibility influence residential property prices? Hedonic estimates from southern Taiwan. *Journal of Transport Geography, 18* (1), 166-174. doi: 10.1016/j.jtrangeo.2008.10.012

Arya, A., Glover, J., & Mittendorf, B. (2010). Hierarchical reporting, ag gregation, and information cascades. *Managerial & Decision Economics, 27* (5), 355-362.

Bac, M., & Kucuksenel, S. (2006). Two types of collusion in a model of hierarchical agency. *Journal of Institutional and Theoretical Economic s-Zeitschrift Fur Die Gesamte Staatswissenschaft*, *162* (2), 262-276. doi: 10.1628/093245606777583585

Baldwin, R. E., & Okubo, T. (2006). Heterogeneous firms, agglomeratio n and economic geography: spatial selection and sorting. *Journal of Eco nomic Geography, 6* (3), 323-346. doi:10.1093/jeg/lbi020

Behrens, K., Duranton, G., & Robert-Nicoud, F. (2014). Productive Citie s: Sorting, Selection, and Agglomeration. *Journal of Political Economy, 122* (3), 507-553.

Bloom, N., Eifert, B., Mahajan, A., McKenzie, D., & Roberts, J. (2013). Dose Management Matter? Evidence from India. *The Quarterly Journal of Economics*, *128* (1), 1-51. Retrieved from https://www-jstor-org.libpro xy1.nus.edu.sg/stable/26372493

Bowes, D. R., & Ihlanfeldt, K. R. (2001). Identifying the impacts of rail transit stations on residential property values. *Journal of Urban Economics, 50* (1), 1-25. doi:10.1006/juec.2001.2214

Cao, J., Liu, X. C., Wang, Y. H., & Li, Q. Q. (2013). Accessibility im pacts of China's high-speed rail network. *Journal of Transport Geograp hy, 28*, 12-21. doi:10.1016/j.jtrangeo.2012.10.008

Cavailhes, J., Gaigne, C., Tabuchi, T., & Thisse, J. F. (2007). Trade an d the structure of cities. Journal of Urban Economics, *62* (3), 383-404. doi:10.1016/j.jue.2006.12.002

Cheng, P., Liu, X. L., Chen, A., & He, Y. B. (2011). Basic Research and Catching up With Chinese Industrial Technology: A Case Study of The HSR Industry. *Management Review, 23* (12), 46-55. (in Chinese)

Chen, L. W., Yang, K. Z., & Shen, T. Y. (2009). The Difference Between Economic Agglomeration Density and Labor Productivity: An Empirical Study Based on Beijing Microdata. *Economic (Quarterly), 8* (01), 99-114. (in Chinese)

Ciccone, A., & Hall, R. E. (1996). Productivity and the Density of Economic Activity. *American Economic Review, 86* (1), 54-70.

Cohen, J. P., & Brown, M. (2017). Does a new rail rapid transit line a nnouncement affect various commercial property prices differently? Regi onal *Science and Urban Economics, 66*, 74-90. doi:10.1016/j.regsciurbec o.2017.05.006

Combes, P. P., & Lafourcade, M. (2004). Trade Costs and Regional Disparities in A Model of Economic Geography: Structural Estimations and Predictions for France. *Unpublished Manuscript*.

Davis, J. C., & Henderson, J. V. (2008). The Agglomeration of Headquarters. *Regional Science and Urban Economics, 38* (5), 445-460.

Desmet, K., & Rossi-Hansberg, E. (2013). Urban Accounting and Welfare. *American Economic Review, 103* (6), 2296-2327. doi:10.1257/aer.103.6.2296

Deng, C., & Xu, M. (2019). The Non-linear Impact Mechanism of Financial Development on Chinese Urban-Rural Income Gap——Based on the Dual Perspectives of Scale and Structure. *Nanjing Journal of Social Sciences,* (06), 8-18. (in Chinese)

Diao, M. (2018) Does Growth Follow the Rail? The Potential Impact of HSR on the Economic Geography of China. *Transportation Research Part A, 113*, 279-290.

Ding, R. X., & Ni, P. F. (2017). The New Pattern of Regional Economic Space in China: The Perspective of Urban Real Estate. *China Industrial Economics,* (05), 94-112. (in Chinese)

Dong, Y. M., & Zhu, Y. M. (2016). Can HSR Construction Reshape Chinese Economic Spatial Layout: A Regional Heterogeneity Perspective Based on Employment, Wages and Economic Growth. *China Industrial Economics,* (10), 92-108. (in Chinese)

Duranton, G., & Puga, D. (2000). Diversity and specialisation in cities: Why, where and when does it matter? *Urban Studies, 37* (3), 533-555. doi:10.1080/0042098002104

Duranton, G., & Puga, D. (2005). From sectoral to functional urban spe cialisation. *Journal of Urban Economics, 57* (2), 343-370. doi:10.1016/j.j ue.2004.12.002

Falkinger, J., Fehr, E., Gachter, S., & Winter-Ebmer, R. (2000). A simple mechanism for the efficient provision of public goods: Experimental evidence. *American Economic Review, 90* (1), 247-264. doi:10.1257/aer.90.1.247

Florida, R., Mellander, C., & Stolarick, K. (2008). Inside the black box of regional development - human capital, the creative class and tolerance. *Journal of Economic Geography, 8* (5), 615-649. doi:10.1093/jeg/lbn023

Forslid, R., & Okubo, T. (2014). Spatial sorting with heterogeneous firms and heterogeneous sectors. *Regional Science and Urban Economics, 46*, 42-56. doi:10.1016/j.regsciurbeco.2014.02.005

Fu, Y. M., & Gabriel, S. A. (2012). Labor Migration, Human Capital Agglomeration and Regional Development in China. *Regional Science and Urban Economics*, *42* (3), 473-484.

Fujita, M., Krugman, P. R., & Venables, A. J. (1999). The Spatial Economy: Cities, Regions, and International Trade. *Mit Press Books, 86* (1), 283-285.

Fujita, M. & Mori, T. (2005). Frontiers of the New Economic Geography. *Papers in Regional Science*, *84* (3), 377-405.

Fujita, M., & Ogawa, H. (1982). Multiple equilibria and structural transition of non-monocentric urban configurations . *Regional Science & Urban Economics, 12* (2), 161-196.

Gao, Y. Y., Su, W., & Wang, K. N. (2019). Does High-speed Rail Boost Tourism Growth? New Evidence from China. *Tourism Management, 72*, 220-231.

Geng, B., Bao, H. J., & Liang, Y. (2015). A Study of the Effect of a HSR Station on Spatial Variations in Housing Price Based on the Hedonic Model. *Habitat International, 49*, 333-339.

Glaeser, E. L., & Kahn, M. E. (2004). Chapter 56 – Sprawl and Urban Growth. *Handbook of Regional & Urban Economics, 4*, 2481-2527.

Hall & Peter. (2009). Magic Carpets and Seamless Webs: Opportunities and Constraints for High-Speed Trains in Europe. *Built Environment, 35* (1), 59-69.

He, D., & Zhuo, Y. Q. (2016). An Empirical Analysis of the New Energy Auto Industry Industry-University-Research Innovation Network from the Perspective of Social Networks——Taking Three Northeast Provinces as Examples. *Journal of Technical Economic*s, *35* (12), 52-59. (in Chinese)

He, J., Lv, T., Huang , Y. H., & Jiang, H. (2018). Incentive Structure and Capacity Accumulation of Technology Overtaking: A Case Study Based on Chinese HSR. *Management World, 34* (10), 191-207. (in Chinese)

Hensher, D., Li, Z., & Mulley, C. (2012). The Impact of HSR on Land and Property Values: A Review of Market Monitoring Evidence from Eight Countries. *Road & Transport Research*, *21* (4), 3-14.

Holmstrom, B. (1989). Agency costs and innovation. *Journal of Economic Behavior & Organization, 12* (3), 305-327.

Hou, Q., & Li, S. M. (2011). Transport Infrastructure Development and Changing Spatial Accessibility in the Greater Pearl River Delta, China, 1990-2020. *Journal of Transport Geography, 19* (6), 1350-1360.

Hou, Q. J., Chen, K. H., Lin, J., & Duan, P. L. (2015). Research on the Functional Evolution of Chinese New Energy Automobile Industry Innovation System——Also on the Role of Government Measures. *Journal of Industrial Technological Economic*s, *34* (03), 12-25. (in Chinese)

Huang, Z. K., Liu, J. Y., & Ma, G. R. (2016). Geographic Location, China Railways High-speed and Information: Evidence from Chinese IPO market. *The Journal of World Economy,* (10), 127-149. (in Chinese)

Isaac, R. M., Mccue, K. F., & Plott, C. R. (1985). Public goods provision in an experimental environment . *Journal of Public Economics, 26* (1), 51-74.

Inoue, H., Nakajima, K., & Saito, Y. U. 2017. The Impact of the opening of high-speed rail on innovation. *RIETI.*

Jiang, M. R., Fan, Y., Xia, Y., Chen, Q. R., & Yao, Y. (2017). Environmental Impact and Economic Assessment of Chinese HSR Investments. *China Population, Resources and Environment,* (02),75-83. (in Chinese)

Jiang, W. (1994). The Reform of State-owned Enterprises and the Problem of a Principal Agent. *Economic Research Journal,* (11), 18-21+34. (in Chinese)

Kim, H. & Sultana, S. (2015). The Impacts of HSR Extensions on Accessibility and Spatial Equity Changes in South Korea from 2004 to 2018. *Journal of Transport Geography, 45*, 48-61.

Li, C. T., & Song, M. (2010). Innovation Activities in Chinese Manufacturing Firms: The Roles of Firm Ownership and CEO Incentives. *Economic Research Journal, 45* (05), 55-67. (in Chinese)

Li, H. C., Linda, T., & Hu, S. X. (2016). Agglomeration and Equalization Effect of HSR way on Cities in China. *The Journal of Quantitative & Technical Economics, 33* (11), 127-143. (in Chinese)

Li, X. Z., Ji, X. L., & Zhou, L. L. (2017). Can HSR way Improve Enterprises' Resource Allocation? Micro-Evidence from the Annual Survey of Industrial Firms in China and HSR way Geographic Data. *Economic Review,* (06), 3-21. (in Chinese)

Li, X. S., & Sun, B. W. (2017). Does Chinese HSR Promote Regional Manufacturing Agglomeration? —— Evidence from Cities along Beijing-Guangzhou HSR way Line. *China Soft Science,* (07), 81-90. (in Chinese)

Lin, X. Y., Zhang, A. P., & Hao, Y. P. (2017). Research on the Theory of Triple

Helix of Chinese HSR way Technology Innovation. *Journal of Beijing Jiaotong University (Social Science Edition), 16* (02), 22-33. (in Chinese)

Lin, Y. F. (2010). New Structural Economics: A Framework for Reconstructing Development Economics. *Economics (Quarterly), 10* (01),1-32. (in Chinese)

Lin, Y. T. (2017). Travel Costs and Urban Specialization Patterns: Evidence from Chinese HSR way System. *Journal of Urban Economics, 98*, 98-123.

Liu, L. W., & Zhang, M. (2018). HSR Impacts on Travel Times, Accessibility, and Economic Productivity: A Benchmarking Analysis in City-Cluster Regions of China. *Journal of Transport Geography, 73*, 25-40.

Liu, Y. Z., & Li, Y. (2017). HSRs and City Economic Growth in China. *Journal of Financial Research*, (11), 18-33. (in Chinese)

Long, Y., Li, Y., & Song, H. (2019). The impact of HSR way Network on Investment Performance of Venture Capital. *Economics Perspectives, 695* (01), 78-93. (in Chinese)

Long, Y., Zhao, H. D., Zhang, X. D., & Li, Y. (2017). Venture Capital under the Spatiotemporal Compression——HSR Opening and Regional Changes of Venture Capital. *Economic Research Journal, 52* (04), 195-208. (in Chinese)

Lucas, R. E., & Rossi-Hansberg, E. (2002). On the internal structure of cities. *Econometrica, 70* (4), 1445-1476. doi:10.1111/1468-0262.00338

Lu, F. (2020). *XinHuo*: China People's University Press. 288-426. (in Chinese)

Ma, J., Liu, X. D., Chen, Y. S., Wang, G. P., Zhao, X., He, Y. L., Xu, S. W., Zhang, K., & Zhang, Y. X. (2018). Chinese New Energy Automobile Industry and Technology Development Status and Countermeasures. *China Journal of Highway and Transport, 31* (08), 1-19. (in Chinese)

Ma, Y., & Zhen, Z. H. (2017). Cooperation and Competition in Chinese HSR Innovation: A New Institutionalism Perspective. *Journal of Shanghai University of International Business and Economics, 24* (04), 73-80. (in Chinese)

Melitz, M. J. (2003). The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity. *Econometrica, 71* (6), 1695-1725.

Mills, E. S. (1967). An Aggregate Model of Resource Allocation in a Metropolitan Area. *American Economic Review, 57* (2), 197-210.

Monzon, A., Ortega, E., & Lopez, E. (2013). Efficiency and spatial equity impacts of high-speed rail extensions in urban areas. *Cities, 30*, 18-30. doi:10.1016/j.cities.2011.11.002

Preston, J. & Wall, G. (2008). The Ex-Ante and Ex-Post Economic and Social Impacts of the Introduction of High-Speed Trains in South East England. *Planning Practice & Research, 23* (3), 403-422.

Qin, Y. (2017). No County Left Behind? The Distributional Impact of HSR Upgrades in China. *Journal of Economic Geography, 17* (3), 489-520.

Rosen, S. (1974). Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition. *Journal of Political Economy, 82* (1), 34-55.

Sasaki, K., & Mun, S. I. (1996). A Dynamic Analysis of Multiple-Center Formation in a City. *Journal of Urban Economics, 40* (3), 257-278.

Sasaki, K., Ohashi, T., & Ando, A. (1997). High-speed rail transit impact on regional systems: does the Shinkansen contribute to dispersion? *The annals of regional science, 31* (1), 77-98.

Jacob, S. (1966). *Invention and Economic Growth*. Boston. Harvard University Press

Shao, S., Tian, Z. H. & Yang, L. L. (2017). HSR and Urban Service Industry Agglomeration: Evidence from Chinese Yangtze River Delta Region. *Journal of Transport Geography, 64*, 174-183.

Shaw, S. L., Fang, Z. X., Lu, S. W., & Tao, R. (2014). Impacts of high speed rail on railroad network accessibility in China. *Journal of Transport Geography, 40*, 112-122. doi:10.1016/j.jtrangeo.2014.03.010

Slezak, S. L., & Khanna, N. (2000). The Effect of Organizational form on Information Flow and Decision Quality: Informational Cascades in Group Decision Making. *Journal of Economics & Management Strategy, 9* (1), 115-156. doi:10.1111/j.1430-9134.2000.00115.x

Song, W. J., Zhu, Q., Zhu, Y. M., Kong, C. C., Shi, Y. J., & Gu., Y. T. (2015). The Impacts of HSR ways for Different Scale Cities. *Economic Geography, 35* (10), 57-63. (in Chinese)

Su, H. J., & Zhao, J. (2011). Sectoral Specialization, Functional Specialization and Growth in Cities——Evidences from Panel Data on Chinese Prefecture-level City. *China Industrial Economics,* (04), 25-34. (in Chinese)

Venables, A. J. (2011). Productivity in cities: self-selection and sorting. *Journal of Economic Geography, 11* (2), 241-251. doi:10.1093/jeg/lbq040

Wang, L., & Duan, X. J. (2018). High-speed rail network development and winner and loser cities in megaregions: The case study of Yangtze River Delta, China. *Cities, 83*, 71-82.

Wang, Y. F., & Ni, P. F. (2016). Economic Growth Spillover and Regional Space Optimization under the Influence of HSR way. *Chinese industrial economy,* (02), 21-36. (in Chinese)

Wei, S. H., Chen, Y. K., & Lu, S. H. (2016). Urban Sprawl, Multi-center Agglomeration and Productivity. *China Industrial Economics,* (08), 58-75. (in Chinese)

Yan, C. L., & Gong, L. T. (2014). Is Infrastructure Investment Open to Private Capital? *Economic Science,* (06), 41-52. (in Chinese)

Yang, Q., Ji, Y., & Wang, Y. N. (2019). Can HSR way Improve the Accuracy of Analysts' Earnings Forecasts? Evidence from Listed Companies. *Journal of Financial Research, 465* (03), 168-188. (in Chinese)

Ye J. Y., Lin, J., Zhang, P. F., & Cao, S. W. (2019). Understanding the Unique Role of State-owned Enterprises: The Knowledge Spillover Perspective. *Economic Research Journal,* (06), 40-54. (in Chinese)

Yoshino, Naoyuki & Abidhadjaev, Umid, Impact of Infrastructure Investment on Tax: Estimating Spillover Effects of the Kyushu High-Speed Rail Line in Japan on Regional Tax Revenue (June 1, 2016). ADBI *Working Paper* 574, Available at SSRN: https://ssrn.com/abstract=2787604.

Zhang, J. (2017). HSR Construction and County Economic Development: The Research of Satellite Lighting Data. *Economics (Quarterly), 16* (04), 1533-1562. (in Chinese)

Zhang, K. Z., & Tao, D. J. (2016). The Economic Distribution Effect of Transportation Infrastructure——Evidence from the Opening of HSR. *Economic Perspectives,* (06), 62-73. (in Chinese)

Zhang, L. (2010). Why does the Emerging Economy Choose A Government-led Financial System. *The Journal of World Economy, 33* (09), 134-158. (in Chinese)

Zhang, M. T., Yu, F., Zhong, C. B., & Lin, F. Q. (2018). HSR ways, Market Access and Enterprises' Productivity. *China Industrial Economics, 362* (05), 138-157. (in Chinese)

Zhao, F. Q. (2018). Thoughts on the New Role of Government to Ensure the Sustainable Development of Chinese New Energy Vehicle Industry. *Auto Manufacturing Engineer,* (1), 18-22. (in Chinese)

Zhao, X. Q. (2013). Independent Innovation of Chinese Auto Industry——Analysis of the System Roots of the Strategy Failure of Market for Technology. *Journal of Zhejiang University (Humanities and Social Sciences Edition), 43* (03), 164-176. (in Chinese)

Zheng, S. Q., & Kahn, M. E. (2013). Chinese Bullet Trains Facilitate Market Integration and Mitigate the Cost of Megacity Growth. *Proceedings of the National Academy of Sciences of the United States of America, 110* (14), 1248-1253.

Zhou, H. L., Chu, M. C., Fu, Z. X., Xu, W. H., & Zhou, Z. C. (2019). Research on the Measurement of the Cooperation of Industry-University-Research of New Energy Vehicles in China Based on Patent Analysis. *Henan Science, 37* (04), 661-667. (in Chinese)

Zhou, M. S., & Zhang Q. Q. (2016). "Face Project" or "True Talent"? A Research Based on the Relationship between Political Promotion Incentive and Innovation Activity in State-owned Listed Companies. *Management World,* (12), 116-32+87-88. (in Chinese)

Zhou, Y. L., Yang, J. D., Huang, Y. H., & Geoffrey, J. D. H. (2018). Study on the Impact of HSR on Land Price and Its Mechanism: Evidence from Micro Land Transactions. *China Industrial Economics, 362* (05), 119-137. (in Chinese)

Zong, T. T., Li, F. A., & Deng, G. J. (2018). Comparative Analysis and Enlightenment of the Development of HSR way Industry and Automobile Industry in China. *Chinese Commerce,* (26), 162-163. (in Chinese)