Dispersion of Agglomeration through Transport Infrastructure

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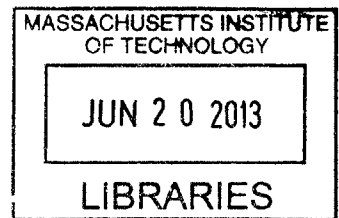Master of Science, Peking University (2007)

Submitted to the Department of Urban Studies and Planning
in Partial Fulfillment of the Requirements for the Degree of

Doctor of Philosophy in
Urban and Regional Planning

at the

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
June 2013

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ABSTRACT

My dissertation aims to assess transport infrastructure's influence on the productivity, scale and distribution of urban economic activities through changing intercity accessibility. Standard project-level cost-benefit analysis fails to capture the economy-wide impacts in justifying investments in the transport sector. I propose a research framework that: (1) synthesizes the spatial emphasis of the New Economic Geography theories with the temporal perspective of the growth theories; (2) extends the scope of agglomeration effects by highlighting a city's access to external resources as a partial substitute for its own endowment; and (3) bridges the spatial discontinuity between regional and urban studies by introducing intercity accessibility as a determinant of intra-city land uses. I apply the proposed framework to study the spatial economic impacts of China's high-speed rail system at network, corridor, and node (city) levels.

The GIS-based spatial analyses of the network accessibility measured by three alternative indicators consistently illustrate that, the extensive transport investments during 2001-2010 have reduced the disparities in accessibility among cities in China, with the coefficient of variation dropping by nearly 50%. Differently, estimations from the panel data models shed light on the complexity in the relationship between accessibility and economic activities, which consists of both generative and redistributive components and simultaneously leads to convergent and divergent economic outcomes. Yet, empirical evidence denies the saturation effects of accessibility. Extended estimations using different instrument variables (IV) partially relieve the concerns on endogeneity issues. Further analyses of a particular transport corridor reveal that, with HSR, the regional urban hierarchy is evolving towards a more interwoven structure, with major cities reaching for overlapped hinterlands. HSR's short-run influences on the location choice of economic activities vary in terms of spatial coverage and are not necessarily restricted to cities with direct HSR access. The city-level comparative case studies indicate that HSR stations introduce external demand for urbanization, leading to new development once matching land supply exists. A cluster analysis of ten demand-supply-related factors generates three prototypes of station-area development. For each type, public and private sectors have adopted different institutional arrangements, yet common challenges exist in preventing speculative investments and matching the development portfolio with the composition of actual needs.

The findings lead to important policy implications for decision-makers in China. First, China has not exhausted the agglomeration benefits dispersing through transport infrastructure given the remarkable regional disparities. From an economic development perspective, HSR lines connecting coastal megacities with lagging inland cities are effective in reducing disparities in accessibility and should be encouraged. Second, for the appraisal of major transport projects including HSR, it is reasonable to extend the standard CBA to include the generative benefits; to evaluate the impacts on regional disparities based on redistributive effects; and to avoid overbuilding through identification of saturation effects. Third, HSR has the potential to reshape the path of urbanization. The evolution of the urban hierarchy towards a more interwoven structure may eventually raise the need for adapting administrative arrangements to fit the actual economic interaction. As to urban configuration, HSR stations may catalyze compact urbanization around transit facilities. However, local governments should avoid using HSR stations as a vehicle for excessive generation of land concession revenues.

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ACKNOWLEDGEMENTS

My deepest gratitude goes to Professor Karen R. Polenske. To me, Karen is an admirable adviser and an amiable family member. She taught me the core quality necessary to survive in the academic world--the ability to think independently and critically. She guided me through every key step of the Ph.D. program, pulling me out of intellectual difficulties many times.

I sincerely thank Professor William C. Wheaton, who encouraged me to think like an economist. An urban planner by training, I am attracted to and enlightened by the rigorousness of economic theories and methods. It is Professor Wheaton who opened the door to that magic world for me.

I am truly grateful to Dr. Yu-Hung Hong for the hands-on advice in my dissertation writing, from building the framework to sharpening the arguments. His hearty support went far beyond this, even at the cost of his own inconvenience.

I express my deep appreciation to Professor Ying Jin at Cambridge University, the U.K., and Professor Jinhua Zhao at University of British Columbia, Canada, for their inspiring comments on my research. I thank Professor Hongliang Zhang and Dr. David Block-Schachter for assisting me in the techniques of econometric modeling. I thank Xiaohu Dong for his kindly help on coding and data mining. I thank Professor Frank Levy, Professor Joe Ferreira and Professor Johan Carmin for teaching me the methods of research design and building my analytic capacity. I thank Ms. Sandra Wellford for her guidance on fulfilling the requirements of the PhD program. I thank Ms. Pamela Siska for her enormous help in reviewing the writing of my dissertation.

I thank my dearest girls, Yang Chen, Yuan Xiao, Yue Hou, Jingsi Xu, Shan Jiang, Xin Li, Zhengzhen Tan, Feifei Zhao and Lulu Xue, for the joyful moments we shared and for the moral support during my hard times. I thank my officemates Feng Fu, Hongtao Liu and Liyan Xu for the enlightening conversations on my research topic.

I owe many thanks to Mr. John Scales for offering me the opportunity to work with the World Bank. I particularly thank Dr. Zhi Liu for guiding me through the early stage of my career development. I extend my appreciation to Mr. Richard G. Bullock, Mr. Binyam Reja and Mr. Gerald P. Ollivier for their kindly guidance and support for my work. I thank the team of young professionals, Li Qu, Yi Yang, Shuai Ren, Xi Zhao, Hongye Fan, Nanyan Zhou, Runze Yu and Andrew Salzberg for the enjoyable experience of working together.

The years I spent at Peking University are equally unforgettable. I sincerely thank Professor Kongjian Yu, Professor Dihua Li and Professor Tiyan Shen--without their support I could not have obtained the opportunity to start my academic endeavor at MIT.

Special gratitude I give to Quentin Feng Li, for the love, tolerance, encouragement, and the beautiful memories.

To my parents

FANG Zaichao, CHENG Caiyun

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Chapter I INTRODUCTION

Exploring the relationship between transport investments and economic development has

a long tradition. Recent progress in transport technology, particularly the construction of the

high-speed rail (HSR) system in China at an unprecedented scale, has again raised wide research

enthusiasm among scholars and policy-makers in this domain. As part of the continuous efforts

to extend the theoretical horizon and enrich the empirical evidence under this topic, I examine

how transport infrastructure influence urban economic performance through changing intercity

accessibility and factor mobility. The purpose of my research is to develop an integrated analytic

framework to assess transport infrastructures' influences on urban economic activities, which is

currently missing from the standard project-level cost-benefit analyses. I applied this framework

to analyze the spatial-economic influence of China's HSR system. I choose China as the case for

three reasons: (1) China has dedicated huge amount of fiscal resources to constructing the most

ambitious HSR network in the world, and (2) China has social economic features that differ from

the mature economies, and (3) the rapidness of changes in China enables my analyses over

relatively short observation period.

HSRs are usually passenger-dedicated lines, with direct impacts on the time and costs of

passenger travel. The measurement of accessibility in this research, therefore, is based on

passenger's mobility, without taking into account freight transport. The basic spatial unit of

analyses is the urbanized areas of the prefecture-and-above level cities in China, at a total

number of 287. I treated these urban areas as nodes linked by the transport routes and highlighted

the physical connections between cities rather than within them. I explored how transport

infrastructures influences the productivity of urban economies, migration in domestic labor

market, location choice of economic activities, and the conversion of land uses. I assume that the

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wider economic impacts associated with improved accessibility could be reflected by the growth rate of urban economy, wage rate, employment, land development and the output of travel-dependent service sectors. I also examined how cities' endogenous features interact with their access to external economic resources and jointly determine the realization of HSR's specific impacts on urban economic performance.

In Section 1.1, I introduce the socio-economic background and the pending policy inquiries that motivated my research. Section 1.2 contains research questions and hypotheses based on existing theories and my field observations. I then discuss the intellectual contributions and innovative perspectives of my research in Section 1.3, and conclude with an illustration of the overall structure of my research in Section 1.4.

1.1   Problem statement

Several pending policy inquiries motivated my research. First, analysts have been questioning the validity and efficiency of transport infrastructures as a major policy tool to stimulate economic growth. Second, the standard project-level cost-benefit analysis fails to capture transport infrastructures' spillover effects on the rest of the economy. Third, there has been huge ambiguity in the claimed wider economic impacts associated with transport infrastructures, and systematic estimation seldom exists. The recent development of HSR in China has made these unaddressed issues even more urgent for policy makers than before.

High-speed rail (HSR) has various definitions under different criteria, and in this research, I use the broader definition of HSR by the International Union of Railways (UIC), which refers to railway lines that support average traveling speed at 200 km per hour or above, including both upgraded mixed-use lines and brand new passenger-dedicated lines.

HSR has a long tradition in Japan and European countries. In 1964, the *Tokaido*

Shinkansen in Japan between Tokyo and Shin-Ōsaka marked the modern era of high-speed trains. In the subsequent decades, high-speed trains emerged in developed European countries, such as France, Germany, Spain, and the United Kingdom. Only in recent years has the HSR caught global attention. An important context is the global economic downturn since 2008. Nations across continents have initiated infrastructure investment as a major component of the economic stimulus packages, and HSR is one of the candidates on the investment list. On February 8, 2011, the Obama administration of the United States unveiled a plan to spend $53 billion over the next six years to develop a high-speed passenger rail system that would link the nation's larger cities (WhiteHouse 2011). Meanwhile, for the first time, systematic planning, construction, and operation of HSR is taking place in developing countries. Mainland China has made eye-catching achievements in terms of total amount of investment, length of HSR lines, speed of construction, and geographical coverage of services.

I find huge ambiguity in the claimed wider economic benefits of HSR investment and the inadequacy in existing analytic tools to estimate such benefits. HSR investment triggers broad policy discussions because it cost billions of dollars to build, and it takes up a huge proportion of public resources. However, policy-makers sometimes make rush decisions to allocate public funds to HSR projects without careful assessment of the long-run impacts on economic development. In China, there has not been any publically released document assessing the wider economic impacts of the national railway development plan. Moreover, local authorities tend to have unfounded optimism that HSR will become a magic engine that will automatically boost economic growth.

Scholars have questioned China's HSR investment for lack of justification and warned the government about the enormous financial risks of such investment (Zhao 2009). Currently,

project-level cost-benefit analysis (CBA) still dominates the assessment of the feasibility of HSR projects, but there is increasing desire among policy-makers to account for the less tangible wider economic benefits in financial analysis. Due to the asymmetry between costs and benefits, it is improper to apply the standard CBA framework to HSR projects ---they incur huge amounts of construction and maintenance costs, but a significant proportion of benefits go beyond the project's scope, which have not been effectively estimated. Expect for a few busy corridors that may generate sufficient financial return to make the investment worthwhile, CBA on HSR projects often yields negative estimated return rates. Therefore, in feasibility studies, policy-makers turn to wider socio-economic benefits to justify the use of public funds. To extend the traditional CBA framework by including wider economic benefits of HSR, one precondition is systematic estimation of the indirect benefits. For large scale of transport investment like HSR, it is reasonable and necessary to consider the wider economic impacts. Yet this part of indirect benefits, are less visible and hard to estimate compared to the costs and project-level benefits, even though they definitely exist. The reliance on ambiguous wider economic benefits is potentially problematic, that is, once the benefits are subject to manipulation, they can help any unqualified project pass the feasibility study standard. Therefore, it becomes a very important and urgent task to estimate the magnitude and nature of the claimed wider economic benefits.

In practice, due to the complexity of quantifying HSR's wider economic benefits, development authorities usually emphasize the immediate job-creation effects and increase in domestic consumption during the construction period of HSR (Ma 2009; Tang 2009; Wu 2009; Zhang 2009). The short-term impacts may be significant but not sustainable. In contrast, the long-term impacts of HSR on economic performances are seldom discussed. In addition, policy-makers and analysts in China usually have approached the economic benefits of HSR in a

qualitative way (Zhang 2009; MOR 2010), while few properly designed quantitative empirical studies exist. The lack of quantitative research in this field is partly caused by the complexity of intertwined direct and indirect impacts associated with HSR investment, and the difficulty to attribute enhanced economic performances to transport improvement. Another reason is the absence of a holistic perspective among analysts, who usually emphasize the travel time savings along a specific transport corridor after the operation of a single HSR line, ignoring the network feature of the transport system and the spillover effects of transport investment.

In response to these pending policy inquiries, I propose an analytic framework for systematic estimation of the wider economic impacts associated with major transport investment, using China's HSR as a specific case. The findings will lead to a careful reflection on the investment-led growth mode in China; a methodological improvement that integrates the wider economic impacts of transport infrastructures in project appraisal; and an alternative vision of urbanization for China in the coming decades.

1.2   Research Questions and Hypotheses

The purpose of my research is to develop an integrated analytic framework to estimate the potential contribution of transport infrastructure investment to urban economic performance, and apply this framework to assess the wider economic impacts of China's HSR development plan. Specifically, I use intercity accessibility as a key intermediary variable, and examine how HSR influences urban economic performance through changing the interregional flows of production factors such as capital and labor, that highly depend on accessibility.

A basic hypothesis of this dissertation is that: an important mechanism for intercity transport infrastructures to influence urban economic performance is changing a city's access to external production factors, such as capital, labor and knowledge. In other words, in a globalized

economic setting, a city derives agglomeration effects not only from the clustering of its own resource endowment but also from its access to external production factors through transport infrastructure. Even though economic theories predict the existence of transport infrastructure's influence on urban economic performance, the nature, magnitude and distribution of such influence remain unexplored. These features of transport-related economic impacts depend not only on the scope of analyses, but also on the indicators used to represent different aspects of urban economic performance. Therefore, I break down the basic assumption into several testable sub-hypotheses below.

First, transport investments during 2001-2010 have led to a convergence in accessibility among regions in China. HSR's impacts on intercity accessibility patterns concentrate in lower tier cities. Yet, HSR's contribution to accessibility improvement is conditional, depending on the composition of the cities on the routes and existing conditions of transport facilities.

Second, the influence of intercity accessibility on urban economic performance may consist of both generative and redistributive components, and could encounter saturation effects as economic heterogeneity among cities decreases with market integration. Improved accessibility may lead to divergence or convergence of economic performance among cities.

Third, the introduction of HSR may shift travel patterns among cities and lead to restructuring of the regional urban hierarchy. HSR's impacts on different aspects of economic performance may vary in terms of time horizon and spatial coverage. The magnitude of HSR's impact also depends on a city's intrinsic features, such as size and location on the routes.

Fourth, HSR station could bring an external driving force to urban development. The potential for new development is determined by the possibility of matching demand for development with supply of land near the station. In addition, joint effort of both public and

private sectors is indispensable to materialize this development.

The proving or disproving of these four hypotheses sheds light on the features of the wider economic impacts associated with transport infrastructure investment in general and with HSR in particular. An in-depth understanding of these features assists rational decision-making of public investment in the transport sector.

1.3   Research significance and contributions

The targeted audience of my research includes the following: (1) policy-makers in line ministries of the central government who develop long-term plans for national transport infrastructure development; (2) municipal government officials who are eager to take advantage of HSR's potential stimulating effects on local economies; (3) private sector investors, especially multi-branch firms and developers facing location choices among cities. The findings from my study will contribute to a deepened understanding of the economy-wide, long-term impacts of HSR investment, and substantiate the analytical foundation of decision-making on major transport infrastructure development.

My research contributes to the existing literature in the following aspects:

First, I introduce a spatial dimension to the endogenous growth theory. The classical endogenous growth theory explains the dynamics of economic activities in the context of a closed economy, where the output of an economic entity is determined by the level of production factors at the home locality. I extend the endogenous growth model by introducing the interaction among different economic entities in an open economic setting. The access to external resources, measured by an accessibility indicator, enters the production function by improving the total factor productivity and altering the effective inputs of labor and capital.

Second, I extend the scope of agglomeration effects in the New Economic Geography

(NEG) theory. The NEG theory predicts increasing return to scale, which refers to the agglomeration effects at urban localities due to the dense concentration of production factors. However, development in transport infrastructure has led to dispersion of such agglomeration effects. The prosperity of an urban economy is jointly determined by a city's own endowment as well as its access to external resources through transport infrastructure, with the latter being partially substitutable for the former. I extend the scope of agglomeration effects by emphasizing the growing importance of access to external resources in the globalization era.

Third, my research also bridges the spatial discontinuity between regional and urban studies by proposing a multi-scale research framework at network, corridor and node (city) levels. While numerous studies have examined the interaction of transport improvement and economic performances along specific HSR lines (Hensher 1997; Gutiérrez 2001; Arter 2009; Cascetta, Papola et al. 2011) or around HSR stations(Amano 1990; Bertolini and Spit 1998; Pol 2007), there is much less research that provides a comprehensive picture of the HSR network and its broader impacts on economic development. A small literature on network effects is about the Trans-European Network (TEN) , which is the only HSR network in operation (Vickerman 1995; Gutiérrez, González et al. 1996; Carsten Schürmann 2001). The main focus of their studies is to examine how the HSR network changes the center-periphery pattern within and among European countries. My study goes one step further to relate the change in accessibility to urban economic performance. Banister(2007) pointed out that scale is an important factor to consider when assessing the economic impacts of HSR, and proposed a composite three level analytical framework. My study extends this research by including the productivity benefits due to the overall improvement in network accessibility, which is not reflected in corridor and node level analyses.

Finally, my research is a pilot study on transport investment's impacts on economic development using empirical evidence of China. The existing literature has a spatial focus on the developed economies. China is an emerging economy with large regional disparities in economic performance, and the HSR network has been built at unprecedented speed and scale. This provides a unique opportunity to extend this well-established research topic. It is reasonable to expect that the influence of HSR on China's economy will show different patterns compared to the mature economies. For a long time, quantitative empirical study was unimaginable in a Chinese context due to low availability and/or poor quality of data. Policy-makers and analysts in China mostly approached the economic benefits of HSR in a qualitative manner (Zhang 2009; MOR 2010). Recent improvement in the spatial coverage and quality of social-economic statistics makes my research possible. Among the very few studies on the railway network in China, Wang and Jin(2009)'s paper showed how the railway system and intercity accessibility evolved during the 20th century. Their paper is very informative regarding the history of China's railway system, but does not cover the HSR revolution during the past decade (2001-2010). This is exactly the time horizon of my study. Scholars also started to estimate the impacts of HSR network on China's urban system using econometric models (Yeh 2011). However, the prediction from existing studies is weakened by using two-period data of beginning and ending years, a small sample of cities and arbitrarily estimated intercity travel time. My research uses annual statistics for 287 cities during 2001-2010, together with travel time extracted from real timetables.

1.4   Structure of the dissertation

The remaining parts of my dissertation proceed as follows: In Chapter II I explain the construction of my research framework by integrating relevant theories and analytical tools, with

a diagram showing the multiple mechanisms through which transport infrastructure investments may influence economic performance. Chapter III and Chapter IV are network level analyses, in which I put HSR in the context of the multi-modal national transport system and examine the general features of the synergy between transport infrastructure and economic performance. In Chapter III I analyze and visualize the evolution of intercity accessibility patterns in China during 2001-2010, with special emphasis on the role of HSR in reshaping accessibility. In Chapter IV, I report the results from a series of panel data models assessing the influence of accessibility improvement on various aspects of urban economic performance. I replicate the econometric modeling using different sub-samples to illustrate how the accessibility elasticity varies across regions, by city size and across different accessibility levels. In Chapter V and Chapter VI, I examine a particular HSR corridor between Wuhan and Guangzhou and cities along this route, aiming to identify the features of economic influences that distinguish HSR from other types of regional transport infrastructures. Chapter V focuses on HSR's channelizing effects on intercity travel patterns and the short-run location choice of economic activities, while Chapter VI is dedicated to the relationship between HSR station and urban land development. Chapter VII concludes with summary of findings, policy implications and discussions on limitations of my study and opportunities for future research.

Chapter II   AN INTEGRATED RESEARCH FRAMEWORK

In this chapter, I develop the research framework to conduct my study of HSR's impacts on intercity accessibility and urban economic performance. Section 2.1 is an introduction to the theories underlying my study. In Section 2.2 I review existing analytic tools that have been developed in different disciplines to explore the synergy between transport infrastructure investment and economic growth, with discussion of the strengths and limitations of each analytical tool. In Section 2.3 I propose an integrated multi-scale research framework that takes advantage of both quantitative and qualitative approaches, and covers the full spatial horizon from the intercity transport network to a specific HSR corridor and cities connected by the HSR.

2.1   Theoretical foundations

The current research is built upon three schools of theories: (1) New Economic Geography (NEG) theory, (2) urban economics theory and (3) endogenous growth theory. I synthesize the spatial emphasis of the New Economic Geography theory with the temporal perspective of the growth theories. Along the spatial dimension, I bridge the inter-city scale of analyses in NEG theory with the intra-city scale of study in urban economics theory. Revisiting these theories gives a comprehensive theoretical framework to conduct the proposed multi-scale analysis.

2.1.1   New Economic Geography (NEG) theory

NEG theory aims to explain the distribution of economic activities over space, assuming increasing returns to scale, imperfect competition and the influence of transport costs. The founders of NEG theory, Krugman and Fujita (1991a, 1991b), proposed a Core-Periphery model by applying the monopolistic competition paradigm in spatial analysis. The Core-Periphery model has become a frequently used analytic tool in recent empirical studies (Mayer 2004; Fujita

and Mori 2005; Henderson 2005; Pflüger and Südekum 2006).

NEG theory emphasizes the importance of the broadly defined transport costs as barriers to economic activities, including the difficulties in exchanging goods, people, and ideas. The motivation to avoid transport cost leads to clustering of economic activities to take advantage of agglomeration economies. Agglomeration economies are the benefits obtained from production agents and consumers being close to each other at certain locations. The argument for agglomeration economies is based on Marshall's (1890) three-pillar doctrine: input sharing, labor pooling, and knowledge spillovers (Duranton and Puga 2004). The initial Krugman model highlights the agglomeration benefits due to reduced costs of freight delivery while touching little upon the costs of human travel. This might be a proper treatment in an economy dominated by agriculture or manufacturing, as the shipment of raw materials and final products is the major concern of production. However, for a service-based economy, the mobility of people is of greater importance and deserves more attention. In contrast to a constant decline in the cost of freight shipping, the cost of moving people over space remains high because time is a major input into human travel, and the value of time continues to rise as people become more productive (Glaeser and Kohlhase 2003). HSR provides a new technological option that reduces travel time and lowers the cost of passenger transport. This study focuses on the labor pooling and knowledge spillover mechanisms of agglomeration effects, both of which are strongly related to the mobility of passengers.

NEG theory predicts a non-linear relationship between transport costs and agglomeration. As transport cost decreases, economic activities may follow a pattern of dispersion, concentration and re-dispersion (Holl 2004). According to Graham (2007), transport investment can render a large amount of activity more accessible by reducing travel time or cost, thus giving

rise to positive agglomeration benefits. However, unless travel becomes absolutely costless, reducing transport cost does not diminish the advantages of agglomeration. Instead, improved accessibility will flatten the spatial decline of agglomeration benefits and change the ways that economic activities occur. In the specific case of HSR, the imperfectly competitive labor market benefits from three possible changes: (1) increasing participation rates, (2) longer working hours, and (3) improved matching between laborers and jobs (DFT 2005). For knowledge sharing, HSR facilitates face-to-face communication, which is still considered to be essential to foster innovation and spread knowledge, particularly the tacit proportion. Tacit knowledge is not as easy to obtain as the codified components of knowledge, even in the era of advanced information technology (Cowan, David et al. 2000; Jensen, Johnson et al. 2007).

Analysts commonly use NEG theory to explain international trade or economic interaction among regions, treating cities as abstract points in space (Krugman 1991a). In addition, NEG theorists cover the mobile production factors (capital, labor and knowledge) but do not discuss the impact of transport cost on the immobile factor---land. At the local level, I need an alternative theoretic framework to explore the relationship between transport costs and economic activities.

2.1.2 Urban economics theory

Urban economics theory focuses on the spatial dimension of economic motivations underlying the formation, functioning and development of cities. A major theoretical inquiry concerns the interaction between land use and transport costs. Alonso (1964) and Muth (1969) constructed the land-rent gradient to explain how land values that are related to transport costs determine the patterns of land use and urban form. Each type of urban activity has its own bid-rent function and the combination of various bid-rent functions defines the rent gradient. In a

typical monocentric model, jobs are expected to concentrate in the Central Business District (CBD). Distance (or in a more precise term, transport cost) from any location to the CBD, determines not only the current land values that lead to assignment of land to different urban uses, but also the expected location values of land that influence the desire for development and redevelopment over time. In the Alonso model, the driving force for urban land development stems internally from the CBD.

However, HSR stations could also generate demand for land development in their proximity due to convenient access to external production factors. HSR stations distort the smooth downward sloping shape of a rent gradient (Figure II-1).

Figure II-1 The impact of HSR station on rent gradient
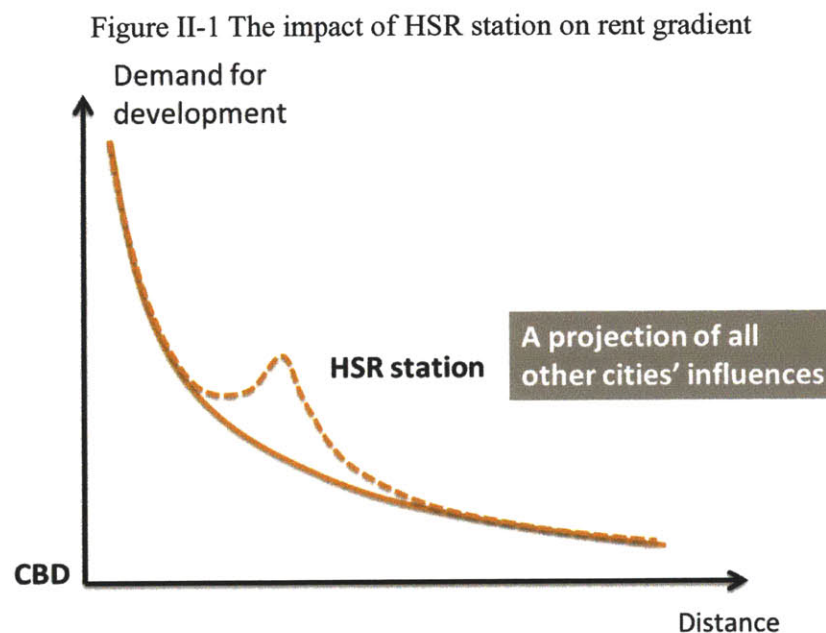
Source: author

This is particularly true for medium and small cities within commuting distance of a megacity. The HSR stations may turn a periphery location into a gateway of the home city. Such a gateway location, once combined with favorable policy and matching investment, will foster the formation of sub-centers and reshape the configuration of the city. This study extends the explanatory power of the Alonso model by introducing an external driving force on urban land

development that is associated with the HSR stations. The external stimulus of land development, which concentrates around the HSR station areas, overlaps with that from the existing CBD and may change the monocentric urban form to a polycentric one (Wheaton 1974).

2.1.3 Endogenous growth theory

Krugman and Alonso's models shed light on the spatial interaction between transport costs and economic activities, while growth theories highlight the dynamics of economic activities over time. The evolution of economic growth theory is subject to shifting paradigms. The neoclassical school of grow theory, represented by the Solow-Swan model, assumes that capital and labor are the two major endogenous contributors to economic growth, while technology is exogenously determined (Solow 1956; Swan 1956). I adopt the perspectives of endogenous growth model, which has been developed by Romer (1987) and Lucas (1988). The endogenous growth model treats technology as determined by the accumulation of human capital and physical capital within the economy and considers the expansion of the knowledge base as the original driving force of economic growth. The expansion of knowledge leads to continuous improvement in total factor productivity and non-diminishing return to scale.

Yet the standard endogenous growth model does not include the location of production and consumption, and the discussion on growth is conducted in the context of independent, close economic entities. If we apply the argument of endogenous growth theory to a multi-regional situation, transport cost and accessibility will become influential factors in determining the size and evolution of the local knowledge base. At any location of economic activities, the accumulation of knowledge not only depends on the stock of local human capital, but also relies on the interaction with other economies. This is particularly the case for economic localities at lower tiers of urban hierarchy. Therefore, I extend the endogenous growth model by including

accessibility, which represents generalized transport costs, as an explanatory factor.

2.2 Existing analytical tools

Economists, geographers and transport experts have developed a rich set of analytic tools

to explore the shared research interest on the contribution of transport infrastructure investment

to economic development. Each method has its own advantages and limitations.

2.2.1 Econometric models

Economists normally treat transport infrastructure as accumulation of public capital stock

and estimate the impacts of public infrastructure spending on private sector productivity.

Aschauer (1989) and Munnell (1990) conducted pilot studies in the U.S. context using

econometric models. They estimated the elasticity of productivity against public infrastructure

investment using time series data from the 1940s to 1980s, with the estimated elasticity falling in

the range from 0.34 to 0.41. Later on, Canning (1999) used panel data and obtained a much

smaller estimated elasticity, which fell in the range of 0.03 to 0.11. The shrinkage in the

estimated elasticity is the result of eliminating time-invariant factors that are specific to

economic entities.

There are several caveats regarding the classical econometric analyses. First, these

analyses relate the input (capital stock) rather than the output (transport costs) of transport

investment to economic performance, but in reality more investment does not necessarily

guarantee lower transport costs or better service. The same amount of investment in the transport

sector could generate totally different outcomes. In addition, classic econometric models do not

explicitly consider the spatial interaction among regions, which is exactly a key function of

transport infrastructure as compared to other types of public investment. One exception is the

multi-regional input-output model (Polenske 1970). Although the multi-regional input-output

model accounts for spatial interaction properly, such analysis is hardly possible to conduct with disaggregated spatial units due to the absence of proper data sets. This research measures the outcome of transport infrastructure investment by accessibility indicators and accounts for spatial interaction among different economic entities, for which purpose I need to draw lessons from spatial analysis.

2.2.2 Spatial analysis

Unlike the economists, geographers emphasize the spatial distribution and interaction of economic activities using gravity models (Curry 1972; MacLean 1974; Erlander 1980; Porojan 2001). The key underlying assumption of gravity models is that the economic interaction, in terms of trade, migration, or capital flows, is proportional to the scale of economic activities at different locations, and inversely proportional to the distance between locations. The development of geographical information system (GIS) tools has facilitated spatial analysis on the spillover effects of transport infrastructure with extensive datasets (Gutiérrez, Condeço-Melhorado et al. 2010). In recent years, the integration of GIS-based spatial analysis and classic econometric models has led to a wealth of empirical studies under the category of "spatial econometrics"(Anselin, Florax et al. 2004; Arbia 2006).

However, most empirical studies built on traditional gravity models do not explicitly account for transport costs. Instead, researchers use Euclidian distance as a proxy for the spatial friction among different locations. This treatment is valid in a cross-sectional analysis, but becomes problematic when considering time series. Euclidian distances are fixed and could not reflect the change in spatial friction among locations due to transport infrastructure investment. My research belongs to the generally type of spatial econometric analysis and I enhance the gravity-type models by replacing distance with real travel time among different locations. To

achieve this goal, I integrate analytic tools from transport discipline.

2.2.3 Transport models

Transport experts have developed various models to forecast travel demand and simulate the productivity enhancement within the transport sector. Often using discrete choice behavioral models, they identify and calibrate factors that influence intermodal choices, such as, the travel time by mode, service frequency, fare and level of comfort, etc. (Ben-Akiva and Lerman 1985; Lee and Boyce 2004). The behavioral models have been widely applied to forecast the shifted and induced demand in passenger travel along HSR corridors (Hensher 1997; Chang and Chang 2004; Lee and Chang 2006; Couto and Graham 2008). This school of empirical studies focuses on the direct impacts of transport improvement without considering the wider economic impacts beyond the transport sector. My study relies on the estimations of transport models to improve the measurement of accessibility and therefore to integrate the analyses within and beyond the transport sector.

2.3   An integrated multi-scale research framework

Transport infrastructure's impacts on economic performance consist of many aspects, with variation in magnitude at different spatial levels, so I propose a multi-scale analytic framework to provide a comprehensive picture. I develop this analytic framework by synthesizing New Economic Geography (NEG) theory, urban economics theory and endogenous growth theory. Methodologically, I integrate analytic tools that have been developed by economists, geographers and transport experts to examine the synergy between transport infrastructure investment and economic development. This multi-scale framework covers the national inter-city transport network, a regional HSR corridor and cities as nodes on the transport network.

I use quantitative approaches for network analysis. At this level, I conduct a panorama

analysis of prefecture-and-above level cities on the national transport network of China,

examining the change in intercity accessibility over the last decade by GIS spatial analysis and

estimating the elasticity of urban economic performance to accessibility with econometric

models. I put HSR into the context of the overall expansion of intercity transport network, and

identify the role that HSR has been played in changing accessibility. The change in urban

economic performance is not particularly attributable to HSR development but as a result of

improved multi-modal accessibility among rail, road and air travel options. At the corridor level,

I use comparative statics to show changes in regional travel patterns and HSR's channelizing

effects on economic activities. The economic impacts assessed are directly linked to the

construction and operation of the HSR line. I compare the passenger flow patterns and urban

economic activities for cities along the Wuhan-Guangzhou HSR in the pre- and post-HSR

settings. I examine whether HSR cities outperform non-HSR competitors within the same region.

At the city level, I conduct comparative case studies to identify the conditions for HSR station to

become an engine of urban development. Cluster analysis based on key influential factors

generates the prototypes of cases that I choose. I rely on field observation, document review, and

interviews with stakeholders to obtain information for the case studies. Table II-1 below

summarizes research focuses and methods of proposed analyses at different spatial levels.

Table II-1 Research focus and method of multi-level analyses

Spatial level	Research focus	Method
Network	- Patterns and evolution of intercity accessibility	GIS-based spatial analysis
	- Elasticity of urban economic performances to accessibility	Econometric modeling with panel data
Corridor	- Shift in travel patterns - Relocation of economic activities	Comparative statics of before- and after HSR period
Note (City)	- Urban land development in HSR station area	Cluster analysis and comparative case studies

The relationship between transport infrastructure and economic development could be explored from various perspectives. Banister and Berechman (2001) proposed a scheme to illustrate the underlying mechanisms that shape the interaction between transport infrastructure, location choice and economic growth. I modify Banister's scheme to incorporate the key arguments of NEG theory, urban economic theory and endogenous growth theory (Figure II-2).

Figure II-2 Relationship between transport infrastructure investment and economic performance
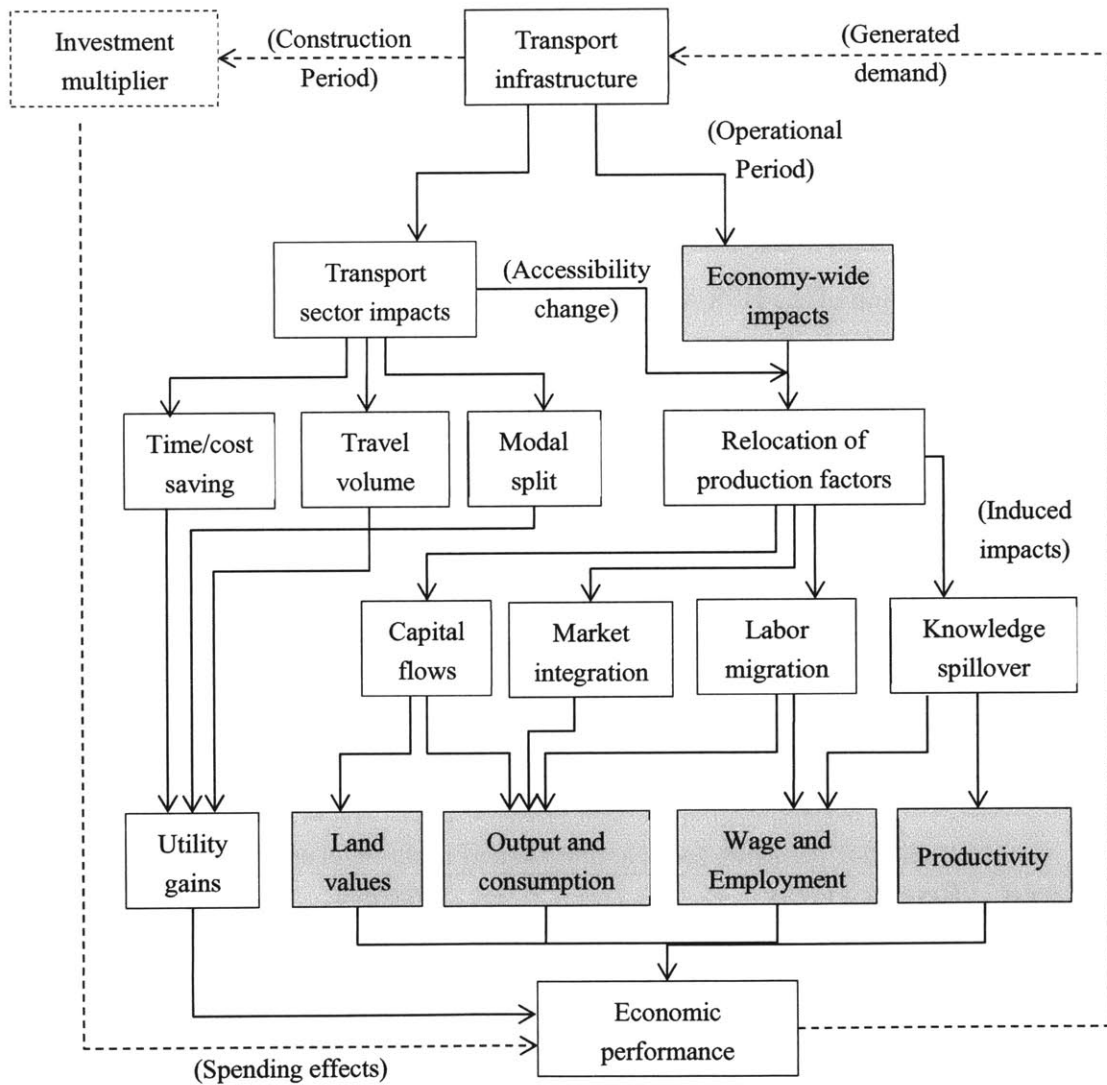
Source: Banister and Berechman (2001), author revision

The construction of transport infrastructure stimulates amplified investment in related industrial sectors through forward and backward linkages, and such spending effects are often assessed with input-output models. Economic growth generates extra demand for transport and could, in turn, trigger new investment in transport facilities. I do not explicitly discuss these two effects that are represented by dash lines and arrows. Instead, my study focuses on the economy-wide impacts of transport infrastructure during the operation period, backed by the prediction of agglomeration effects in NEG theory.

The agglomeration effects occur when improved accessibility promotes relocation of production factors (i.e., capital, labor and knowledge) and integration of market, which eventually show up in a series of urban economic performances indicators (listed in the shaded boxes). I extend the standard endogenous growth model by hypothesize that the access to external production factors is partially substitutable to a city's own resource endowment. At the network level, I highlight accessibility's influences on mobile production factors, using spatial analysis tools and econometric models. The corridor analysis illustrates HSR's specific influences on time and costs savings, travel volume and modal split within the transport sector, and the consequential impacts on relocation of economic activities. The node/city level analyses assesse HSR's impacts on the immobile factor--land, assuming that HSR stations may bring external driving force of urban development. This analysis expands the explanatory power of the classical rent gradient model in urban economic theory.

Chapter III   EVOLUTION OF INTERCITY ACCESSIBILITY PATTERNS

The purpose of this chapter is to provide a comprehensive picture of the evolution of intercity accessibility patterns during 2001-2010 in China. I illustrate the impacts of accumulated transport infrastructure investment on accessibility, particularly the operation of HSRs since 2007. It is the first study of this kind in China that covers all 287 prefecture-and-above level cities using real travel time. My analysis provides detailed description of the key explanatory variable--intercity accessibility--of the econometric models in Chapter IV. It also helps to identify the corridor and cities that experienced the most significant improvement in accessibility, which I choose for my case studies in Chapter V and Chapter VI.

I start with a brief review of the development of China's national transport network during 2001-2010. In Section 3.1, I document the development of railway system before and after the introduction of HSR. I also show the development of civil aviation and expressways during the same time period, which jointly contribute to the improvement of intercity accessibility in China. In Section 3.2, I selectively review literature on the trans-national HSR network in European countries, where empirical evidence abounds, as well as relevant studies on the relationship between transport investment and accessibility improvement in a Chinese context. In Section 3.3, I explain the indicators I use to measure accessibility and the identification of urban hierarchy to simply the calculation of travel cost matrices. Section 3.4 contains technical details about data mining and calibration of accessibility indicators. I report findings from the spatial analyses on China's intercity accessibility patterns in Section 3.5 and summarize in Section 3.6.

3.1   Expansion of the national transport network

In the past decade, China has experienced fundamental changes in the national transport

network, with significant expansion in total length of transport infrastructure and great

improvement in transport service quality featured by faster speed, more comfort and increased

frequency. The Railway sector has made remarkable contribution to such changes, especially

after the introduction of HSR since 2007. At the same time, other types of transport infrastructure

have also witnessed expansion. The current research is particularly interested in travel modes

that may compete with high-speed rail, so I focus my analysis on development in civil aviation

and expressway construction.

3.1.1 China's national railway system before HSR

In early 1990s, the average traveling speed of passenger trains in China was merely 48

kilometers/hour (km/h), with all types of trains included (Ministry of Railways 1998).   At that

time, passenger transport by rail was struggling for survival, when confronted with shrinking

market share and continuous business losses. Slow speed is considered to be the bottleneck of

rail passenger services. To reverse such a situation, the Ministry of Railways (MOR) in China

launched six rounds of speed-up campaigns on existing lines in the decade from 1997 to 2007

(Table III-1).

Table III-1 Six "speed up" campaigns in China's railway system 1997-2007

Dates	Change in rail service	Maximum travel speed (km/hr)
04/01/1997	Introduce T (express) trains and overnight trains	140
10/01/1998	Introduce luggage-dedicated trains and express trains for tourism destinations	160
10/21/2000	Reclassify trains to T (express) trains, K (fast) trains and ordinary trains, expand speed-up to trunk lines in West China	160
10/21/2001	Increase the number of T trains, expand speed-up on railway lines to a total length of 13,000 km	160
4/18/2004	Introduce Z (non-stop) trains; expand speed-up on railway lines to a total length of 16,500 km	200
4/18/2007	Introduce D (bullet) trains, further speed up on 18 trunk railway lines	250

Source: Ministry of Railways, P.R. China, author summarizes.

During this pre-HSR period, MOR focused on increasing the travel speed and capacity on existing lines through double-tracking, electrification, upgrading, reducing turn curvature and installation of continuous welded rail. Meanwhile, the total length of railway network did not change very significantly. The last round of speed-up in 2007 is considered as the prelude to the HSR revolution in China, when MOR put bullet trains in operation on several trunk railway lines, and the total length of railway lines that support bullet trains reached 6,000 km (ChinaNet 2007). From then on, the potential capacity on existing lines is almost exhausted, and China enters an era of constructing brand new HSR lines.

3.1.2 China's HSR revolution

The upsurge in HSR construction took place following the "The Medium- to Long-Range Plan of Railway Development in China." A major target of the trillion *yuan* investment initiative is to establish a national HSR network at a total length of 160,000 km by 2020, consisting of "Four Horizontal, Four Vertical" passenger-dedicated railway lines (MOR 2008). The original plan for a national HSR system was approved in 2004, and was updated with major changes in 2008 to cover more cities from the less-developed regions in West China.

In July 2011, upon the opening of the Beijing-Shanghai HSR, China's total length of HSR in operation reached about 9,000 kilometers, and another 6,000 kilometers was expected to be completed in 2012 (Xinhua, 2011). China's government is using HSR as an image to visualize its rising economic status and increasing influence on the global economy. Besides the eye-catching achievement, HSR has also triggered heated debates on justification for such an investment, as well as concerns about financial risks due to the "leap-forward" style of construction. After the shocking crash of bullet trains on the Wezhou-Fuzhou Line on July 23, 2011, HSR became the target of severe public criticism. The tragedy undermined market

confidence in HSR investment, and raised the financing cost of ongoing and planned HSR projects. Accordingly, China's Ministry of Railways (MOR) cut the planned investment in 2012 by $32 billion, which is about 28% less than the peak level as of 2011.

The maps in Appendix A show the evolution of China's railway network during 2001-2010 (Figure A-2, A-3). Before the introduction of HSR, the major change of the railway system is the extension of new lines to the most remote areas in China, such as, Xinjiang, Tibet and Heilongjiang Province, and the densification and completion of existing railway network in East China. The construction of upgraded and new HSRs started since 2007. There are three types of HSR lines in operation as of 2010: (1) the "four horizontal four vertical" national HSR grid, which are passenger-dedicated lines (PDLs) that support traveling speed of 300-350 km/h; (2) regional inter-city HSRs, which are also PDLs and are often integrated with commuting rail system; (3) mixed-use upgraded lines which support bullet trains traveling at 200-250 km/h. Except for the Southeast region of China where HSRs began to form a network, HSR lines in the rest part of China are standing alone sections that strengthen accessibility primarily along the transport corridors they serve.

3.1.3 *Development of civil aviation and expressway system*

HSR provides a fast and convenient travel option, and is expected to dominate traveling over the medium to long distance. In terms of long distance travel (typically longer than 800 km), HSR encounters rivalry from airlines; while over short distance (typically shorter than 300km), it competes with cars and buses running on expressways. Even though the three transport modes have overlapped patronage, each of them dominates a niche sub-markets divided up by distance.

China's civil aviation has experienced a big boom since 2003, with the number of passengers growing at about 16% annually (CAAC, 2010). This trend goes hand in hand with the

economic prosperity in China. As people's income increases, traveling by air becomes more attractive and affordable to ordinary people. In addition, due to severe competition, airline companies adopt pricing strategy that offers huge discount in fare during off-peak seasons, which also contributes to the increase in number of passengers by air. However, the total number of airports in operation did not increase in proportion to the growth of passenger flows. It began with 143 in 2001, dropped to 126 in 2003 and picked up steadily thereafter to reach 175 in 2010 (Figure III-1). The number seems to be encouraging, but the fact is, in 2010 the top 50 airports took up 95% of the market share, and the concentration and spatial distribution of passenger flows hasn't changed much since 2001. This indicates that airports primarily serve passengers who come from and to the major cities in China. According to Civil Aviation Authority of China (CAAC), about 130 out of the 175 airports are running at losses. Many small feeder airports suffer from high maintenance costs and difficulties in attracting passengers, and are commonly at risk of being shut down even with heavy subsidy from local governments.

Figure III-1 Number of airports and passengers by air (2001-2010)
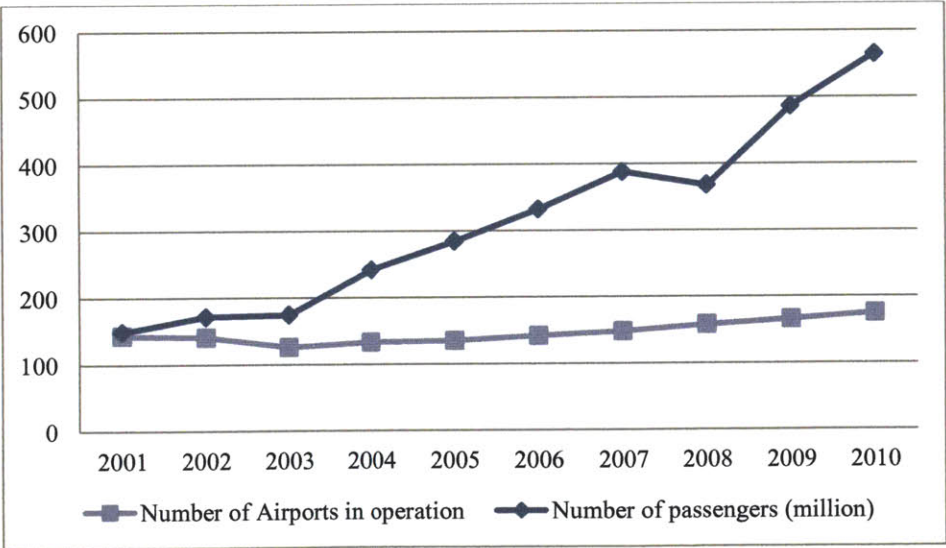
Source: Statistical bulletins of airports in China (2001-2010), CAAC
The construction of China's national expressway system started in 1988. In the first

decade that followed, this grand plan to make a national trunk expressway network made very limited progress. There were piecemeal, short segments of expressways around the major cities of Beijing, Shanghai and Guangzhou. However, things changed completely in the second decade, when expressway construction took place all over China, connecting cities with each other. The total length of expressway increased from 4,771km in 1998 to 65,065km in 2010. So far, prefecture level cities are mostly connected by expressways, except for very few in very remote and underdeveloped areas. The annualized growth rate of expressway length is around 24% during this time period. In 2011, China has surpassed the United States to become the country with the longest national expressway.

Figure III-2 Length of China's expressway 1989-2010
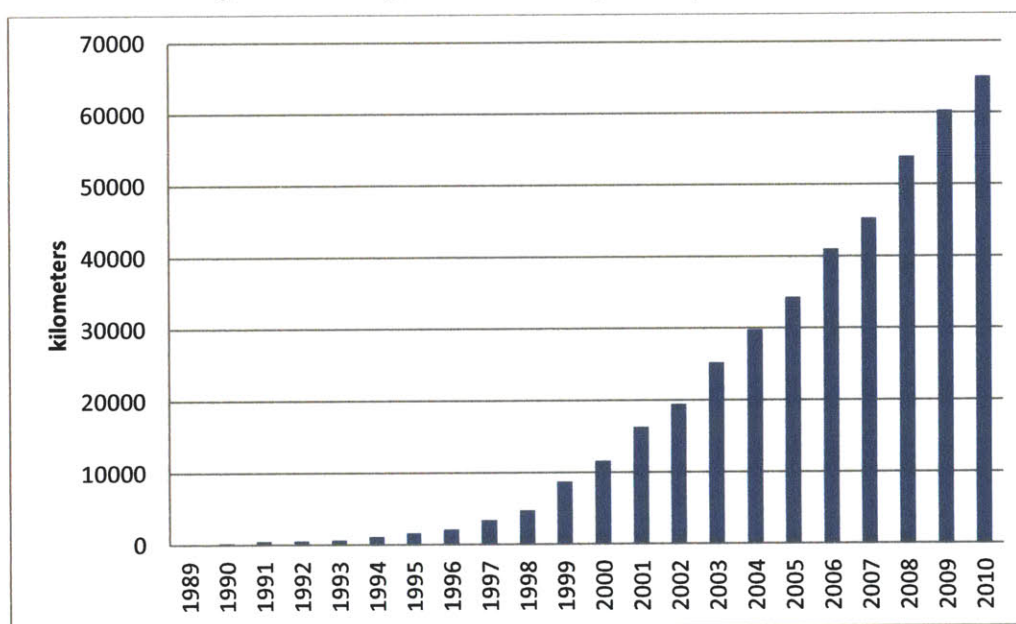
Source: China statistical yearbook 2011

The construction and operation of the expressway system has been a great success, without encountering the financial difficulties that hinder the development of small airports. The financing scheme for expressway projects is decentralized, diverse and innovative. Local governments raised the most part of funds by issuing ear-marking bonds and establishing

publically listed expressway companies that charge tolls. Expressways are among the most profitable investment, with gross profit margin as high as 60 percent. This phenomenon has already triggered domestic backlash on overpricing of expressway tolls. Despite the financial controversy, it is true that expressways did strengthen intercity accessibility significantly, especially with regard to cities' connection with their close neighbors. According to the statistics from Department of Transport, most trips by expressway cluster in the distance range between 50km to 150km, while the average travel distance by rail is 500km. The expressway system makes huge contribution to local accessibility while railways play a more important role in improving inter-regional accessibility.

3.2 Relevant studies on intercity accessibility

Intercity accessibility is the key parameter of the current study. In the following section I review studies that have been conducted at comparable spatial scale with similar research focuses. The purpose of reviewing this literature is to find suitable measurements of accessibility. One school of relevant studies is on intercity accessibility in Europe due to the construction of the Trans-Euro HSR network. The other strand of literature consists of several recent empirical studies that assess China's intercity accessibility change due to the development of railway and expressway systems. The limited studies in a Chinese context are very informative, but the time period and sample of analysis differ from my research.

3.2.1 Accessibility studies on Trans-Euro HSR network

Spiekermann and Wegener (1994) proposed the time-space map to visualize the expected change in accessibility patterns in Europe as influenced by the Trans-Euro HSR network, which was planned at the time of their study. They indicated that Europe would become a "shrinking continent" on the time-space map upon the completion of Trans-Euro HSR network. Yet they

also warned that HSRs connect only important cities, but not the vast space between them. The time-space mapping hides the fact that the regions in between might become peripheral zones, in which accessibility becomes poorer in relative or even in absolute terms due to the elimination of interim stops once high-speed trains are introduced.

Gutiérrez, González et al. (1996) also did an *ex ante* study to illustrate the absolute and relative changes in accessibility in European countries between 1993 and 2010, following the construction of Trans-Euro HSR network. The map of absolute change suggests that high-speed trains will produce a reduction in the core-periphery imbalances. In contrast, the analysis of relative changes shows that HSR network will increase the imbalances between the main cities and their hinterlands. They conclude that HSR is creating discontinuous space in which the spatial distribution of accessibility depends less on the geographical location of the nodes and more on the type of infrastructures they are linked up to. In a later study, (Gutiérrez 2001) evaluated the accessibility of the Madrid-Barcelona-French border HSR, and identified polarizing effects at the national level and balancing effects at both corridor and European levels. Results are also sensitive to accessibility indicators. The author used three different indicators to measure accessibility: weighted average travel time (WATT), economic potential and daily accessibility. He reported very concentrated effects in the daily accessibility indicator, less concentrated in the economic potential indicator and more dispersal in the location indicator.

Martin and Reggiani (2007) provided a comprehensive review of various indicators used to measure accessibility. They compared data envelopment analysis (DEA) and principle component analysis (PCA) as two approaches to calibrate synthetic accessibility indices. They concluded that DEA and PCA indices are two good candidates to synthesize the partial information contained in different accessibility indicators, and produce consistent rankings for

the global accessibility of the European cities for three different scenarios in 1996, 2005 and 2015 respectively.

Besides the analyses of accessibility over the entire HSR network, there are also studies on the accessibility to major economic centers in Europe. (Sánchez-Mateos 2009) examined the likely winners and losers due to the operation of a new HSR line in the U.K., using travel time to London as the main benchmark to measure accessibility of a station on conventional rail and HSR networks. The analysis shows that, the accessibility benefits from the proposed line merely spread to a limited number of cities that have direct access to HSR service, and many cities close to HSR would not see any travel time reductions on journeys to London. As a result, the HSR line is expected to strengthen London as the center of the UK.

3.2.2 Studies on China's intercity accessibility

Wang and Jin et al (2009) analyzes the expansion of China's railway network and the evolution of its spatial accessibility over a long period from 1906 to 2000. They conclude that China's railway construction has followed four major eras: preliminary construction, network skeleton, corridor building, and deep intensification, all of which followed a path of inland expansion. The spatial structure of China's railway network is characterized by concentric rings with its major axis in North China and the most accessible city gradually switching from Tianjin to Zhengzhou. After the 1970s, areas with greater improvement in accessibility shifted gradually from the Central Region to the Eastern Region. This study provides a comprehensive insight of China's railway history, but does not cover recent HSR construction, which is exactly the time horizon of my study.

Li and Shum (2001) calibrated the accessibility based on China's the national trunk highway system. They reviewed the changes in accessibility during 1990-2000 and projected the

trend for 2000-2020. They found that northeast region benefits most form the early phase of construction and during 1990-2000 expressway expansion generally aggravated China's regional disparity. They also projected that the extension of expressways to the southwest and other interior provinces will help to mitigate disparity in accessibility. Now over a decade has passed since their study yet there is no new empirical research to verify their prediction.

Jin Cao et al. (2012) analyzed the impacts of China's HSR network on accessibility for 49 cities with HSR planned or in operation. The authors conducted accessibility assessment by HSR as if they were all in operation, and made comparison against the accessibility by conventional railway and by airline. They also use weighted average travel time, daily accessibility and economic potential as the indicators to measure accessibility. They concluded that central-eastern cities gain more accessibility improvement as measured by WATT and daily access. The economic potential indicator showed that HSR brings most significant changes in accessibility to cities along the Beijing-Shanghai corridor and those in Pearl River Delta region. This study used a node-to-node travel time without considering local access time to train stations or waiting/connecting time. As a result, the accessibility is systematically over-estimated and may distort the outcome of comparative analysis between different transport modes.

A key message from the existing empirical analysis is that, caution is needed when considering the accessibility effects of HSR lines. Accessibility changes could be significant or marginal depending upon the geographical scale and the indicators selected. Accessibility is influenced not only by the layout of HSR lines, but also the intra-city connectivity to the network through local ground transportation and the effectiveness of intermodal transfer.

3.3 Methodology

I use the spatial analysis module of GIS system to conduct the analysis on intercity

accessibility. GIS tools have been widely used to analyze the spatial and temporal patterns of accessibility. A major advantage of using GIS lies in its strong capacity to visualize evolution of accessibility across space and over time. In previous studies, scholars introduced various mapping schemes including the time-space map proposed by Spiekermann (1994) and the contour of accessibility (Li and Shum 2001; Wang, Jin et al. 2009). Both methods provide clear insight into accessibility patterns by interpolating accessibility values for the whole region from limited points. The caveat with such treatment is that the estimated accessibility values in areas outside the known points can deviate enormously from the real situation, since in the real world accessibility does not change smoothly across space. In addition, the generalized pattern of accessibility is sensitive to the interpolation method used. Therefore, I will stick to the nodal accessibility at each city point without interpolation or extrapolation. This may lose a bit of visual richness in mapping but keeps my analyses rigorous. In the accessibility map, the locations of points represent centroids of prefecture-and-above level cities, and the size of the points is proportional to their accessibility. In following sections I introduce the indicator I choose to measure accessibility and the calculation of values for accessibility indicators.

3.3.1 Accessibility indicators

Accessibility indicator is the key parameter of this research. The concept of accessibility is not an ambiguous one, but it is still possible to find many different definitions and measurements (Gutiérrez, González et al. 1996; Vickerman, Spiekermann et al. 1999; Willigers and Floor 2007; Chang and Lee 2008). Among the whole collection of possible measurements, I selected the three most widely used types of accessibility indicators: (1) weighted average travel times(WATT), also known as location index; (2) economic potential, also known as economic mass or effective density; and (3) daily accessibility, with definitions in Table III-2.

Table III-2 Accessibility Indicators

Name	Mathematical Expression	Variable definitions
Location index (WATT)	$L_i = \dfrac{\sum_{j=1}^{n} t_{ij} M_j}{\sum_{j=1}^{n} M_j}$	L_i is the location indicator of location i, t_{ij} is the minimum travel time between i and j, M_j is the mass of location j (often use GDP or population)
Economic potential	$P_i = \sum_{j=1}^{n} \dfrac{M_j}{g_{ij}^{\alpha}}$	P_i is the economic potential of location i, M_j is the mass of location j, g_{ij} is the transport cost between location i and j; α is a parameter that reflect the speed of spatial decay
Daily accessibility	$DA_i = \sum_{j=1}^{n} Pop_j \delta_{ij}$	DA_i is the daily accessibility indicator of node i, Pop_j is the number of inhabitants at location j, $\delta_{ij} = 1$ if $t_{ij} < 4$ hours, and 0 otherwise.

Source: (Gutiérrez 2001; Martín and Reggiani 2007)

The unit of L_i is travel cost, in which case, the lower the value is, the more accessible the location is. The mass of destination locations is used as a weight to represent the importance of routes connecting major urban aggregations. This measure is not a gravity-type indicator since the distance decay is not accounted for. It is proper to interpret this indicator from the locational rather than the economic point of view. The single accessibility value does not make much sense; instead, this indicator is used to compare accessibility across space, time and travel modes.

Clark, Wilson et al. (1969) proposed the standard definition of economic potential to measure the opportunity of interaction for one location with others, and this indicator has been widely used in a series of empirical studies (Keeble, Owens et al. 1982; Evers, Meer et al. 1987; Gutiérrez 2001; Graham and Kim 2008). Economic potential is a proxy of the passenger flows between the home city and other locations, which is often used to represent the strength of

economic linkages with other urban agglomerations, or in other words, the access to external production factors. (Geertman and Ritsema Van Eck 1995) argued that the number of passengers traveling from location i to j is directly proportional to the mass of that destination M_j and inversely proportional to a certain power α of the travel time between i and j. This is exactly how the economic potential indicator is constructed.

Daily accessibility is based on the concept of a fixed constraint for travel, measuring the number of opportunities that can be reached from a location within a given travel time, distance or cost. In practice, the sum of population within a certain travel time band is used to represent the accessible pool of labor force or consumers by any transport mode. A time limit of four hours is normally considered as a critical cutting point for same-day business trips. Daily accessibility is a discrete measurement, which does not distinguish the subgroups of reachable population as long as they are within the four-hour travel time band. However, in reality, the attractiveness of a location to labor force decays over space in a continuous way.

This research assumes that it is the access to external production factors rather than the pure savings in travel costs that eventually contribute to urban economic performance. I therefore use economic potential as the major indicator to measure intercity accessibility. I also develop a hybrid accessibility indicator to measure business-trip accessibility by setting the travel time ceiling at four hours on the standard economic potential index, which I refer to as daily economic potential indicator in following analysis. A null value of this indicator means no considered destination could be reached within four hours. I use WATT as a supplementary measurement of accessibility to check the consistence among different indicators. For this indicator, the higher the value, the less accessible the urban location. It is worth noting that, even though improvement in transport infrastructure usually reduces WATT, an increase in WATT does not

necessarily infer deterioration in transport facilities or services. It may well occur because long

trips take dominance over short trips, or new linkages to remote locations become available.

3.3.2 Identify urban hierarchy

In the standard version of accessibility measurements, travel costs are estimated for all

pairs of cities, which is data-intensive and unnecessary. In reality, many theoretical interactions

between cities do not exist, or are too weak to consider. Before rushing into an estimation of

travel costs, I identify the major, effective economic linkages between cities within the

hierarchical urban system.

(Christaller 1933) proposed a conceptual model to illustrate urban hierarchy with Central

Place Theory. In this classic theoretical model, he considered cities and towns as central places at

different tiers. Each central place provides a given set of products and services, and covers a

certain service catchment or population. Bottom-level central places are smaller in size and

provide limited types of goods and services, usually daily necessities; while top-level central

places are large and accommodate a whole variety of economic activities. I group the cities in

China into three tiers: The first-tier cities are economic centers with national-level economic

importance. This group of cities includes Beijing, Tianjin, Shanghai, Guangzhou, Shenzhen,

Chengdu and Chongqing. The second tier consists of provincial capitals and provincial economic

centers that are not necessarily administrative capitals, for instance, Qingdao in Shangdong

province. The third-tier cities are ordinary municipalities. Specifically, I apply administrative and

economic rules to construct the national urban hierarchy:

(1) The national centers have economic interactions among each other, and they all have
economic connections with Hong Kong.

(2) Provincial centers have economic connections to national centers.

(3) Provincial centers are connected to their next-door provincial center which has stronger economic power.

(4) Ordinary prefectures have economic connections to the closest national center.

(5) Ordinary prefectures have economic linkages to their own provincial centers.

(6) Ordinary prefectures on the provincial boarders also have economic connections to the next-door provincial center which has stronger economic power.

Applying these rules to all the 287 cities gives a tree-shape structure of intercity economic connections (Figure III-6).

Figure III-3 The hierarchical economic linkages among different tiers of cities
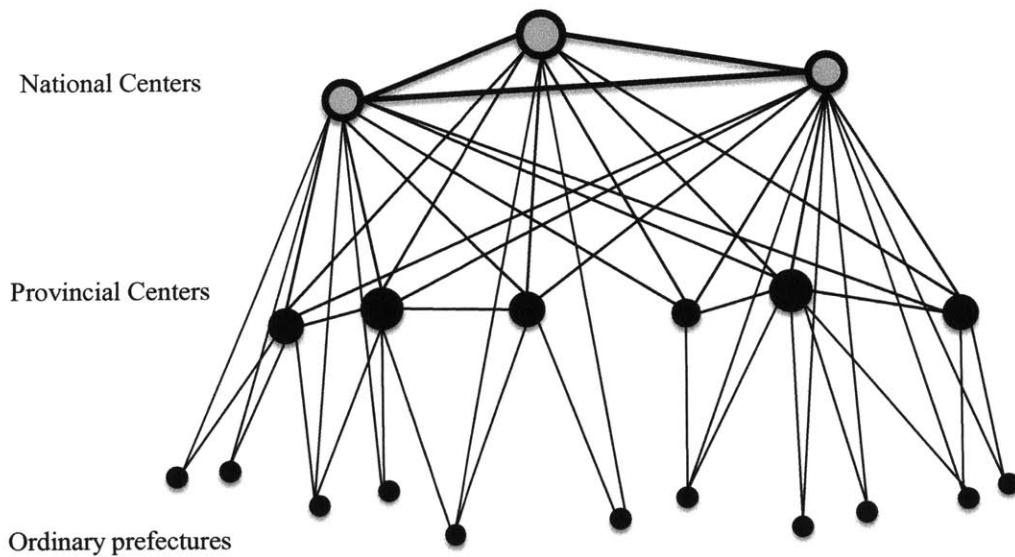
Source: author

To make sure that the urban hierarchy is consistent with reality, I double check the theoretical linkages against the actual passenger flows using available data from typical years. If the passenger flow indicates a strong linkage between two cities that are not predicted by the above rules, I make adjustment accordingly.

3.4   Parameterization and data

I conduct the research on intercity accessibility on 287 prefecture-and-above level cities

in China. In GIS maps, each city is represented by its centroid. In theory, I need to construct a

287*287 matrix for each travel mode in every year, but following the structure of urban hierarchy,

I manage to reduce the data intensity significantly and focus on the major and effective intercity

economic linkages.

I use the minimum travel time among the three available modes (rail, air and expressway)

as the proxy of the travel cost between cities. There are alternative measurements, such as the

weighted average travel time among the three modes or the generalized travel cost including

monetary costs. I choose the minimum travel time for two reasons. First, HSR generally cuts

down minimum travel time among cities, not necessarily dragging down average travel time

significantly. In addition, there is no data available for the modal split on each origin-destination

(OD) pair, which makes it impossible to precisely estimate the weighted average travel time.

Since the key interest of my research is high-end travel, which is more sensitive to time cost

rather than monetary cost, I assume that this sub-group of passenger chooses the fastest mode of

traveling regardless of fare. In the following parts I will explain the technical details to construct

travel matrices for each mode.

I use GDP of cities as a measure of their economic strength. The GDP data come from

China City Statistic Yearbooks for the years from 2002 to 2011. Spatially, I use GDP in the core

urban area (*Shi Xia Qu*,市辖区) to represent the size of urban economy, which excludes the

proportion of GDP in the adjacent counties and rural areas.

3.4.1   Travel time matrices by rail

I extract travel time by rail from the 2010 timetable database issued by the Ministry of

Railways. The time schedule database includes the following information for all the passenger

trains that were in operation as of 2010 (Table III-4).

Table III-3 Features in the 2010 railway timetable database

Items	Feature
ID	A series of numbers or a combination of numbers and a letter to denote a specific train service.
STATION	Name of the station
S_NO	The order of the station on the line. S_NO = 1 means it is the starting station.
DAY	1 means the same day and 2 means the next day.
A_TIME	Arrival time
D_TIME	Departure time
R_TIME	Total running time from the origin

This database enables me to calculate the travel time between any two stations that have

railway connections. For stations that have multiple rail services, I use the minimum travel time.

Then, I use a lookup table to select the railway stations in the cities that are included in my

sample. For cities that have more than one railway station, I merge them into one unique origin

or destination. When direct rail service is not available, I do a manual modification considering

connecting trips. The connecting time is calculated based on service frequency, which is also

obtained from the timetable. With the 2010 travel time matrix by rail, I restore the historical data

by taking out new services yearly. Some of the service changes are documented in detail in the

China Railway Yearbooks. However, besides introducing a brand new type of rail service, there

are still minor changes of opening, stopping or upgrading rail services on certain routes. I use the

printed travel time schedules in each year issued by the Ministry of Railways to double-check the

validity of data. I compare the ID list, origins and destinations and running times of all fast trains

for two consecutive years, and make adjustment as needed.

Travel time by rail includes not only time on the trains but also time to access the railway

station at both end of trips. Travel time to railway stations in each city is estimated by the Google

Map search engine. I include waiting and connecting time, which is a function of the frequency

of scheduled trips. Suppose desired arrival times are evenly distributed between 9 am and 5 pm.

The railway agency would position the trips to minimize the expected difference between when

the train arrives and the desired arrival times. With a uniform distribution, this means even

spacing. The average expected delay is then $0.5*8hours / (n+1)$ where n is the number of

scheduled trips. So it is two hours for one trip, one hour for three scheduled trips, etc. This seems

reasonable and adds about zero to two hours to the total trip time.

3.4.2 Travel time matrices by air

I extract intercity travel time from the 2010 airline time schedule database bought from a

private consulting agency. The time schedule database includes the following information of all

the airlines that were in operation as of 2010 (Table III-5).

Table III-4 Features in the 2010 airline timetable database

Items	Feature
D_CODE	A standard three-letter code for the departure airport
A_CODE	A standard three-letter code for the arrival airport
COMPANY	Airline company that runs the service
D_AIRPORT	Name of the departure airport
A_AIRPORT	Name of the arrival airport
A_TIME	Arrival time
D_TIME	Departure time
MODE	Type of aircraft
STOP	Number of stops in the trip
TIME	Total flight time duration

The above information enables me to calculate the travel time for the year 2010 between

any two airports that have direct flights. Although there can be multiple flights between cities,

the travel time for direct flights is about the same, which is different from that of rail services. So

it does not matter whether to use the minimum travel time or an average travel time here. For

cities that do have their own airport, I assume that people go to the closest airport to catch flights.

In this case, some of the ordinary municipalities need to go to the regional centers by air via their provincial center. In China people seldom makes intra-provincial travel by air, except for in Xinjiang Province, where the cities are so far away from each other and local transport is mostly air-based. For the short distance travel between provincial centers and their municipalities, I leave the air option as absent.

To restore the historical travel time matrices, I rely on the yearly issued statistical reports for all airports by the Civil Aviation Authority of China (CAAC). These statistical reports document changes in airline services including opening of new airports, termination of service in existing airports and cancelation of flights. I use the information to make adjustment to the 2010 air travel time matrix and get the matching data for previous years respectively.

To make comparison among transport modes meaningful, I use the comprehensive time which is the actual fly time plus the premium of ground access time at both ends of the trip and the security check time allowance. Therefore, I look up the time it takes from each city to access the closest airport on Google Map. I set the security check time to be 30 to 60 minutes depending on the class of the airport. I use the same logic and formula to account for time delay due to service frequency of flights.

3.4.3   Travel time matrices by expressway

The highway network in China has witnessed huge boom ever since the middle 1990s. Most of the 287 cities established expressway connection during the late 1990s or early 2000s, except for the most remote areas in southwest China. An ideal way of generating the highway-based travel time matrix is to use network analysis in GIS, if the shape and feature data (e.g., travel speed limits) are available for each year. Unfortunately, existing GIS data do not contain enough spatial and temporal details to support such network analysis.

As an alternative, I use the online search engine of Google Map to look up the travel time

by expressway, only for the city pairs that I identified with the urban hierarchy. With Google

Map I come up with two different travel time matrices, one with expressways and the other

without. I consider the latter matrix as the point of departure before any construction of

expressway. Then I developed a table that records the opening years of expressway between each

two cities. Data sources include the yearly published National Expressway Atlas of China and

the news reporting the opening ceremony of new expressways. Using the table of opening years,

in addition to the travel time matrices with and without expressways, I mask out the intercity

travel time matrix for any year between 2001 and 2010.

One caveat with this method is that, when the distance between two cities is long, and the

expressway is opened section by section, then this method cannot capture the gradual changes

over years. Fortunately, if this is the case, usually the travel time by road is not the shortest

among other modes, so the impact of possible measurement error on the minimum travel time is

negligible. Also, when the distance is long, the market share of travel by road becomes very

small, and the measurement error still will not have a huge impact on the average travel time.

3.5   Results of analyses

In this section, I illustrate the evolution of intercity accessibility in China between 2001

and 2010, and analyze the underlying factors that have driven the changes in accessibility. I

discuss accessibility patterns in terms of absolute values and relative changes, with special

emphasis on the role of HSR in reshaping accessibility patterns. To achieve these goals, I

compare six accessibility indicators for 2001 and 2010: (1) the all-mode economic potential

based on minimum travel time of three transport modes; (2) the economic potential based on

railway travel time; (3) the all-mode daily economic potential by setting a 4-hour time ceiling on

(1); (4) railway-based daily economic potential by setting a 4-hour time ceiling on(2); (5) WATT based on minimum travel time of the three transport modes; (6) WATT based on railway travel time. The maps below visualize the changes in accessibility measured by these six indicators. On each map the size of points are proportional to the value of accessibility.

3.5.1   Accessibility measured by economic potential

The all-mode economic potential shows spatial association with the level of economic development in China (Figure A-4). First-tier cities in the three most developed coastal urban clusters have the highest economic potential in 2001 and 2010. These megacities are Guangzhou and Shenzhen in Pearl River Delta, Shanghai and Hangzhou in Yangtze River Delta, and Beijing and Tianjin in the Bohai Bay Area. Other cities within the core hinterland of the three urban clusters also indicate considerably higher economic potential than elsewhere. Outside the three major urban clusters, several couples of provincial centers show great economic potential, including Chongqing and Chengdu in Southwest China, Wuhan and Changsha in Middle-South China, and Jinan and Qingdao in North China. It is interesting to note that economically developed cities also enjoy good access to external resources, given that the economic potential indicator excludes the home city and purely represents the influences from other cities.

Railway-based economic potential resembles the pattern of accessibility as measured by all-mode economic potential (Figure A-5). The major difference is that, provincial centers outside the three major urban clusters show much lower economic potential. Most of them are located in Western China, including Chongqing and Chengdu. Such difference indicates that, air transport makes significant contribution to the all-mode accessibility for provincial centers in Western China, as an important component of economic potential comes from their connections with Beijing, Shanghai and Guangzhou by air travel. For cities in Eastern and Middle China, the

gap in railway-based economic potential is smaller between different tiers of cities as compared

to the all-mode economic potential. The narrower gap in economic potential implies a certain

degree of equalization in railway service within the eastern region, as well as the fact that air

transport has polarization impacts on the economic potential of major megacities.

Figure A-4 and Figure A-5 also illustrate the spatial correlation between economic

potential and the HSR lines---cities with high economic potential are those connected by HSR.

This, however, does not necessarily imply a causal relationship between the presence of HSR

lines and high economic potential. Further examination is needed to determine HSR's

contribution to the levels of economic potential at urban locations.

The levels of economic potential is to some extent path dependent, that is, the most

accessible cities in 2001 remain the top ones on the accessibility ranking list of 2010. However,

with regard to relative changes in all-mode economic potential, the winners are mostly small and

medium sizes cities that were not very accessible previously. This indicates convergence in

economic potential among different tiers of cities.

Figure A-6 shows the changes in all-mode economic potential in relative terms. Three

groups of cities experienced the most significant improvement in all-mode economic potential

during this period, driven by different types of transport infrastructure development. Cities on the

frontier of the national "Grand West Development" strategy have the most remarkable

improvement in all-mode economic potential. These cities are located along a belt from northeast

to southwest China, which largely benefited from the expansion of expressways and

conventional railways to the remote regions. The second group of cities in Mid-to-North China

also experienced significant increase in economic potential. They most likely benefited from

densification of the conventional railway system, completion of expressway network, and

opening of new airports (e.g., Changzhi, Qingyang, Erdos). The third group of cities with great improvement in economic potential is those along the Wuhan-Guangzhou HSR in Middle-South China. Cities on Chengdu-Chongqing HSR and Zhengzhou Xi'an HSR also fall into this group. The spatial pattern of relative changes in economic potential indicates possible association between HSR lines and improvement in accessibility.

The spatial association between HSR and accessibility improvement becomes more evident in the map showing the relative changes of railway-based economic potential (Figure A-7). In contrast to the pattern of the changes in all-mode economic potential, the major improvement in railway-based accessibility occurred in cities in Southeast China and the emerging Sichuan-Chongqing urban cluster. The map also illustrates that major passenger-dedicated HSRs outperformed upgraded or expanded conventional rails in making cities more accessible. The coastal HSRs connecting Shanghai with second-tier cities in Zhejiang and Fujian brought the most significant improvement of railway-based accessibility to the latter. This HSR ended the history of there being no railway line running along the coast. The Wuhan-Guangzhou HSR has generated wide-spread improvement in accessibility for cities along this corridor. Other HSRs not reaching any national economic center exert smaller impacts on railway-based economic potential, such as, Zhengzhou-Xi'an HSR, Taiyuan-Shijiazhuang HSR and Jinan-Qingdao HSR.

In order to delineate the particular impacts of HSR, I develop a counterfactual scenario for the year 2010 as if there were no HSR in operation and compare it with the real situation. The difference between the counterfactual scenario and the real situation indicates that HSR lines do contribute significantly to cities' accessibility that they connect (Figure A-8). Both passenger-dedicated lines and the upgraded lines improve accessibility of cities, though the new

lines tend to bring even greater changes. As compared to the without-HSR counterfactual scenario, the accessibility of HSR cities increased by 17% on average, with a maximum increase of 157%. The Wuhan-Guangzhou HSR line brings the most remarkable improvement in all-mode economic potential for small and medium size cities along this transport corridor. There are two reasons for its great success in improving accessibility. First, this line supports mid-to-long distance travel, for which the time saving is more significant as compared to local trips. Second, this HSR connects lower-tier cities to megacities at the heart of Pearl River Delta, which have long been the most influential economic centers in South China and the main destinations of business trips from Hunan and Hubei Province. In like manner, the Shanghai-Nanjing strengthened the connection within the Yangtze River Delta, and the coastal HSR line improved connectivity between the coastal cities in East China. In addition, cities at the middle points of HSRs connecting two major provincial centers witnessed remarkable improvement in economic potential, such as, Suining between Chengdu and Chongqing, Sanmenxia between Zhengzhou and Xi'an, and Yangquan between Taiyuan and Shijiazhuang.

3.5.2   *Accessibility measured by daily economic potential*

The economic potential indicator with a 4-hour travel time ceiling better represents the accessibility of business trips. Figure A-9 illustrates the all-mode daily economic potential for 2001 and 2010. Similar to the pattern as shown in Figure A-4, cities with highest daily economic potential are the megacities in the three major urban clusters in Eastern China. Lower-tier cities immediately surrounding the megacities or located on major transport corridors connecting megacities also show high daily economic potential, with Chongqing as the only exception. Yet the gap in all-mode daily economic potential is much narrower between different tiers of cities in Eastern China than that including long trips. This result indicates that Eastern China is a much

more integrated region, where it is convenient for people to make same-day trips among cities. In contrast, even second-tier cities in Western China show lower daily accessibility than many third-tier cities in the Eastern region. The gap in daily all-mode accessibility remains wide between the East and the West.

If railway is the only option for same-day travel, then the pattern of daily accessibility becomes quite different (Figure A-10). Distance is a more determinant factor than the all-mode case with air travel option. Cities with high economic potential are megacities and those clustering closely around them. Cities outside the three major urban clusters have much smaller daily accessibility since they rely on airlines to make same-day trips to major destinations. But there is one exception. People from cities along the Wuhan-Guangzhou HSR enjoy convenient daily trips by rail, even though they are not located within the core of the Pearl River Delta.

Daily accessibility of cities on top of China's urban hierarchy remains highest during the study period. Yet the gap of daily accessibility between first-tier cities and lower-tier cities is closing. The most significant changes in all-mode economic potential occurred in lower-tier cities (Figure A-11). Spatially, these cities are mostly located in Middle China. Some of them experienced step changes in daily accessibility due to the opening of airlines from and to megacities, such as, Fuyang, Yuncheng and Ji'an. The remaining cities are sitting along major HSRs. The contribution of HSR to daily accessibility becomes more evident as measured by the railway-based economic potential. As shown in Figure A-12, cities with significant improvement in daily accessibility are exactly those along the HSR lines, particularly those along the Wuhan-Guangzhou HSR and the coastal HSR.

However, part of the step changes in daily accessibility does not show up on the maps of relative changes. For some cities, the daily economic potential in 2001 was zero as no major

destinations were within the four hours' travel time limit, and it is impossible to calculate the relative change ratio for them. Typical examples include Datong, Changzhi, Erdos, Jixi, Shiyan, Panzhihua, Qingyang and Wuzhou, most of which are at peripheral locations of the provinces they belong to and have new airport or expressway being put into operation. The imperfection of measurement lies in the arbitrariness of drawing a cut-off line at four hours. A city could only experience a very minor drop in travel time from 4.1hours to 3.9 hours but show a huge jump in economic potential.

3.5.3 Accessibility measured by WATT

The top two maps in Figure A-13 show all-mode WATT in 2001 and 2010 respectively, and the bottom two maps show railway-based WATT for each year. The average all-mode WATT has come down from 4.5 hours to 4.1 hours and the average railway-based WATT has reduced from 11.3 hours to 10.3 hours. Among all cities, 74% experienced reduction in all-mode WATT and 58% had reduction in railway-based WATT. However, the overall pattern of WATT has not changes very much though the years---remote inland cities still have high WATT, which are located on a C-shape curve from northeast to northwest and southwest regions of China.

The magnitude of relative changes in WATT provides different perspectives (Figure A-14). The spatial patterns of accessibility changes measured by all-mode WATT and by all-mode economic potential are largely consistent. Cities experienced great reduction in WATT as shown in Figure A-14 are mostly those with large gains in economic potentials as shown in Figure A-6. The most remarkable reduction in all-mode WATT occurred in second- and third-tier cities with airport, HSR or expressway being opened during the study period. It is worth mentioning that Wuhan-Guangzhou HSR again outperformed other HSRs in bringing down WATT for cities along its route.

Figure A-15 illustrates the relative changes in accessibility measured by railway-based WATT. The relationship between HSR lines and accessibility improvement partly resembles that measured with railway-based economic potential in Figure A-7. Cities on Wuhan-Guangzhou HSR and the Coastal HSR witnessed the most remarkable reduction (50-70%) in railway-based WATT. The rest are cities close to national borders that are not connected by conventional railway in the base year 2001, such as, Karamy, Lhasa, Boshan and Lincang.

3.6   Summary

In this section, I examine the evolution of intercity accessibility patterns in China by comparing the absolute levels across cities and the relative changes over time. The GIS-based spatial analyses of the network accessibility measured by three alternative indicators consistently illustrate that the extensive transport investments during 2001-2010 have effectively reduced the disparities in accessibility across regions in China. As shown in the distribution curve of accessibility measured by economic potential, the coefficient of variation dropped by 50% during the 10-year period (Figure III-4).

Figure III-4 Distribution curves of economic potential 2001 and 2010
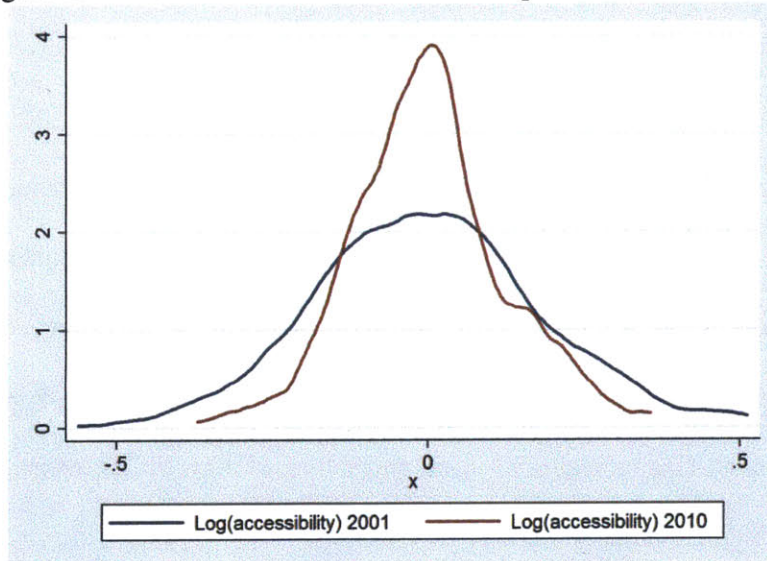
The magnitude of improvement, however, varies in space and across urban hierarchy. By all measurements, the most remarkable improvement in accessibility occurred in lower-tier cities located in inland provinces outside the core catchment of the coastal megacities. The levels of accessibility at urban localities demonstrate spatial association with the landscape of economic development in China. My analyses also find spatial association between levels of economic potential and the presence of HSR lines.

HSRs have played a significant role in reshaping accessibility. The type of transport infrastructure determines its specific impacts on accessibility. Air travel greatly distorts accessibility patterns on a national level, but its impacts are spatially restricted to a small number of scattered urban localities. Expressways mainly influence the pattern of local travel within prefectures. HSR primarily reshapes connectivity at a regional level, which dominates the economic interaction among prefectures at the lower tiers of urban hierarchy.

By developing a counterfactual scenario without HSR for 2010 and comparing it to the real situation, I find that the accessibility of HSR cities is 17% higher on average, and the maximum improvement in accessibility reached 157% in Chenzhou city on the Wuhan-Guangzhou HSR. HSRs that have contributed significantly to the improvement of accessibility share two features: (1) they strengthen the vertical connection between megacities and lower tier cities rather than among a cohort of lower-tier cities (e.g., the Wuhan-Guangzhou HSR), and (2) they remove bottleneck of fast travel rather than bring unnecessary competition with existing travel modes (e.g., the Coastal HSR).

HSR has a potential to dominate the niche market for medium-to-long distance travel of 300-1000 km. The centroids of the three major urban clusters in East China and the two emerging urban clusters in Middle and West China are about a thousand kilometer from those of

their closest neighbors. As a result, HSR is potentially a suitable transport option to enhance economic integration within the urban cluster as well as to facilitate cooperation among different urban clusters.

To sum up, the extensive investment in the transport sector during 2001-2010 has effectively narrowed the gap in accessibility across regions in China. It is encouraging to find that even though the disparities in accessibility still exist between developed and lagging regions and among different tiers of cities, the evolution of the accessibility patterns is heading towards a convergence. The findings from my analyses of accessibility patterns to some extent support policy-makers' argument that HSRs will facilitate integration of lower-tier cities into the catchment of major economic centers. However, HSR alone is not a sufficient condition for accessibility improvement. Its impact on accessibility depends on the type of destinations that HSRs connect and the current status of transport facilities along the specific corridors.

Yet another set of key questions remains unanswered: will accessibility improvement influence urban economic performance, and if so, how much? Is it always beneficiary to be more accessible? Will the benefits be generative or merely distributive? The analyses of the evolution of accessibility patterns have shed light on the potential association between accessibility and economic performance. Such relationship is yet to be examined rigorously and will be the focus of this research in the following chapters.

Chapter IV   ELASTICITY OF ECONOMIC PERFORMANCE TO ACCESSIBILITY

In this chapter, I further explore how the changes in intercity accessibility may be associated with urban economic performance. The purpose of estimating the elasticity of urban economic performance with respect to accessibility changes is to make possible the integration of wider economic impacts into the decision-making process of transport investments. I examine whether the economic benefits associated with improved accessibility are generative (i.e., creating net benefits) or redistributive (i.e., moving development opportunities around), and whether the changes occur in quantity (e.g., amount of investment and employment) or in quality (e.g., price and wage) of the urban economic activities. Given China's dramatic social-economic transition during the study period as well as the huge heterogeneity among cities in different regions, I extend the analyses to show the variation in the elasticity of accessibility across regions or by city size, and whether the contribution of accessibility to economic performance diminish with accessibility improvement.

I estimate a series of panel data models to identify the elasticity of various features of urban economic performance to accessibility, ranging from the GDP, productivity and total employment of the cities to specific sectors that are expected to rely heavily on fast passenger transport, such as IT and finance sector, foreign direct investment and tourism. My analysis covers the urbanized areas of 287 prefecture-and-above level cities[1] in China to assess the economic influence of accessibility that spreads over the national transportation network. Section 4.1 is a brief introduction to the motivation and context of this empirical research. In Section 4.2, I selectively review relevant studies that examine the relationship between transport infrastructure investment and economic development, with special focus on researches built on

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[1] In China, there are 283 prefecture-level cities and 4 province-level cities, which are, Beijing, Tianjin, Shanghai, Chongqing.

the New Economic Geography (NEG) theory that empirically quantifies the agglomeration

benefits of accessibility improvement. In Section 4.3, I develop the conceptual framework and

explain the econometric models and estimators I use for the empirical analysis. Section 4.4

contains the indicators I choose to measure urban economic performance and the data sources. In

Section 4.5, I report and interpret findings from the estimation results. Section 4.6 concludes.

4.1 Multiple dimensions of transport infrastructure's economic impacts

Transportation by itself is not a sufficient factor for growth, but the lack of transport

infrastructure can become a severe constraint on development (Lin 2012). In many developing

countries, inadequate capacity in transportation infrastructure impedes economic growth by

conferring a high cost of reaching market, labor and knowledge (Estache 2004). Analysts argue

regional transportation investment generate not only "spending and demand effects" during the

construction periods, but also create remarkable "cost saving and productivity impacts" once put

into operation (Weisbrod 2009). I list below typical economic impacts associated with major

transport infrastructures (Table IV-1).

Table IV-1 Categories of transport infrastructure's socio-economic impacts

Spending effects
- Increase final demand and create jobs within construction sector
- Increase demand and create jobs in construction related sectors through backward and forward linkages
- Increase household income and lead to more domestic consumption
Operational effects
Within transport sector
- Save travel time and/or cost
- Introduce competition with airlines and expressways
- Improve travel safety and reduce losses from accidents
- Release capacity for freight transport on existing railway lines
On the whole economy
- Expand access to large and diversified labor pool
- Expand catchment of home market
- Enhance forward and backward linkages among producers
- Facilitate knowledge-sharing through face-to-face communication

The spending effects are often temporary and local, while the cost-saving and productivity impacts are long-lasting and far-reaching (Oosterhaven and Romp 2003). The operational effects can be further divided into influences within the transport sector versus the broader impacts on the whole economy. A rich set of literature assessed the impacts of HSR within transport sector by estimating behavioral models to determine the probability of passenger shifting and forecast the steady-stage inter-model market share (Román, Espino et al. 2007; Hsu, Lee et al. 2010; Wang 2011). In contrast, assessing the wider economic impacts of HSR investment remains puzzle among researchers and professionals.

In this chapter, I propose an analytic framework to assess the wider economic impacts of regional transport investment, which is applicable but not restricted to the appraisal of HSR projects. The fundamental assumption is that transport infrastructure affects the organization and efficiency of economic activities by changing the way cities interact with each other, and such interaction is increasingly important in the context of globalization. Under this analytical framework, intercity accessibility is jointly determined by the three major modes of passenger transport: air, rail and road[2]. The advantage of capturing the outcome of transport investment as change in accessibility is that this method can be applied to assess the economic impacts of any type of intercity transport project. The impacts of a specific project can be evaluated or forecasted by taking out or adding into the existing transport network and detecting the changes in accessibility accordingly.

4.2   Empirical studies under the NEG framework

The existing literature provides useful guidance for me to develop the methodological framework and select proper indicators to represent urban economic performance. Analysts following the New Economic Geography (Krugman 1991a; Krugman 1991b) theories argued

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[2] Telecommunication and internet can also facilitate interaction, which is beyond the scope of my study.

that transport infrastructures generate agglomeration benefits by expanding access to labor forces, enlarging market reach and facilitating knowledge spillover. They have made great efforts to quantify the magnitude of such benefits with properly designed methods and indicators (Brotchie 1991; Preston and Wall 2008; Banister and Thurstain-Goodwin 2010). Although reducing transport costs and improving accessibility may exert remarkable impacts on economic development, the spatial distribution of benefits may lead to regional divergence or convergence, depending upon the local circumstances: better accessibility might help the undeveloped periphery to grow faster through increased trade, investment and knowledge sharing, or it could strengthen the center by attracting even more productive resources from the periphery (Blum, Gercek et al. 1992; Fayman, Metge et al. 1995; Vickerman 1997; Kim 2000). The NEG framework provides an opportunity to integrate theoretical reasoning with the rigor of empirical modeling. There is a large volume of literature that associates socio-economic benefits with transport investment, and I selectively review literature that is closely relevant to the current study. I group the studies by the specific aspects of economic performance.

One school of the empirical studies analyzed impacts of transport infrastructure on productivity enhancement and relocation of economic activities. According to Rietvel (1994), at the interregional level, transport infrastructure stock has a considerable impact on the productivity of mobile production factors, but the impacts of transport infrastructure on the location choice of economic activities are usually limited. Rice and Venables et al. (2006) outlined an analytical framework within which interactions between the different aspects of regional disparities in productivity can be investigated econometrically. Further, the work of Combes, Duranton and Gobillon (Combes et al, 2008) and of Venables (2010) develop general frameworks to investigate respectively the sources and mechanisms that lead to wage disparities

across regional labor markets through sorting and self-selection. Graham and Kim (2008) investigate the relationship between accessibility and productivity using a large sample of financial accounting information from individual firms in the UK. Meré and Graham (2010) further investigate the effect of firm level heterogeneity and non-random sorting of firms across space. These studies have shed important light on the statistical relationship between accessibility and productivity, and on the complexities of empirical modeling. The studies have also shown that such statistical relationships may be highly context specific. Having carried out a meta-analysis of 729 measurements of agglomeration effects from 34 studies, Melo et al (2009) conclude that the elasticity of accessibility to productivity estimates for any particular empirical context may have little relevance elsewhere.

According to Vikerman (2007), the labor market effects arise in three possible ways: First, improved transport facilities may enable access to jobs, which would not otherwise have been possible by linking areas of surplus labor to those of labor shortage. Second, travel time savings shift the total time budget line outward, and may help the workers to obtain high utility level by re-allocating time between job and leisure. Third, the impacts on productivity arise through workers being able to move from less productive to more productive locations. The first and third types of impacts are more of redistributive nature, while the second mechanism brings generative benefits. In addition to these three mechanisms, another origin of generative impacts on productivity is likely to be intensified face-to-face communication along with HSR trips, which fosters the sharing of localized tacit knowledge.

Regarding HSR'simpacts on economic growth, the study by the European Commission (1997) estimated that the Trans-European Networks (TENs) would add 0.25% to EU GDP and 0.11% to employment over 25 years. Analysts make such estimation using computable general

equilibrium (CGE) models. Researchers also use comparative statics to study the growth rate of cities and regions that have direct access to HSR versus those without HSR. Early studies on *Shinkansen* in Japan indicated that regions served by the HSR stations generally have higher population and employment growth rate than those without direct HSR service (Nakamura and Ueda 1989; Amano 1990). These analysts also indicated that the existence of expressways could enhance the positive impact of *Shinkansen*. However, other scholars challenged the validity of Amano's study by questioning the small sample size and the comparativeness of cities he chose for case studies (Sands 1993).

Analysts also explored the possible variation of HSR's economic impacts across different industrial sectors. Because tourism is reported to be one of the major purposes of traveling by HSR, a number of empirical studies allocated special attention to the tourism industry. Researchers found that HSR may affect the tourism industry in two contradictory ways: an increase in day-return journey that brings more visitors, and a drop in the number of overnight stays and a loss in hotel business (Bonnafous 1987; Haynes 1997; Albalate 2010). In a recent study on the South European HSR lines between Perpignan and Barcelona, Masson and Petiot (2009) showed that the resulting increased spatial competition may reinforce the tourism activities agglomeration around Barcelona to the detriment of the periphery city Perpignan.

Although the interaction of transportation infrastructures and land use patterns are well documented on the metropolitan level (Badoe and Miller 2000; Wegener and Fuerst 2004), such relationship has seldom been discussed at the regional level. In a case study in the municipality of Ciudad Real in Spain, (Garmendia, de Ureña et al. 2008) showed that the impacts of a high-speed train station as intra-urban polarizing elements on housing development and price are limited. The decision to localize the residence with respect to the HST station varies with the

type of inhabitant (local versus immigrant, tenant versus owner, etc.) and their relationship to high-speed trains (commuter versus non commuter, etc.). Andersson, Shyr et al. (2010) estimated the value of high-speed rail accessibility using a hedonic price function for the residential property market in Taiwai, and concluded that HSR access has at most a minor effect on housing price. According to existing literature, the impacts of HSR on land value and housing price is less deterministic and less significant compared to that of commuter rails or subway lines. This is intuitively reasonable, because land value and housing price depend mostly on intra-city accessibility, while high-speed rail majorly changes intercity accessibility.

4.3   Methodology

I develop the conceptual framework for this empirical analysis by adding interaction among regions, a key research focus of NEG theory, to the a-spatial endogenous growth model. Then I explain the details of the econometrics models and estimators to be used in this research.

4.3.1   Conceptual framework

In the classic model of economic growth, the output Y is determined jointly by the stock of capital (K), the input of labor (L) and the level of technology (A). The underlying assumption of neoclassical or exogenous growth models is that, A is a function of time and is determined outside the model (Eq.IV-1).

$$Y = A(t)f(K,L) \hspace{4cm} \textbf{Eq. IV-1}$$

Differently, in endogenous growth models, the level of technology is considered to be the outcome of local knowledge spillovers from the accumulation of both capital and labor (Romer 1994), and the production function takes the following form (Eq. IV-2):

$$Y = A(K,L)f(K,L) \hspace{4cm} \textbf{Eq. IV-2}$$

Following Arrow's (1962) treatment of local knowledge spillover, capital investment not

only increases the stock of physical assets but also augments the level of technology for all firms

in the economy. Romer (1990) argued that increasing labor supply caused negative effects on

technology changes because it reduces the incentives for firms to discover and implement labor

saving-innovations.

The standard version of endogenous growth models is developed in the context of a

closed economy, where the country or region in question is considered as a stand-alone economic

entity. In an open economy, where regions have frequent interaction with the rest of the country

or even the world, access to external resources outside the home region also plays a critical role

in the improvement of technology. In addition, inter-regional connections facilitated by modern

transportation also bring changes to the local endowment of labor and capital. In other words, the

output of a region not only depends on the capital and labor endowment of the region itself.

Therefore, I adapt the endogenous model in which access to external resources, measured by

accessibility M_i, enters the production function through two channels (Eq. IV-3):

$$Y_i = A(R_i, M_i) f[K_i(M_i), L_i(M_i)] \qquad \text{Eq. IV-3}$$

Where R_i denotes level of local innovative activities, K_i and L_i are the *effective* inputs

of capital and labor of region i that can be further decomposed as follows:

$$K_i(M_i) = k_i(1 - \theta_i^k M_i) + (\bar{K} - k_i)\mu_i^k M_i \qquad \text{Eq. IV-4}$$

$$L_i(M_i) = l_i(1 - \theta_i^l M_i) + (\bar{L} - l_i)\mu_i^l M_i \qquad \text{Eq. IV-5}$$

Where k_i and l_i are the original endowment of capital and labor without any transport

connections to other regions; $\bar{K}$ and $\bar{L}$ are the total amounts of capital and labor stock in the

reachable parent region (often the nation); θ_i^k and θ_i^l measure the magnitude of capital and

labor outflows due to unit change in accessibility, namely, the "centripetal effects," and μ_i^k and

μ_i^l represent the magnitude of capital and labor inflows due to the unit change in accessibility, which is, the "centrifugal effects." The magnitude of capital and labor inflows may vary among connected regions but I use an average coefficient μ for simplicity.

In the most extreme case, where regions are isolated islands of production, $M_i = 0$ $K_i(M_i) = k_i$ and $L_i(M_i) = l_i$. In reality, M_i is often greater than zero and its influence on the capital and labor stock of the home region depends on the relative magnitude of θ as compared to μ, and the relative dominance of the home region within the parent region. If $k_i\theta_i^k < (\bar{K} - k_i)\mu_i^k$, the inflows of capital exceed that of outflows, so that the home region gains extra capital in addition to its own endowment. If $k_i\theta_i^k > (\bar{K} - k_i)\mu_i^k$, there will be net losses in capital at the home region. The same rule applies to labor market. Accessibility M_i serves as a multiplier, amplifying the overall impacts no matter whether it is positive or negative. Although it is hard to draw a simple conclusion from the conceptual model regarding the changes to a single region caused by interactions with other regions, the overall effect is mostly redistributive because capital and labor are rival goods. When it comes to technology, I assume that the influence from accessibility is always positive because economists usually consider knowledge as non-rival goods. Improving interaction with other regions generates a positive externality on knowledge production and spillover, which is exactly the source of generative benefits from transport investment.

4.3.2   Panel data models and estimators

I estimate panel data models to determine the elasticity of economic performance to accessibility for the prefecture-and-above level cities. I fit the data with pooled models and individual-specific effect models. I start with the most restrictive model---the pooled model,

which specifies constant slope coefficients and a universal intercept (**Eq.IV-6**):

$$y_{it} = \alpha + x'_{it} \beta + \varepsilon_{it}$$ **Eq. IV-6**

Where y_{it} is the economic performance indicator; x_{it} is a vector of explanatory variables

including the accessibility index, and ε_{it} is the error term. If the explanatory variables are

uncorrelated with the error, then this model could be consistently estimated by pooled OLS

models.

However, for most economic datasets, the error terms are potentially serially correlated

and unobserved individual heterogeneity may correlate with explanatory variables. The existence

of unobserved individual heterogeneity will lead to omitted variable bias in estimation. So I use

individual-specific effects models to allow for unobserved individual heterogeneity, where α_i

allows each city to have a different intercept term (**Eq.7**):

$$y_{it} = \alpha_i + x'_{it} \beta + \varepsilon_{it}$$ **Eq. IV-7**

There are two variants of individual-specific effects models: the fixed-effect (FE) model

and the random-effect (RE) model. The FE model treats α_i as an unobserved random variable that

is potentially correlated with the explanatory variables, while the RE model assumes that α_i is

distributed independently of the explanatory variables. The FE model is widely used in

econometric analyses given that it allows for partial endogeneity in the explanatory variables,

which is a more realistic assumption for economic data. The time-demeaned fixed-effect

estimator, or the *within estimator*, uses the deviation from each i's time-averaged values to

estimate β (**Eq. IV-8**), while the individual-specific, time-invariant feature α_i cancels out.

$$y_{it} - \overline{y}_i = (x_{it} - \overline{x}_i)\beta + \varepsilon_{it} - \overline{\varepsilon}_i$$ **Eq. IV-8**

The random-effects estimator can be calculated by using partially time-demeaned

variables constructed as follows (**Eq.IV-9**):

$$y_{it} - \hat{\lambda}\bar{y}_i = (1-\hat{\lambda})\mu + (x_{it} - \hat{\lambda}\bar{x}_i)'\beta + v_{it}$$

Eq. IV-9

The models mentioned above focus on the one-way effects, with $u_{it} = \alpha_i + \varepsilon_{it}$. The

two-way effects models, with $u_{it} = \alpha_i + \gamma_t + \varepsilon_{it}$, additionally allows for time-specific effects

(**Eq.IV-10**).

$$y_{it} = \alpha_i + \gamma_t + x_{it}' \beta_i + \varepsilon$$

Eq. IV-10

Although the fixed-effect estimator mitigates the possible bias of the pooled OLS

estimation by eliminating the potential correlation between accessibility and the unobserved

city-specific, time-invariant determinant of economic performance, the estimation results may

still be biased if changes in accessibility are correlated with the unobserved time-varying factors

that influence economic performance. As an extension to the panel data analyses, I further

conduct two-stage least squares (2SLS) estimation with properly selected instrumental variables

(IVs). I also selectively control for additional explanatory variables to the extent that data

availability allows.

4.4   Parameters and data

In this section, I present a brief overview of the indicators that I choose to measure

different aspects of urban economic performance, with data sources identified.

4.4.1   Economic performance indicators

Existing literature has indicated that improvements in accessibility may lead to changes

in the size of urban economy, productivity, employment, capital investment, and industrial

sectors which rely heavily on convenient travel, such as, high-end services sectors and tourism.

Therefore, I list below the indicators that represent urban economic performance from different

perspectives. They are the dependent variables of regression equations (Table IV-2).

Table IV-2 List of economic performance indicators

Group	Category	Economic Indicators	Source
General economic performance	Size of economy	GDP	(a),(b)
		Population with local household registration	(a),(b)
	Productivity	Per capita GDP	(a),(b)
		Average annual wage rate of full-time urban employee	(a),(b)
	Employment	Total employment	(a),(b)
		Employment in public agencies and state-owned firms	(a),(b)
		Employment in private firms and self-employment	(a),(b)
Sectoral economic performance	High-end services	Employment of information technology industry	(a)
		Employment of finance industry	(a)
	Capital investment	Foreign direct investment (FDI)	(a),(b)
		Property price	(b),(c)
		Real estate investment	(a),(b)
	Tourism industry	Revenue from domestic tourism*	(b),(c)
		Number of domestic visitors*	(b),(c)

*Note: data for property price, tourism revenue and number of tourists are only available for the entire prefecture.

I calculated the accessibility indicator in this research based on the minimum intercity travel time weighted by the economic size of destination cities. This is a good proxy of high-end travel that is sensitive to time but not so much to monetary costs. Therefore, it is reasonable to expect the relationship between accessibility and travel-dependent industrial sectors to be stronger than that between accessibility and general economic performance indicators. To assess the sector-specific elasticity of accessibility, I choose two high-end service sectors: the information technology (IT) and finance industries, which are often considered to generate huge demand for business trips based on existing literature. I include foreign direct investment (FDI) as a measurement of inter-regional capital flows. I also include the real estate industry, which is expected to benefit from intercity capital investment (Garmendia, de Ureña et al. 2008; Andersson, Shyr et al. 2010), and the tourism industry, which is predicted to be one of the major beneficiaries of fast travel (Masson and Petiot 2009; Becker and George 2011).

GDP is the gross output measured in 2001 constant RMB. Population refers to people with local household registration (Hukou), excluding migrate population. Ideally I should use the

total number of permanent residents but such statistics are not reported consecutively at the

prefecture level. I also convert per capital GDP and wage rate to 2001 constant RMB. I use wage

rate as an alternative measurement of productivity, following the tradition of empirical research

in this domain (Head and Mayer 2006; Laura and Sandra 2010). Employment is the total number

of people with full-time jobs, which consist of public sector employment and private sector

employment. The current industrial coding system of China consists of 20 sectors[3]. The

information technology (IT) sector includes telecommunication, broadcasting, satellite service,

internet service, and software development. The finance sector includes banking, securities,

insurance and others. Foreign direct investment I use in this analysis is the amount of actually

utilized investment from outside China, rather than the contract value. Property price is the sales

price of residential units per square meter. Real estate development includes the new construction

of both commercial and residential buildings. Tourism revenue includes all the expenses on

transport, sightseeing, lodging, restaurant, shopping and recreation. The number of tourists not

only include people who travel for sightseeing or on vacation, but also include those paying visit

to a city for academic, cultural, sports or religious events (Statistical Year Book of China, 2011).

I extract data from three main sources: (a) China City Statistical Yearbook (2002-2011);

(b) the CEIC China Database; and (c) China Regional Economics Statistical Yearbooks

(2002-2011). Whenever possible, I use the alternative source to double check the validity of data

from different sources. Most socio-economic indicators contain two values that correspond to

different geographical units: the whole area within the prefecture's administrative boarder (*quan

shi*) and the core urbanized area (*shi xia qu*) where most urban production is located. The latter

does not include suburbs and counties that are subordinate to the prefecture-level city. In the

previous chapter of accessibility analyses, I treat cities as points at their centroids to calibrate the

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[3] From National Bureau of Statistics of China, http://www.stats.gov.cn/tjbz/hyflbz/

intercity travel time matrix and accessibility. The nodal accessibility is a proper measurement of the transport service for the core urbanized area but not for the whole prefecture including suburbs and surrounding counties. Therefore, I use the statistics for the core urbanized area to assign values for the economic performance indicators in order to maintain spatial consistency between the dependent and independent variables.

Some of the prefecture level cities have been established between 2001 and 2003, therefore data are not available for early years of the study periods. Most of them are from less developed regions of China such as Guangxi and Inner Mongolia. Another group of cities experienced fundamental changes in administrative borders, which makes the statistics of economic indicators inconsistent over time. Typical examples are Dongguan and Zhuhai in Guangdong province. I exclude these cities from the regression analyses, reducing the number of cities from 287 to 260. Such treatment may lead to sample selection bias due to the fact that the new cities and cities with great changes in administrative borders are those that experienced a rapid development in recent years. However, because these two groups of cities take up only about 6% of the total sample, it is a worthwhile tradeoff to maintain the consistency of the data.

4.4.2   Descriptive statistics

The original values of economic performance indicator follow highly skewed distribution. I take logarithm transformations for dependent variables and explanatory variables so that they approximately follow normal distribution. Convenience lies in that the coefficients estimated represent the elasticity of urban economic performance with respect to accessibility.

Economic performances indicators and the accessibility index may vary across individuals and over time. Variation over time of a given individual is called *within variation*, while variation across individuals is called *between variation* (Cameron and Trivedi 2005). Table

B-1 in Appendix B provides basic summary statistics of the selected economic performance indicators and the accessibility index. For most variables, between variations dominate the overall variations among different observations. Per capita GDP and accessibility have comparable magnitudes of between and within variation. Only wage rate has larger within variation than between variation. This distinction is important because estimators differ in their use of within and between variations. For most variables listed in the table, within estimation may lead to considerable efficiency losses.

All of the economic performance indicators are positively correlated with accessibility, with correlation coefficients ranging from 0.545 to 0.819. The simple correlation coefficients do not provide sufficient evidence regarding the underlying relationship between accessibility and urban economic performance, but at least suggest that, in general, better accessibility co-exists with stronger economic performance, and the magnitude of correlation is considerably large. Moreover, the correlation pattern between economic performance and accessibility is consistent over time. For instance, the correlation between log (GDP) and log (accessibility) fluctuated very slightly between 0.707 and 0.738. Similar trend exists for other variables. This preliminary examination helps to exclude the possibility of systematic wrong entries in the database.

4.5   Estimation results

In this section, I present and interpret the estimation results from a series of panel data models. I focus on the regression results of fixed-effect (FE) models among other estimators, and further analyze the variation in the elasticity of urban economic performance with respect to accessibility by regions and city size, as well as across different accessibility levels. Then I extend the analyses by using instrument variables (IVs) further to account for potential endogeneity between accessibility and error terms, and by selectively controlling for other

explanatory variables to test the robustness of the estimation results.

4.5.1 Choice of estimator

For each economic performance indicator, I estimate pooled OLS, fixed-effect and random-effect models, with and without the time trend controlled by year dummies. The pooled OLS models use both cross-sectional and time-series variations, while the fixed-effect estimators only consider within group variation of variables. In all the six models in Table B-2 in Appendix B, I set the coefficients of accessibility, or the slope, to be identical for all cities. In model (1), all cities are expected to have the same intercept and slope, while in model (2) the intercept is different from year to year. In the one-way individual effects models, model (3) and model (5), the intercepts vary across cities. In the two-way individual effects models, model (4) and model (6), I allow the intercept term to vary both across cities and over time, while the elasticity of accessibility remains the same for all cities. As shown in the table, the pooled OLS models return positive, large and statistically significant coefficients of accessibility with regard to all economic performance indicators. R-squared values are quite large given that I only use a single regressor besides year dummies. However, estimations from the pooled OLS models are often biased due to the unobserved omitted variables. I use the fixed-effect models to eliminate the bias of estimation caused by time-invariant, unobserved heterogeneity in error term.

After controlling for city-specific features and time trend, most accessibility coefficients drop and some even turn negative, except for in the wage rate equation, where the coefficients of accessibility remain positive, significant and stable across alternative estimators. When conducting econometric modeling with panel data, analysts often prefer fixed-effect models because they allow for a certain degree of endogeneity between regressor and error terms. In contrast, the strong exogeneity assumption of random-effects model is seldom met. I run the

Hausman Test on the estimation results of model (4) and (6) and find that model (4), the two-way fixed-effect model, is a more appropriate specification of the underlying relationship between regressor and error terms. The disadvantage of the FE models is that they could not identify the coefficients of time-invariant regressors. Fortunately, accessibility does not belong to this category. Below I focus on the estimation results of the two-way fixed-effect models. Given that in panel data the error terms usually are subject to heterogeneity and autocorrelation, I report the corrected cluster-robust standard errors and corresponding significance levels of the coefficients.

4.5.2 Fixed-effect estimation

Table B-3 in Appendix B summarizes the estimated elasticity of general economic performance indicators with respect to accessibility. No evidence indicates any correlation between accessibility and the size of urban economy as measured by GDP and population. GDP is determined jointly by the scale and efficiency of production, and the overall effects of the two may offset each other. When cities become more accessible, people have more freedom to move between urban locations as well as between urban and rural areas. However, the validity of the elasticity of population with respect to accessibility is questionable due to measurement errors in the data. The population of each city was only reported for people with local household registration. There could be a huge gap between the reported population and the actual number of people who live in the city. In major destinations of migrant workers, population is systematically underestimated while in the origins of migrants the population is likely to be overestimated. A typical example is the city of Shenzhen, where the reported population is 2.6 million in 2010 while the number of people who live and work in the city exceeds 10 million.

Accessibility is positively correlated with productivity measured by wage rate: a 10% improvement in accessibility is associated with a 1.77 % increase in wage rate. Several

underlying mechanisms may explain such positive correlation: (1) improved accessibility

facilitates face-to-face communication, which is essential for knowledge sharing and

productivity enhancement; (2) improved accessibility reduces searching cost for jobs and also

leads to better match between labor and positions; (3) improved accessibility leads to prosperity

of specific industries that rely heavily on fast travel, which often offer higher wage rates than

average. This has been referred to as the benefit of upgraded industrial structure. The positive

relationship between accessibility and productivity, however, does not show up in the coefficient

in per capita GDP equation. This may also be due to the systematic measurement error in

population data, because I calculate per capita GDP by dividing with population. In contrast, the

wage rate data is relatively more reliable as they are aggregated from firm reported salaries.

Accessibility is negatively correlated with total urban employment, with a coefficient of

-0.121 at 5% significance level, as well as employment in public agencies and state-owned

enterprises (SOEs), with a coefficient of -0.124 at 5% significance level. One possible

interpretation is that, with China being a country in transition, cities that are more accessible tend

to be more open to market-economy than those that are not accessible (Squalli and Wilson 2009).

People are not restricted to the employment opportunities offered by public agencies and SOEs.

If this is the case, improved accessibility should be associated with expansion of private sector

employment, but the estimated coefficient does not indicate such relationship. Scholars argued

that the private sector employment in China may be underestimated due to the existence of

informal economic activities that are not reported in official statistics (Albert Park 2011).

Table B-4 in Appendix B summarizes the estimated elasticity of sectoral economic

performance with respect to accessibility measured by economic potential. Accessibility is

positively correlated with employment in the IT and finance industries. A 10% increase in

accessibility is associated with a 2.3 % increase in IT jobs and a 1.8 % increase in finance

employment. According to China statistical yearbook 2011, the finance and IT sectors rank first

and second respectively on the annual income list. The results confirm my previous assumption

that improved accessibility is associated with more employment in higher-income industries,

thus leading to a higher average wage rate. The estimation results also speak to the existing

analysis arguing that the IT and finance sectors in China are characteristic of competition for a

national market and rely heavily on intercity travel[4].

I also test the relationship between accessibility and capital investments, as local

authorities claim that HSRs will attract external investment and boost prosperity in the real estate

market (Bradsher 2011). I find that foreign direct investment is positively correlated with

accessibility, with an estimated coefficient of 0.365 at 5% significance level. This implies that

convenient high-end travel could be a favorable condition to attract foreign investment, which

involves many rounds of investigation and negotiations during the market survey period, and

frequent travel between headquarters and the manufacturing plants once the latter are in

operation. The estimation results from real estate markets, however, are not in line with local

authorities' expectation. Property price and real estate investment do not show significant

correlation with accessibility. This may imply that during the study period real estate markets are

relatively segregated among cities, with few cross-hauling investments and thus are not very

sensitive to intercity transport connections. This is particularly true for the inelastic part of

housing demand for sheltering. Even though accessibility improvement does facilitate

speculative investment in real property in some superstar cities, such a phenomenon is not

prevalent enough to push up property price of the entire city[5]. However, there may still be

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[4] China Information Technology Report 2012, by Business Monitor International Ltd.
[5] Note that due to data availability issue, the property price data is for the entire city rather than the urban core.

positive changes in property price and real estate investment in the proximity of HSR station areas. Such effects are not captured by the data aggregated on a city level. I leave this discussion to the city level analyses with case studies in Chapter VI.

The tourism industry shows a positive and significant correlation with accessibility. With a 10% increase in accessibility, cities have 1.8 % more domestic visitors and earn 5.4% more revenue from tourism. The results add new insights to the existing literature. The existing literature predicts more visitors but not necessarily more revenue with accessibility improvement (Bonnafous 1987; Masson and Petiot 2009). Researchers argued that convenient fast travel attracts more visitors but is likely to reduce the number of the overnight stays at the tourism destinations; thus, the impact on tourism-related spending is unclear. According to my estimation, improved accessibility not only attracts more visitors, but also encourages them to spend more in the destinations. One possible reason is that, people who take the fastest transport mode for travel are often those with strong purchasing power, such as middle-class families or visitors with all expenses covered by employers.

4.5.3   Testing regional and city size effects

For the estimation presented in section 4.5.2, I assume universal accessibility elasticity for all cities. Given the huge diversity among cities in China, however, this may not be a proper assumption. In this section, I further examine whether the correlation between accessibility and economic performance shows different patterns across regions and among cities of different sizes. The purpose of emphasizing the regional effects and the size effects is to identify potential trends of convergence or divergence regarding regional disparities and the structure of urban hierarchy.

The economic geography in China is characteristic of three regions defined jointly by the level of economic development and geographical features. The eastern region covers the three

most developed urban clusters around Bohai Bay, the Yangtze River Delta and the Pearl River Delta. The western region includes twelve inland provinces with high elevation and hilly topography. The middle region consists of six provinces located on the middle stream of Huanghe River and Yangtze River, and another two provinces in the Songhua River watershed in Northeast China (Figure IV-1).

Figure IV-1 China's Three Economic Regions
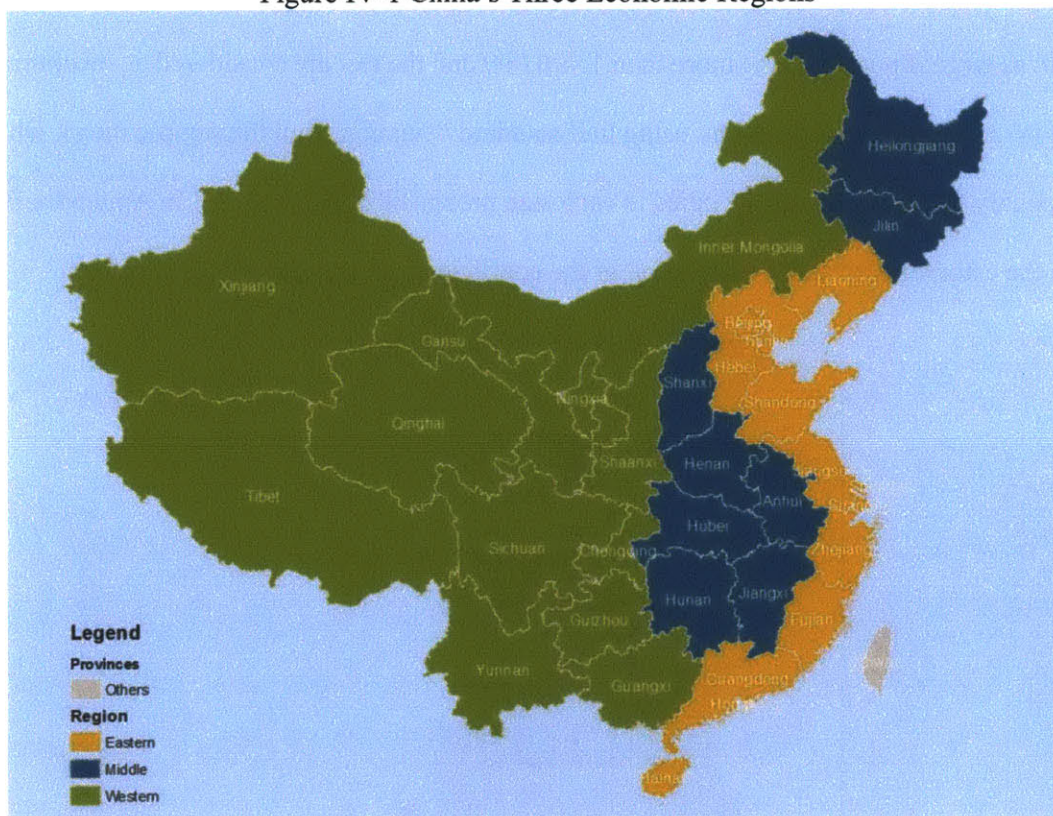
Note: division of regions based on the 10th Five-Year Plan of China, author mapping.

The fixed-effect models cannot identify the coefficients of region dummies because they are time-invariant, but they can estimate the coefficients of the interaction terms of accessibility and regions. The coefficients of the interaction terms capture the regional differences in the estimated elasticity of accessibility. Table B-5 and Table B-6 in Appendix B contain the estimation results for variation in the elasticity coefficients of accessibility across regions.

I also examine the variation in the estimated coefficients of accessibility by city size to show the impacts on the structure of urban hierarchy. Grouping cities by size yields results different from grouping them by regions because cites vary in size in all three regions. City size is an important variable in that it informs whether the urban hierarchy is diverging or converging when accessibility changes. I measure city size by population in the core urbanized area. Based on the distribution of population in the sample, I define cities as small if population is less than 650,000, as large if population is more than 1,400,000 and the rest are considered as medium size (Figure IV-2). I set the thresholds by using half standard deviation from the sample mean, which gives roughly the same number of cities in each size group. Table B-7 and B-8 in Appendix B contain the estimation results for variation in the coefficients of accessibility by city size.

Figure IV-2 Distribution of city size
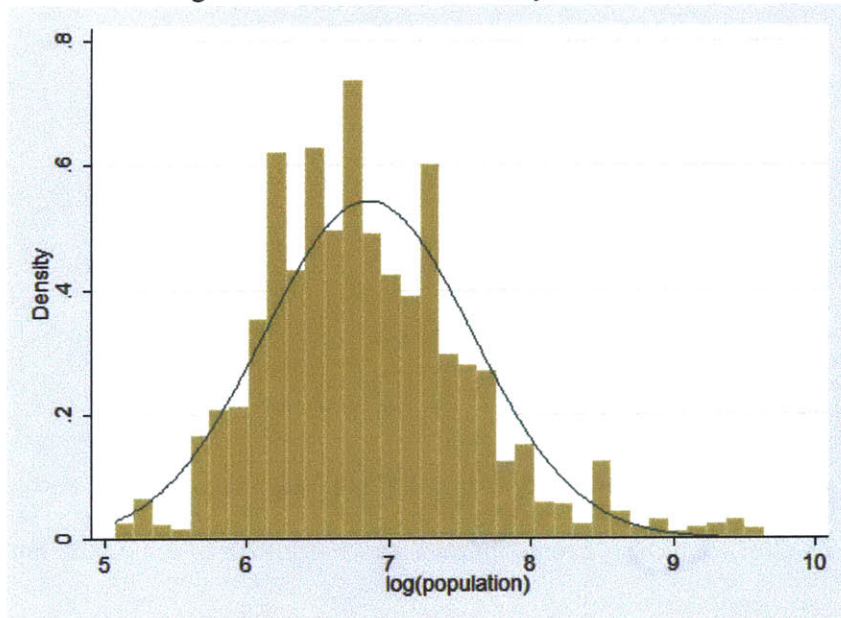
Combining region and city size gives nine subgroups of cities as shown below (Table IV-3). I then control for regional effects and city size effects simultaneously in the regressions for each urban economic performance indicator to obtain a more detailed picture of the variation in the elasticity coefficients of accessibility among cities.

Table IV-3 Cities group by region and size

Size	Region	East	Middle	West	Total
small		261	379	196	836
medium		342	412	300	1,054
large		367	209	134	710
Total		970	1,000	630	2,600

Table B-9 in Appendix B summarizes the estimated elasticity of general economic performance indicators with respect to accessibility. GDP is positively correlated with accessibility in small cities in Western China (0.117 at 10% significance level) and negatively correlated with accessibility in medium-size cities in Eastern China (-0.132 at 5% significance level). Population and per capita GDP do not show any correlation with accessibility across all subgroups. Wage rate shows positive and stable correlation with accessibility in Western and Middle China regardless of the city size, ranging from 0.125 to 0.221 at 1% significance level, while such correlation is not identified in eastern China. Total employment is positively correlated with accessibility only in large cities in the western and the eastern regions, with accessibility coefficients of 0.104 and 0.154 at 10% significance level respectively. Such a positive correlation between accessibility and employment is even stronger in the private sector of these two subgroups of cities, with estimated accessibility coefficients of 0.229 and 0.347 at 5% significance level respectively. The employment of public agencies and SOEs is negatively correlated with accessibility only in medium-size cities in Middle China, with coefficients of -0.117 at 10% significance level (Figure IV-3).

Figure IV-3 The elasticity of general economic performance to accessibility by region and size

Legend:
- GDP
- Population
- Per capita GDP
- Wage rate
- Total employment
- Agency employment
- Private employment
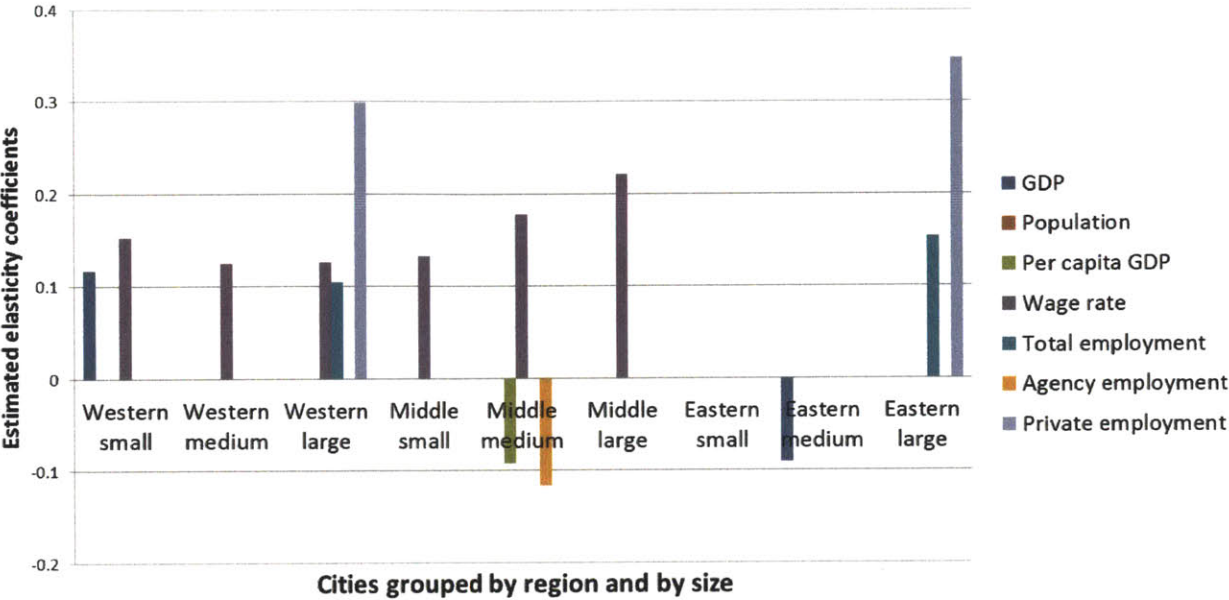
The findings are consistent with the identified patterns of China's domestic migration in recent decades: the majority of migrant workers have been moving from populous provinces in middle regions to coastal provinces in eastern China, while some of them have migrated to the sparsely populated provinces on the western border (Figure IV-4).

Figure IV-4 Inter-provincial migration in China (1990-2005)
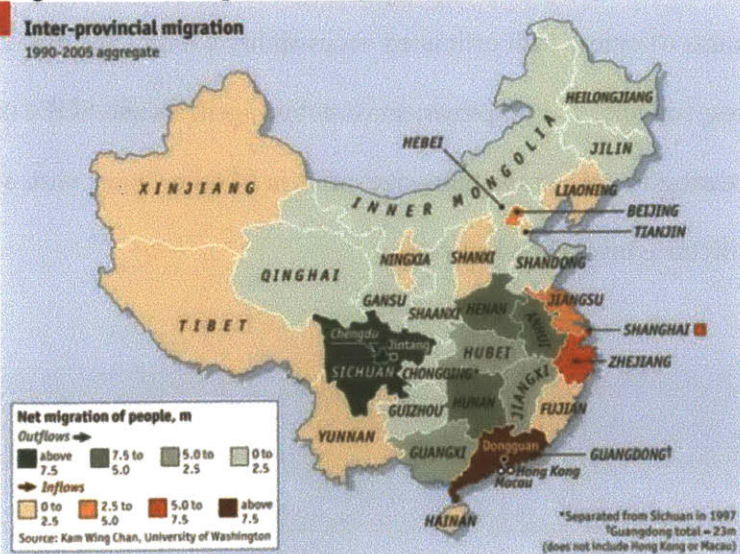
Source: Kam Wing Chan, from the print version of *The Economist*, Feb 25, 2012.

Based on my analyses, the reshuffling of labor forces within China has yielded generative benefits as reflected by a prevailing positive correlation between wage rate and accessibility in western and middle China. Yet, the underlying mechanism could be different among regions. One possible mechanism is the knowledge spillover associated with migration, which is likely to benefit the western region most where large potential for technological upgrading exists. Another mechanism is that migrants can push up or lower the supply curve of labor and therefore influence the level of wage rate. The estimated elasticity for wage and employment jointly shows that workers in western cities get better paid primarily due to enhanced productivity, while the rise in wage rate in middle China could be a joint outcome of a shrinking labor pool and the enhancement in productivity. In eastern cities, where the elasticity of wage rate to accessibility is not significant, the enhancement in productivity associated with accessibility may be marginal in the first place, and the impacts on the wage rate are further diluted by expanded labor supply. According to (Shi 2008), the private sector has absorbed a major proportion of the migrant workers, who are more likely to be affected by intercity mobility. This explains why I identify large positive correlation between the private sector employment and accessibility in large cities, where the influx of migrants dominates the supply of labor.

The signs and magnitudes of the estimated coefficients of accessibility convey several key messages: First, there seems to be a convergence in the productivity among regions but a divergence in the scale of economic activities among cities of different sizes. The western region and middle region have experienced a rise in wage rate with improvement in accessibility, enabling them to catch up with the eastern region. Meanwhile, large cities have attracted more human capital with accessibility improvement, expanding its scale of production. Second, there is no universal evolving trend regarding the disparities of productivity among cities of different

sizes within each region. In the West, small cities witness higher rise in wage rate with unit improvement of accessibility, which implies a possible convergence; but in the middle region, the elasticity of wage rate to accessibility is the biggest in large cities, indicating a divergence in productivity.

Table B-10 in Appendix B summarizes the estimated elasticity of sector-specific economic performance indicators with respect to accessibility. The employment in the IT sector is positively correlated with accessibility in medium-size cities in the middle region and large cities in the East, with elasticity coefficients of 0.265 and 0.257 at 5% significance level respectively. The employment of finance sector is positively correlated with accessibility in cities of all sizes in the East (coefficients ranging from 0.213 to 0.259 at 5% significance level). In the Middle such correlation shows up only in large cities (0.197 at 10% significance level), and in the western region the positive correlation shows up in small and medium-size cities (0.220 and 0.223 at 5% significance level).

Figure IV-5 The elasticity of sectoral economic performance to accessibility by region and size
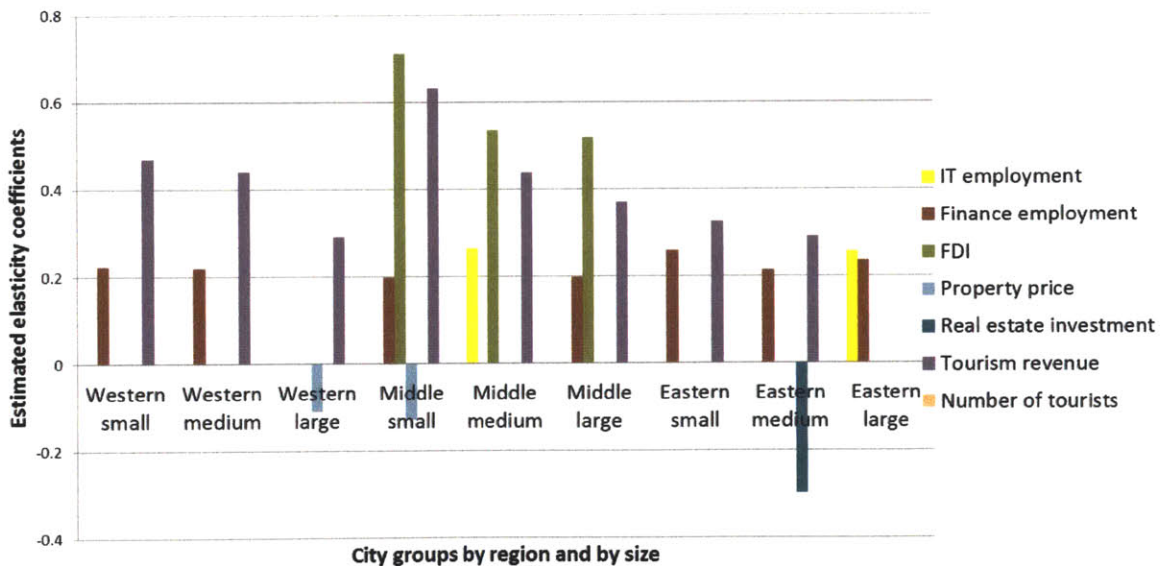
The variation in the estimated elasticity of IT and finance employment across regions

may be explained by the extent to which these two industries are basic sectors to local economy. If the IT and finance industry are basic sectors, it is likely that they rely more on intercity travel. Economic Base Theory assumes that all local economic activities can be identified as basic or non-basic. A basic sector is defined as the part of production that serves external demand, usually exporting products or services to other regions, not necessarily to foreign counties (Andrews, Richard B. 1953).

Accessibility is positively correlated with FDI in middle region of China, with estimated coefficients ranging from 0.452 to 0.695 at 5% significance level. Property price is negatively correlated with accessibility in large western cities and small cities in middle China. Real estate investment shows negative correlation with accessibility in medium-size cities in eastern China, with a coefficient of -0.298 at 10% significance level, while no such correlation is identified for the remaining subgroups. The pattern may due to the fact that developable land is less available in east China. With improved accessibility, developers flee to other locations with a better chance of acquiring land and making profits.

The revenue from tourism shows strong positive correlation with accessibility except in large cities in East China, with coefficients ranging from 0.291 to 0.631. The magnitude of the elasticity coefficients is inversely correlated with city size. The correlation between accessibility and number of tourists, however, is not identified in each subgroup. This result implies that accessibility improvement is associated with prosperity of the tourism industry. Such prosperity is of a generative nature because most subgroups of cities benefit from accessibility improvement. Accessibility is more correlated with qualitative improvement rather than with quantitative expansion of the tourism industry, given that the elasticity of the revenue from tourism to accessibility is larger and more significant than that of the number of tourists.

4.5.4   Testing saturation effects

According to mainstream economic theories, the total product of labor and capital is subject to saturation effect, that is, the marginal contribution of a single production factor to output eventually diminish as it becomes more and more abundant(Samuelson and Nordhaus 2009). In like manner, it is reasonable to expect that at certain stage the impacts of accessibility improvement on urban economic activities may shrink or even vanish. Therefore, I divide cities into five groups according to their accessibility level to test whether or not such saturation effects exist. If the estimated coefficients drop as accessibility level increases from low to high, this could be a signal of saturation effects. I use the rank of cities' accessibility in each year to determine the division of subgroups. Basically, the high accessibility group contains the top 20% most accessibility cities, and the low accessibility group is the 20% cities with the lowest accessibility values.

Table B-11 in Appendix B summarizes the elasticity of general economic performance to accessibility across different accessibility levels. GDP and per capita GDP are uncorrelated with accessibility no matter whether the accessibility level is low or high. Accessibility is associated with population losses in cities in relatively high accessibility groups, and the estimated coefficients range from -0.077 in cities with medium accessibility to -0.097 in those with high accessibility. The wage rate is positively correlated with accessibility regardless of the level of accessibility. Both public and private sector employment are negatively correlated with accessibility in medium to high accessibility groups, and the magnitude of such correlation is even larger in private sectors (Figure IV-6).

Figure IV-6 Elasticity of general economic performance to accessibility by accessibility levels
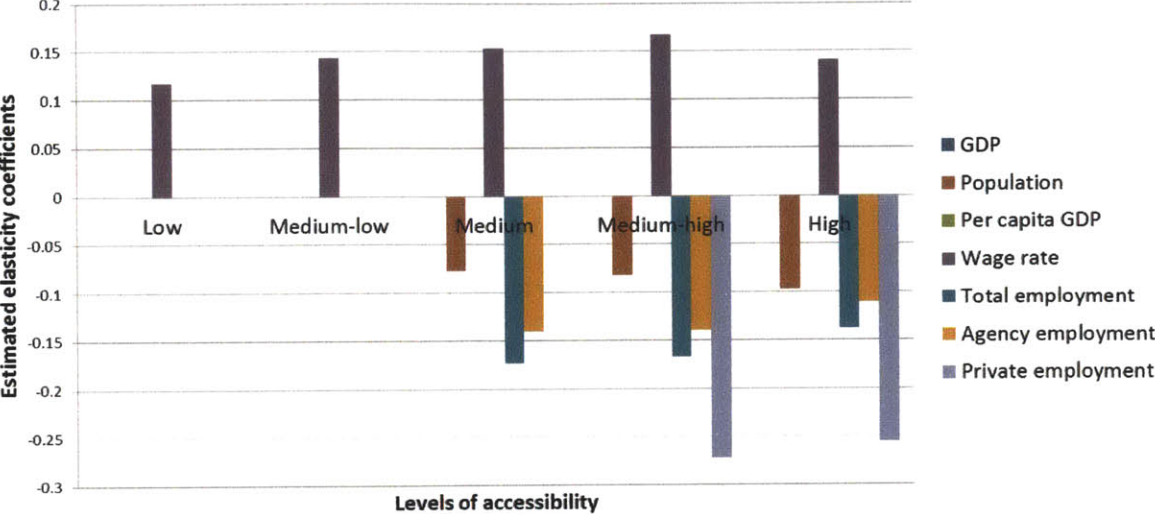
Table B-12 in Appendix B summarizes the elasticity of sector-specific economic performance to accessibility across different accessibility levels. The positive correlation between the IT sector employment and accessibility only shows up in the cities with medium-low accessibility, with a coefficient of 0.191 at 10% significance level. The employment of the finance sector is positively correlated with accessibility except for in the subgroup with the lowest accessibility, and the coefficients range from 0.184 to 0.220 in the remaining subgroups. FDI is positively correlated with accessibility except for in cities with medium and medium-low accessibility, and the estimated coefficients range from 0.514 to 0.673 at 5% significance level. Property price shows slightly negative correlation with accessibility in cities with medium level accessibility, with an estimated coefficient of -0.11 at 10% significance level. Real estate investment is not correlated with accessibility. The positive correlation between the tourism revenue and accessibility remains stable as accessibility increases from low to high. The estimated elasticity coefficients range from 0.318 to 0.480 at 1% significance level. The number of tourists also shows positive correlation with accessibility, except for in cities with medium

level of accessibility. The estimated elasticity coefficients for the other four subgroups rang from 0.219 to 0.264 at 5% significance level (Figure IV-7).

Figure IV-7 Elasticity of sectoral economic performance to accessibility by accessibility levels
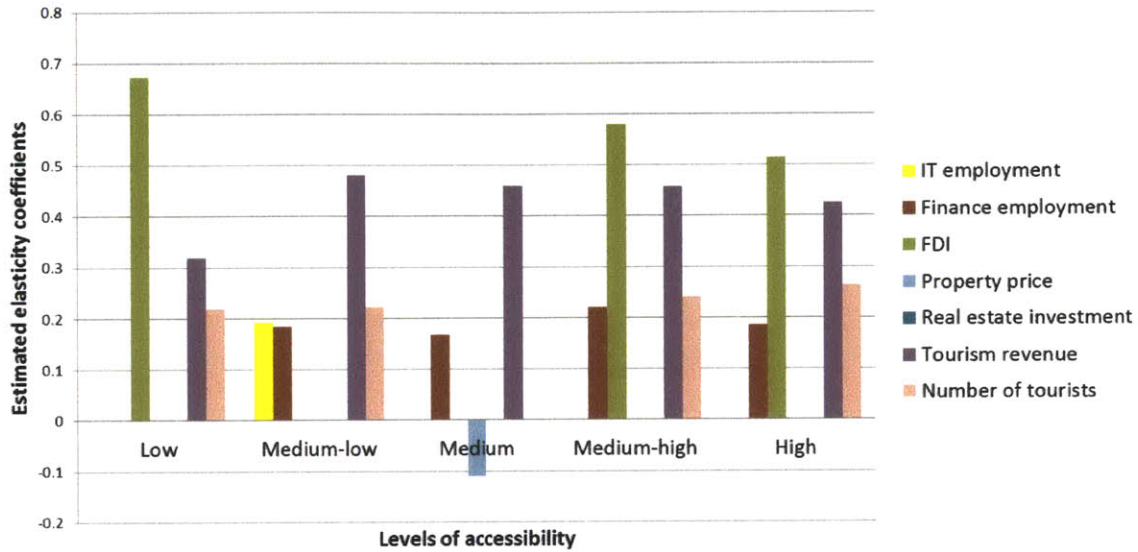
Based on my analyses, no evidence indicates diminishing trend in the elasticity of urban economic performance with respect to the levels of accessibility, no matter whether the identified correlation between economic performance and accessibility is generative or distributive, positive or negative. The result may imply that at the current stage of transport infrastructure development in China, the saturation effects are not yet a major concern. Further improvement in accessibility will continue to exert impacts on urban economic performance.

4.5.5   *Extended analyses with IVs*

Although the fixed-effect estimator mitigates the possible bias of the OLS estimation by eliminating the potential correlation between accessibility and the unobserved city-specific, time-invariant determinants of urban economic performance, the fixed-effect estimates may still be biased if changes in accessibility are correlated with the unobserved time-varying factors that influence economic performance (Cameron and Trivedi 2005; Baltagi 2008). There are two

possible sources of such a correlation. First, the causality can run in the opposite direction since strengthened economy generates additional demand for transport services, which leads to more investment in transport infrastructure and therefore higher accessibility. Second, there are contemporary shocks that may influence both accessibility and economic performance simultaneously. For instance, local stimulus plan to combat economic downturn increases transport investment and boosts economic activities as well. Then I need to cope with the endogeneity issues to come up with unbiased estimation of the elasticity of economic performance with respect to accessibility. A standard practice is to conduct two-step least square (2SLS) regression using instrument variables (IVs). An ideal candidate of IV has impacts on urban economic performance only through affecting the accessibility. IV delineates the exogenous part of variation in accessibility for regression estimation. Although the advantage of IV regression is commonly accepted, the selection of IV is case-dependent.

A popular IV that has been widely used in similar econometric analyses is the city's spatial relationship to ancient transport facilities or the outlay of transport infrastructure in an historic transport blueprint (Baum-Snow, Brandt et al. 2011; Banerjee, Duflo et al. 2012). The underlying argument is that historic access to transport facilities or the original plans have impacts on today's accessibility but do not directly influence the current urban economic performance. The IV I use in this research is a city's distance to major railway lines and trunk highways in 1920s (Figure A-17). I digitize the railways and highways based on a map attached to Sun Yat-sen's book named The International Development of China (Sun 1922). The book is his national strategic plan as the president of the Republic of China in the 1920s. I calculate the distance from a city to the nearest transport corridor as well as the distance to the three nearest corridors by using the proximity analysis module in ArcGIS. I expect the distance to historic

lines to be positively correlated with accessibility. I also assume that being close to multiple

trunk transport lines gives more advantage in transport than being near a single line.

An alternative IV in the literature is the geographical centrality (GC) proposed by Head

and Mayer (2006) and use also by Laura and Sandra (2010). GC is defined as follows:

$$GC_i = \ln \sum_{i \neq j} d_{ij}^{-1}$$

<div align="right">**Eq. IV-11**</div>

Where d_{ij} is the Euclidian distance to all the other cities, GC is a measurement of the

relative position of city in the whole system of urban settlements, which may have some

influence on a city's accessibility. Head and Mayer considered two forms of centrality, European

Union GC and Global GC, for which they sum the inverse distance to all EU cities and to the

centers of every inhabited 1 degree by 1 degree cell on the world population grid map. In this

research, I calculate the point-to-point distance matrix between the 286 cities in Arc GIS, using

cities' latitude and longitude features. I expect GC to be positively related to accessibility.

I also use elevation as a third candidate of IV. The vast territory of China covers a wide

range of topography from flood plains and basins to highlands and mountains. I assume that

cities with higher elevation are less accessible in general. Elevation could have long-term

influences on economic actives at different locations, but there is little chance of direct,

immediate impacts on contemporary urban economic performance. I extract the elevation data

for each city from the National Digital Elevation Model (DEM) of China (Figure IV-11). The

elevation value ranges from 1 meter in Yingkou on the Bohai Bay in Northeast China to 3,656

meter in Lhasa on the Qinghai-Tibet Plateau in Southwest China.

In theory, the IVs should have a panel structure to be used in panel data models that

explicitly account for city-specific effects. All the three candidates of IVs, however, do not vary

over time thus are not proper to be used in the fixed-effect estimators. Instead, I include the IVs

in the pooled OLS models.

Table B-13 in Appendix B summarizes estimated elasticity of economic performance to accessibility from the models using different IVs. The last column contains estimation results of the pooled OLS regression without IV for the purpose of comparison. The first stage regression of accessibility against different IVs shows that the sum of distance to the top three nearest 1920s transport corridor is the best predictor of the current accessibility, with elevation being second. Obviously, the sum of distance to the three nearest 1920 lines is superior to the distance to only one line. When I include distance to 1920 transport lines, geo-centrality and elevation as IVs together, the coefficient of geo-centrality becomes insignificant in the first-stage regression, so I exclude it from model (5), which is the chosen model for the pooled OLS-IV estimation.

Comparing the estimation results in column (5) and column (6), I find that for most economic performance indicators the estimated coefficient of the pooled OLS-IV model is slightly smaller than that of the pooled OLS model and the significance of the coefficients remain the same. In other words, including IVs in the regression does not lead to fundamental changes in the estimates of the pooled OLS models. If the IVs are valid, the very minor differences between these two sets of estimation results indicate that the potential mutual influence between accessibility and economic performance is not a major source of estimation bias. Instead, for most economic performance indicators, the estimation bias stems from the city-specific fixed effects and other uncontrolled explanatory variables. An exceptional case is the FDI equation, for which the estimated coefficient of the OLS-IV model is larger than that of the OLS model.

The accessibility indicator is relatively exogenous to urban economic performance since it is calibrated based on inter-city rather than intra-city travel time. This could partly relieve the

concerns on simultaneity between accessibility and economic performance. Under China's current governance structure, the central government makes investment decisions on national railways and inter-regional expressways while local governments are responsible for infrastructure investment and economic development within the city. The central government trades off between efficiency goals and equality considerations when developing transport investment plans. It initiate regional transport projects not only to relieve congestion along the busiest corridors (e.g., Beijing-Shanghai line), but also to mitigate regional disparity of economic development by reaching the most remote areas (e.g., Qinghai-Tibet Line). In addition, analysts also argued that China build the national HSR system for the shipment of troops in case of emergency (HAI 2010). Therefore, transport investment does not necessarily follow the hotspots of economic growth, which may become a source of inverse causality.

4.5.6 Extended analyses with additional explanatory variables

As I have discussed in the previous section, one source of estimation bias is the time-invariant, city-specific effects, which have already been controlled for in the fixed-effect models. Another source of estimation bias is the omission of potential time-variant determinants of urban economic performance. The list of potential explanatory variables is non-exhaustive. Therefore, in my research, I base the inclusion of additional variable on existing theories and availability of data. Due to data availability constraints, I selectively conduct further analyses on several economic performance indicators. Following the Cobb-Douglas production function, I include capital and labor inputs in the GDP equation. For the wage rate equation I control for educational background and industrial composition, similar to the empirical model developed by Rice and Venables et al.(2006). For tourism revenue and the number of tourist regression, I include number of hotels to represent the provision of tourism facilities. For FDI equation I

control for GDP and A common feature of these explanatory variables is that they all measure

cities' intrinsic factors that changes over time. I extract data from the same sources as the

dependent variables, except for that the educational background variable is from the 5th and the

6th population census in 2000 and 2010 respectively. See below for a list of additional

explanatory variables.

Table IV-4 List of additional explanatory variables

Dependent variables	Additional variables	Definition
GDP	Fixed assets investment	Total amount of investment to fixed capital asset in the certain year
	Labor payment	Total amount of money paid to urban workers
Wage	Education	Percentage of people with college and above degree
	Industrial composition	Percentage of employees in IT, finance and research sector respectively
Tourism revenue Number of tourists	Hotels	Total number of hotels awarded star ranks in each city
FDI	GDP	Total gross output of the urbanized area
	Total employment	Total employment in the urbanized area

For each dependent variable, I compare the estimations from pooled OLS, fixed-effect

models and pooled OLS-IV models using elevation and the sum of distances to the three nearest

1920 transport lines as IVs. Table B-14 in Appendix B reports the elasticity of GDP to

accessibility. Not surprisingly, the coefficients of capital and labor input in all models are

positive and significant. After controlling for capital and labor inputs, the elasticity of

accessibility is still positive at 1% significance level in the pooled OLS models, but the

coefficient drops considerably from 0.98 to 0.04 in models without IVs, and from 0.992 to 0.217

in models with IVs. In the fixed-effect models, accessibility is uncorrelated with GDP no matter

whether or not controls are made for capital and labor inputs.

Table B-15 and B-16 summarize the elasticity of tourism revenue and the number of

visitors with respect to accessibility. The estimated elasticity remains positive at the 1%

significance level across different models. The coefficients in the pooled OLS models shrink considerably after controlling for the number of hotels. In contrast, the estimations of fixed-effect model are pretty stable before and after the inclusion of the number of hotels in regression. This indicates the robustness in the elasticity of tourism industry with respect to accessibility estimated by the fixed-effect models.

The extended analysis for wage equation is even more constrained by data availability. Educational background data are merely available for year 2000 and 2010, and consistent industrial composition data are only available after 2003 due to the revision of industrial sector categorization. Therefore, I control for industrial composition using panel data models, but just conduct a cross-sectional regression that include both education background and industrial composition variables for year 2010.

In the pooled OLS models, the elasticity of wage rate to accessibility becomes insignificant once the industrial composition is explicitly controlled for. In contrast, in the fixed-effect models, the coefficient of accessibility drops from 0.177 to 0.158 but remains significant at the 1% level. This again confirms the robustness of the estimation results of the fixed-effect models, and also implies that accessibility contributes to the rise in wage rate through other channels besides upgrading cities' industrial structure.

In the cross-sectional OLS model controlling for both educational background and industrial composition, the coefficients of accessibility fade out. Caution is needed to interpret the estimation results from the cross-section analysis because for wage rate the within group variation over time dominate the cross-sectional variation. It will be helpful to extend the analysis when multi-year data become available.

As to the FDI equation, after controlling for GDP and employment the coefficient of

accessibility drops from 1.985 to 1.028 in the OLS model, and from 2.558 to 2.406 in the

OLS-IV model. The estimated coefficient of the fixed effect model drops slightly from 0.365 to

0.351 and remain significant at the 10% level, which indicates the robustness of the fixed-effect

estimates.

4.6 Summary

The estimated elasticity of urban economic performance to accessibility uncovers several

key features of the wider economic impacts associated with transport infrastructure investment.

First, the prevailing positive correlation between wage rate and accessibility indicates a

generative nature. The sources of wage rise can be explained by enhanced productivity, better

matching between labor and jobs and upgrading of urban industrial structure. I identified positive

correlation between accessibility and wage rate in the western and middle regions but not in the

eastern region. This may imply a trend in narrowing the earning gaps between the developed

coastal region and the lagging inland regions. In contrast, my research did not identify similar

convergence in wage rates among cities of different sizes.

Second, the association between accessibility and employment is primarily

redistributive, and the polarization effects seem to dominate. With accessibility improvement,

workers pour into large cities in eastern and western China, particularly to the private sectors

which have accommodated the major proportion of the migrant workers. Meanwhile, public

sectors and SOEs in medium size cities in middle China have experienced losses of jobs. The

reallocation of labor forces may lead to a divergence in the scale of economic activities, between

the eastern region and the rest of the country, and also between large cities and small and

medium-size cities.

Third, the employment of IT and finance industries shows positive correlation with

accessibility but such correlation is not stable, varying across regions and city sizes. The findings may be explained by the different extents to which these high-end service industries are basic sectors to local economies. It is more likely to identify stronger positive correlation between the employment of a particular sector and accessibility when this sector is a basic sector and export goods and services to other regions. Such interpretation is subject to further testing.

Fourth, accessibility improvement is associated with increase in FDI but no evidence supports the argument that it also leads to prosperity in real estate market. On the contrary, this research identifies negative correlation between property price/amount of real estate development and accessibility. Improvement in accessibility may discourage real estate investment at urban localities where land resources have become scarce.

Fifth, tourism is positively correlated with accessibility improvement as existing literature predicts. The accessibility-related prosperity in tourism industry is of generative nature since most subgroups of cities are benefited. Accessibility is more correlated with qualitative improvement rather than quantitative expansion in tourism industry, given that the elasticity of tourism revenue to accessibility is larger and more significant than that of the number of tourist.

Finally, empirical evidence denies a diminishing trend in the elasticity of urban economic performance with respect to the levels of accessibility, no matter whether the identified correlation between economic performance and accessibility is generative or distributive, positive or negative. The findings may imply that at the current stage of transport infrastructure development in China, the saturation effects are not yet a major concern.

The estimates of IV panel models indicate that the potential mutual influence between economic performance and accessibility is not a major source of estimation bias. The reason lies in that China's central government rather than local authorities makes inter-regional transport

investment decision; therefore the intercity accessibility is to some extent determined exogenously. Central government's effort to balance efficiency and equality goals divert transport investment from chasing after hotspots of economic growth, and this reduces the possibility of reverse causality from economic performance to accessibility.

Due to data availability constraints, I selectively conduct further analyses on GDP, wage rates, FDI and tourism industry indicators by including other time-variant variables. Controlling for additional explanatory variables does not change the fundamental nature of the major findings, though the explanatory power of accessibility shrinks to different extents. This indicates the robustness in the estimated elasticity coefficients.

My analyses illustrate the diversity and complexity in the relationship between urban economic performance and intercity accessibility, which consist of both generative and redistributive components. Integrating the generative impacts to extend the cost-benefit analysis is appropriate for the national level decision makers. Local development authorities need to be aware of the distributive nature of accessibility improvement and be ready to take opportunities as well as challenges of intensified competition over capital market and labor forces.

The findings from the empirical analyses provide useful reference for policy makers to develop wise and sustainable plan of transport investment. Even so, the current analysis is not free of limitations, and caution is needed to interpret the estimation results.

First, the current research uses economic potential based on minimum travel time as a proxy for the strength of economic interaction among cities. Such measurement has several limitations. First, freight transport is not accounted for since the most direct impacts of HSR occurs in passenger transport market, but in reality the flow of cargo represents an important aspect of intercity economic linkages. The patterns of freight-based accessibility may differ

significantly from the passenger-based measurement I use. Second, ideally the travel cost should be an average travel time weighted by the market share of each transport mode. It is better to also account for the monetary cost by constructing a generalized transport cost.

Second, the findings from my study are quite contextualized and are not readily applicable to other countries. As Crafts (2009) put it, market integration is most likely to generate economic benefits when there is a step changes in the quality of transport system, and therefore is more relevant for developing countries with a major infrastructure deficit than mature economies. In addition, even among developing countries, there could be very different institutional factors and social-economic settings that could either accelerate or hinder the beneficiary influences of transport improvement. It will be informative to compare the current study with empirical evidence from other developing countries.

Finally, the interpretation of estimation results is mostly based on predictions from theories. It is not yet clear whether the reality in China fits well into the classical theoretical framework that has been developed in the mature economies. There may be other unobserved unique reasons that lead to the outcome as reflected by the coefficients of econometric models. To reveal potentially different underlying mechanism, I took several field trips to cities along the Wuhan-Guangzhou HSR line to identify the key factors and trends that determine the relationship between urban economic performance and accessibility improvement. The findings from case studies are the focus of the following two chapters.

Chapter V   THE CHANNELIZING EFFECTS ALONG AN HSR CORRIDOR

In this chapter, I switch the focus of analysis from the national transport network to a specific HSR line that runs between Wuhan in middle China and Guangzhou in south China. The purpose of conducting this corridor-level analysis is twofold: (1) to examine whether the operation of this HSR leads to step changes in travel patterns and increases intercity passenger flows, which often approximate the structure of urban hierarchy; (2) to show how economic activities adjust location choice immediately after the introduction of this HSR. I assume that the aspects and extents of HSR-related economic impacts differ among cities on the HSR line. I continue to use prefecture level cities as the basic geographical unit of analysis. I conduct comparative statics of travel patterns and economic activities in pre-and post- HSR settings. Even though the post-HSR period is relatively short (3 years), for this particular corridor, where HSR is becoming a dominant travel option, the impacts on economic activities occur very rapidly, which makes my analysis reasonable.

Section 5.1 provides background information about the Wuhan-Guangzhou HSR line. Section 5.2 reviews relevant empirical studies on HSR's impact on travel patterns and economic performance at the corridor level. Section 5.3 is a brief description of the methodology and data. Section 5.4 presents findings from the comparative statics of travel patterns and economic performance for the pre- and post-HSR periods. Section 5.5 concludes.

5.1 Choice of the Wuhan-Guangzhou HSR

The Wuhan-Guangzhou HSR, in operation since December 2009, is among the first inter-regional passenger-dedicated HSR lines in China. At a total length of about 968 km, it was the longest HSR line in China in the study period. It runs from middle China all the way to south

China, connecting Wuhan on the Yangtze River with Guangzhou on the Pearl River. It passes

through three provinces from north to south: two populous, fast growing inland provinces, Hubei

and Hunan, and one of the most developed coastal provinces, Guangdong (Figure V-1).

Figure V-1 The Wuhan-Guangzhou HSR line on the map of China

Data source: China's National Geo-information Center, Harvard China Map, author mapping

I choose to study the Wuhan-Guangzhou HSR line for three reasons. First, the ten cities

along this HSR are diverse in population size, strength of economy and ranking on the urban

hierarchy. This HSR connects one first-tier well developed megacity, Guangzhou; two second-tier, provincial capital cities, Wuhan and Changsha, and seven third-tier, ordinary prefectures at different stage of economic development. Second, in Chapter III, I identified Wuhan-Guangzhou HSR as the line that brings the most significant change in intercity accessibility for cities along this corridor. Five cities on this HSR line, Chenzhou, Hengyang, Yueyang, Shaoguan and Zhuzhou are the top on the list of accessibility improvement in Table III-7. It should be easier to observe change in travel patterns and economic performance along this line than elsewhere. Finally, this HSR line has been in operation since 2009, and up to the time of my current research, preliminary observations are available to assess its immediate impacts on travel behavior and economic activities, while for more recent HSR lines, such data have not yet been reported.

5.2 Relevant studies on the corridor-level effects

Empirical studies on the corridor-level effects of HSRs have two major focuses of research interest. One school of analyst study the shift of travel patterns and the split of market share among alternative modes, while the other school examine the relocation of economic activities and the divergence in economic performance in cities with and without HSR. Below I selectively review recent literature on these two topics.

5.2.1 Intermodal competition and market share

Empirical researchers who conducted studies in different contexts have reported that HSRs attract a significant number of passengers from airlines and expressways, dominating the median-to-long distance travel. In Japan, Takatsu (2007) revealed that the *Shinkansen* commands a 50% to 80% market share for journeys between 200 and 800km. In the European countries where HSR is prevailing, market shares of operating HSR range from 60% to as high as 97%

(Amos 2010). Vikerman (1997) provided a comprehensive review of the operation status of HSR lines across Europe. According to Vikerman, in France, the Paris-Lyon Line has been a particularly successful in diverting trips from other modes and generating new trips. Total rail passengers on the corridor doubled from 12.5 million in 1980 to 22.9 million in 1992, 83% of which are HSR passengers. It is worth noting that the significant growth in rail passengers came in the first few years after the opening of HSR. Most of the diverted passengers came from air: Paris-Lyon air traffic halved between 1980 and 1984. Growth of road traffic also stagnated due to competition from HSR. On the expressways running parallel to the HSR lines, car traffic grew at only one-third the rate on other comparable routes. In Germany, however, the patchier introduction of HSR was not able to generate the marked shift in travel pattern as experienced in the concentrated introduction of HSR in France. Deutsche Bahn estimated that only some 12% of rail traffic is diverted from road and air. In Spain, the HSR between Madrid and Sevilla had 3.5 million passengers after two years of operation, of which 32% were diverted from air, 25% from car, 26% were newly generated and the remaining 17% were from regular rail.

A World Bank research paper provided an *ex-post* review of the operation of several HSRs in China (Richard Bullock et al, 2012). The Beijing-Tianjin HSR and Jilin-Changchun HSR, both around 110 km, won the competition against road transport over the short distance. The introduction of the Beijing-Tianjin HSR has shifted about 1 million passengers from buses, yet passengers traveling by regular rail also dropped by half, from 8 million to 4 million per year. The total number of rail passengers amounts to 25 million per annum, 80% of whom are either switched from road traffic and regular rail or are newly generated. A similar pattern is found on the Jilin-Changchun HSR. In an *ex-ante* analysis on the Beijing-Shanghai HSR, Mao (2010) estimated that about 30-40% of passengers on the Beijing-Shanghai route (1,300 km) will take

HSR while the rest remain on airlines, depending on the actual fares of HSR trains and the discount that airlines are willing to offer. Over shorter distance, however, from Beijing to Jinan (420km), he estimated that 85% of total passengers would take the HSR and the predicted market share is less sensitive to prices.

These studies illustrate how passengers switch among different transport options for the entire transport corridor. Yet, not much information is provided regarding the changes in intercity travel patterns when there are multiple destinations along the HSR line. In my research, I will extend this analysis to show how passengers' travel pattern changes between specific city-pairs on the HSR route and the consequential impacts on the structure of urban hierarchy. My analysis helps to identify where the most significant changes actually happen.

5.2.2 HSR's impacts on economic activities

Early evidence from Japan illustrated that cities on the HSR routes outperformed non-station locations in economic growth, although the magnitude of influences varies among different studies. Amano and Nakagawa (1990) considered HSR's impacts on population growth to be marginal, but (Brotchie 1991) reported that HSR has led to 22% higher population growth. Amano and Nakagawa used 1960 to represent the pre-HSR situation and 1985 to represent the post-HSR case, which may not be a proper treatment since there may be huge fluctuation in a single year's data. Brotchie used the annualized growth rate of the ten years preceding and following the introduction of the *Shikansen* in 1964, which is a more proper definition of the pre- and post- HSR settings. Hirota (1984) found that employment growth in retail, industrial, construction and wholesaling was 16-34% higher in the HSR station locations than non-station locations. Nakamura and Ueda(1989) reported that per capita income went up 2.6 % and commercial land values increased by 35 % due to the introduction of HSR stations.

According to (Haynes 1997), the HSR system in France has generated notable positive impacts on urban development. Land values in the proximity of the Lyon Part-Dieu station appreciated remarkably and office space due to access-related demand rose by 43% between 1983 and 1990. In Le Mans, another city on the TGV Atlantic, land values increased by 100% in the first three years. In Vendome on the same HSR line, property values increased by 35% and real estate exchanges increased by 22%, though the time period for such change was not disclosed. The numbers look promising, yet it is misleading to attribute the changes solely to HSR without examining non-HSR cities during the same period and the existing pre-HSR trend of urban development in the HSR cities.

Chen and Hall (2011) analyzed the potential impacts of high-speed trains on local economic development and knowledge intensive development by comparing 26 cities/towns along six radial routes of London-outbound trains. Only the London-Swansea line (307km) and the London-Edinburgh line (628km) support high-speed trains. They tracked the changes in a series of economic performance indices over the 30 years after the operation of high-speed trains since 1971. Their findings suggest that the absolute travel time to London is a key factor to shape economic profiles, regardless of the existence of HSR.

Empirical evidence abounds in developed economies yet the nature and scale of HSR's impacts on economic performance seem to be very context-specific. Very few empirical studies have been conducted in the context of an emerging economy. In my study, I fill the gap in existing studies.

5.3 Methodology and Data

To examine the corridor-level effects of the Wuhan-Guangzhou HSR, I conduct comparative statics on passenger travel patterns and urban economic activities for the pre- and

post-HSR periods. I define 2001-2009 as the pre-HSR period unless there is a data availability issue. The post-HSR period is relatively short, covering only 2010 to 2011, due to the limited operation period of this HSR. For passenger travel patterns, I show the changes in total number of railway passengers after the opening of HSR as compared to the pre-HSR trend. I also include changes in number of passengers on parallel routes by air and by bus to illustrate HSR's impact on alternative transport mode. Then I look into the detailed intercity matrices of rail passenger flows, to illustrate where the most significant increase in rail travel has occurred and then identify factors that have led to such changes. I compare urban economic performance at two levels. One level is between the group of cities on the Wuhan-Guangzhou HSR and their neighboring cities without HSR, using the difference-in-differences analysis technique. I could, in theory, identify the preliminary influence of HSR on urban economic performance, by eliminating the variation between periods and between groups. Yet the validity of analysis depends on the assumption that the two groups of cities keep a parallel trend if the HSR does not come into existence. I use annualized growth rate of each economic indicator to determine whether there is a step change in the trajectory of development. The other level of comparison is within the group of HSR cities. I replicate the pre- and post- HSR comparison for each of the ten cities with HSR. In this case, the direction (i.e., positive vs. negative) and the relative size of changes are more informative than the absolute change in percentage points.

I obtain the passenger flow data from a research institute under the Ministry of Railways of China. The original passenger flow matrix is recorded on a station-to-station basis, and I generate a new matrix with passenger flows aggregated by city. I extract information on number of passengers by alternative modes from second-hand sources, including reports issued by the transport department of local governments and newspaper articles. I collect economic

performance data for cities in the three provinces from the same database I built for analysis in

Chapter IV. I rely on my field observations and interviews with local agencies to interpret the

changing patterns as reflected by the comparative statics analysis.

5.4 Results of analyses

In this section, I report analytical results of how the Wuhan-Guangzhou HSR has

reshaped the modal choice and intercity travel patterns, followed by preliminary findings

regarding the relocation of economic activities along this transport corridor.

5.4.1 Shift in travel patterns

The Wuhan-Guangzhou HSR has led to an upsurge in the total number of railway

passengers. Before the opening of this HSR, the total number of railway passengers within this

transport corridor grew slowly from 35 million in 2001 to 45 million in 2009, at an annualized

rate of 3%. In 2010, the first full year of HSR operation, the number of railway passengers

reached 58 million, an increase of 30%. About one third of the railway passengers choose to take

the HSR (Figure V-2).

Figure V-2 Total number of railway passengers in the Wuhan-Guangzhou corridor 2001-2010
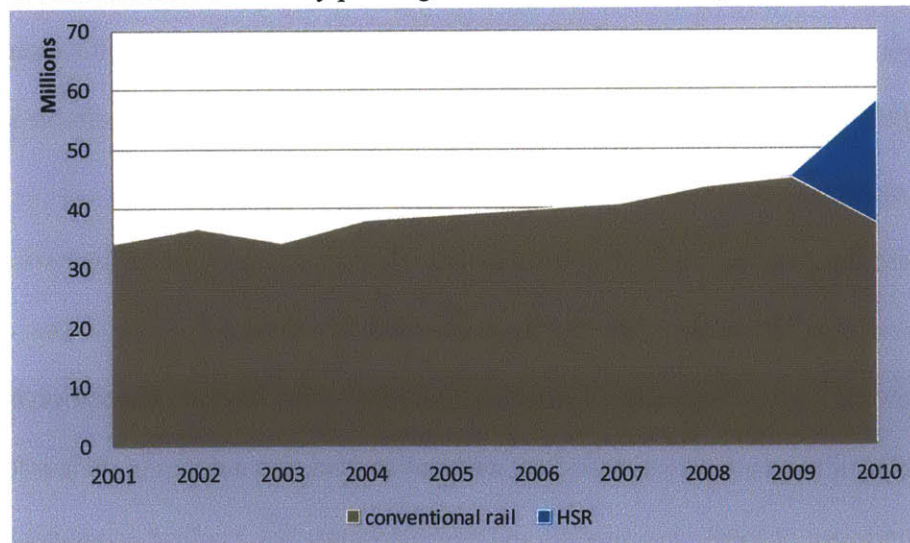
Data source: The Ministry of Railways of China

According to recently released statistics by the Guangzhou Railway Bureau, the total number of passengers traveling by HSR has reached 90 million during the three years' operation period. The railway administration has increased in the frequency of HSR service for five consecutive times along this HSR. The daily capacity of Wuhan-Guangzhou line has increased from 30,000 passengers to 110,000, and the occupancy rate has increased from 30% when this HSR was first opened in 2009 to as high as 80% to 90% by the end of 2012.

The Wuhan-Guangzhou HSR has significantly improved the competitiveness of the railway sector against alternative transport modes. Two airline routes are in operation along this transport corridor, one between Wuhan and Guangzhou and the other between Changsha and Guangzhou. Utill the end of 2010, airline passengers dropped by 28% between Wuhan and Guangzhou and by 46% between Changsha and Guangzhou, with a total loss of 0.7 million. During the same year, railway passengers increased by 52% between Wuhan and Guangzhou and by 82% between Changsha and Guangzhou, with a total increase of 5.5 million (Table V-1). The change in travel patterns indicates that HSR not only shifts people from airlines, but also generates induced demand by offering a fast and comfortable travel option.

Table V-1 Competition between HSR and airlines in Wuhan-Guangzhou transport corridor

City pairs	Distance (km)	Passenger by Rail (Million)			Passenger by Air (Million)		
		2009	2010	Change	2009	2010	Change
Wuhan-Guangzhou	840	3.59	5.46	52%	0.82	0.44	-46%
Changsha-Guangzhou	570	3.18	5.80	82%	1.16	0.83	-28%

Source: Transportation statistic yearbook of China 2010, 2011.

It is not feasible to conduct a similar analysis on the competition between HSR and highway travel over such a short distance due to lack of records on individual trips made by buses and cars. According to a report released by the passenger transport division of the Guangzhou Transportation Commission in early 2011, the Wuhan-Guangzhou HSR did not seem

to have negative impacts on passenger transport by bus from and to Guangzhou (Table V-2). As shown by the number of passengers in 2009 and 2010, bus operators at least maintained their niche market, and even 28% more people travelled by bus between Guangzhou and Qingyuan. This is most likely due to the lower fare and more flexible travel schedules they offered. Wang (2011) reported a similar change of highway transport in the Wuhan-Guangzhou corridor after the opening of the HSR. He identified a significant decline of highway transport only on the Guangzhou-Hengyang section, with a 25% drop in number of cars and a 60% drop in number of buses running between these two cities.

Table V-2 Number of passengers by bus from and to Guangzhou 2009 and 2010

Destinations	2009	2010	change
Shaoguan	545,133	592,855	9%
Qingyuan	3,197,833	4,079,904	28%
Hunan province	419,323	483,691	15%
Hubei province	83,175	97,038	17%

Data source: Guangzhou Transportation Commission, 2011

Then how are the increased railway passenger flows distributed among cities? The magnitude of intercity railway passenger flows approximates the hierarchical relationship among the ten cities. The vertical economic linkages between cities of different tiers dominate the horizontal linkages among cities at the same level of the urban hierarchy. Table V-3 shows the matrix of intercity railway passenger flows as of 2010, including trips made by HSR and conventional rail. The darker the color, the larger the passenger flows. The strongest intercity linkages are between the regional center Guangzhou, and the two provincial centers, Changsha and Wuhan. The secondary linkages are between the provincial centers and their subordinates. For cities between the provincial center and the national center (e.g., Hengyang and Chenzhou), the attractiveness of the national center, Guangzhou, surpasses that of the provincial capital,

Changsha. The travel pattern illustrates that the interactions between cities are positively related to the level of economic development of the destinations and inversely related to travel time. The distribution of passenger flows validates using economic potential as a proper measurement of a city's access to external resources.

Table V-3 Intercity railway passenger flows in Wuhan-Guangzhou corridor 2010(Unit: thousand)

City	Wuhan	Xianning	Yueyang	Changsha	Zhuzhou	Hengyang	Chenzhou	Shaoguan	Qingyuan	Guangzhou
Wuhan		1,236	453	1,483	224	169	86	90	28	2,740
Xianning	1,101		64	127	42	15	8	8	3	348
Yueyang	437	63		1,315	249	117	55	26	8	1,013
Changsha	1,434	119	1,364		1,129	1,663	1,002	164	53	2,936
Zhuzhou	224	43	240	1,087		567	182	57	11	935
Hengyang	171	14	115	1,624	577		310	147	28	2,427
Chenzhou	89	9	57	974	179	295		188	32	1,301
Shaoguan	95	9	30	165	61	161	192		252	2,220
Qingyuan	32	3	10	54	15	36	37	283		519
Guangzhou	2,719	313	974	2,863	944	2,274	1,245	2,404	618	
Total	6,301	1,809	3,307	9,692	3,421	5,298	3,118	3,365	1,034	14,439

Data source: Ministry of Railways

Table V-4 demonstrates the changes in intercity railway passenger flows after the introduction of the HSR. Three major patterns emerge. First, the increase in passenger flows is proportional to intercity distance because for HSR travel, the longer the distance, the more time saved. As a result, cities that are close to both ends of HSR (e.g, Xianning and Qingyuan), experienced the greatest percentage growth of railway passengers (Table V-5). Second, the increase in service frequency also matters in determining passenger flows and (Table V-6). Third, the vertical linkages between higher and lower tier cities have been strengthened, with the three major cities experiencing a remarkable percentage of growth in railway passengers. Given that the existing base of railway passengers in the three major cities was already large before the opening of the HSR, the increase in number of passengers is even greater if measured in absolute terms.

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Table V-4 Change in intercity railway passenger flows 2009-2010

Name	Wuhan	Xianning	Yueyang	Changsha	Zhuzhou	Hengyang	Chenzhou	Shaoguan	Qingyuan	Guangzhou
Wuhan		20%	27%	43%	29%	34%	32%	100%	302%	54%
Xianning	13%		1%	30%	1%	11%	-4%	42%	52%	29%
Yueyang	15%	7%		7%	-4%	10%	15%	38%	107%	6%
Changsha	43%	31%	11%		-3%	37%	87%	95%	252%	81%
Zhuzhou	34%	10%	-7%	-8%		3%	22%	37%	92%	31%
Hengyang	38%	4%	15%	34%	3%		14%	27%	74%	11%
Chenzhou	44%	10%	16%	78%	20%	7%		26%	58%	23%
Shaoguan	92%	45%	33%	94%	50%	24%	25%		9%	28%
Qingyuan	365%	153%	143%	233%	50%	55%	45%	17%		14%
Guangzhou	50%	46%	14%	84%	58%	13%	34%	37%	34%	

Data source: Ministry of Railways

Table V-5 Reduction in travel time by rail after the opening Wuhan-Guangzhou HSR

Name	Wuhan	Xianning	Yueyang	Changsha	Zhuzhou	Hengyang	Chenzhou	Shaoguan	Qingyuan	Guangzhou
Wuhan										
Xianning	0.4									
Yueyang	1.0	0.8								
Changsha	1.9	1.7	0.8							
Zhuzhou	2.5	2.1	1.2	0.3						
Hengyang	3.4	3.3	2.5	1.3	0.9					
Chenzhou	4.3	4.1	3.3	2.3	2.0	1.1				
Shaoguan	5.5	5.1	4.4	3.6	3.2	2.2	0.0			
Qingyuan	8.6	9.7	7.2	6.0	5.5	4.2	2.7	1.1		
Guangzhou	7.2	6.8	5.8	5.0	4.5	3.6	2.5	1.4	0.5	

Data source: Timetable released by Ministry of Railways 2009, 2010

Table V-6 Change in railway service frequency after the opening of Wuhan-Guangzhou HSR

Name	Wuhan	Xianning	Yueyang	Changsha	Zhuzhou	Hengyang	Chenzhou	Shaoguan	Qingyuan	Guangzhou
Wuhan										
Xianning	26									
Yueyang	17	7								
Changsha	43	15	25							
Zhuzhou	-2	1	-1	14						
Hengyang	18	15	11	36	4					
Chenzhou	7	-1	5	23	3	7				
Shaoguan	18	6	8	27	-1	14	0			
Qingyuan	7	4	4	8	5	9	8	4		
Guangzhou	57	24	24	90	23	29	30	31	6	

Data source: Timetable released by Ministry of Railways 2009, 2010

To get a better sense of the step change the HSR has introduced, I compare the post-HSR

passenger growth (Table V-4) with the pre-HSR growth trend during 2001-2009 (Table V-7).

Before the operation of this HSR, the intercity passenger flows by rail generally grew at a single-digit rate, primarily driven by the natural growth of population. In Qingyuan, where railway service is particularly limited, the number of railway passengers even dropped steadily. In contrast, after the introduction of HSR, most cities witnessed a two-digit growth of passengers. Particularly, the passenger flows between Qingyuan and cities on the other end of the HSR increased enormously--even more than tripled.

Table V-7 Annualized changes in intercity railway passenger flows 2001-2009

Name	Wuhan	Xianning	Yueyang	Changsha	Zhuzhou	Hengyang	Chenzhou	Shaoguan	Qingyuan	Guangzhou
Wuhan		8%	8%	10%	9%	7%	13%	6%	1%	8%
Xianning	4%		0%	6%	4%	6%	12%	9%	7%	4%
Yueyang	9%	2%		2%	0%	0%	7%	-2%	0%	-3%
Changsha	10%	7%	2%		7%	8%	4%	5%	3%	5%
Zhuzhou	9%	6%	1%	7%		5%	5%	3%	-4%	8%
Hengyang	8%	8%	1%	10%	5%		6%	0%	0%	6%
Chenzhou	9%	8%	5%	3%	4%	4%		-1%	-3%	7%
Shaoguan	4%	5%	0%	3%	2%	1%	-1%		-3%	1%
Qingyuan	-6%	-7%	-9%	-2%	-2%	-1%	-3%	-2%		0%
Guangzhou	5%	5%	1%	6%	6%	7%	7%	5%	3%	

Data source: Ministry of Railways

In sum, the time-space along the Wuhan-Guangzhou transport corridor has shrunk significantly after the introduction of the HSR, particularly over medium to long distance. Removing the bottleneck in railway transport brought an explosive growth in passenger flows---a typical case in point is the city of Qingyuan. Yet the impacts on the urban hierarchy are mixed. On the one hand, the existing urban hierarchy has been strengthened by enhanced interaction between the regional center and the provincial centers, and between provincial centers and subordinate cities. One the other hand, the urban hierarchy is evolving towards a more interwoven structure, with more cross-provincial interaction established between third-tier cities and the next door major cities. In other words, the hinterlands of major cities increasingly

overlap with each other with lower-tier cities obtain exposure to multiple upper-level cities.

5.4.2 Relocation of economic activities: short-run observations

The intercity passenger flow matrices indicate that the Wuhan-Guangzhou HSR has

enhanced the interaction of cities along this transport corridor. It remains unclear how the

enhancement in intercity accessibility influences the location choices of economic activities, for

producers as well as consumers. In this section, I examine whether the cities with HSR

connection outperform the non-HSR locations, and how they differ from each other in terms of

the magnitude and nature of HSR's impacts. Given that the Wuhan-Guangzhou HSR has been in

operation for only three full years (2010-2012), I focus on economic activities that are able to

adjust over the short run. In the following section, I discuss HSR's short-run impacts on intercity

real estate development, transfer of manufacturing industries, and tourism. For each topic, I

compare the pre-HSR and post-HSR situation between HSR cities and non-HSR ones, as well as

among HSR cities. I pay special attention to the lower-tier cities, because economic growth in

Guangzhou is driven primarily the internal demand of the city itself. Rather, the linkage to the

megacity of Guangzhou could be a vital source of economic development for lower-tier cities.

There are 46 prefecture level cities in the three provinces, among which 10 cities are on

the Wuhan-Guangzhou HSR, 15 cities are connected by other upgraded HSR or short sections of

intercity HSRs, and the remaining 21 cities have not yet obtained direct access to HSR by the

end of 2011. I use these 21 cities as the control group for comparison with the cities sitting on the

Wuhan-Guangzhou HSR.

Real estate development

At an earlier stage of market formation, the real estate markets in most Chinese cities

have been highly segregated, with local developers serving the needs of local residents. However,

in recent years, major developers running business in China have broken the segregation of real estate markets by investing across the provinces. As first-tier cities imposed rigorous restrictions on speculative investment in real property, top developers shifted gears to second and third tier cities for business opportunities. A city's transport facilities and the overall accessibility within the region is one of the factors developers consider when they make location choices for new real estate projects. Therefore, city governments have been vocal in arguing that HSRs will boost the prosperity of real estate market by attracting the major developers.

I first compare the completed real estate investment in each year between the HSR cities and non-HSR cities. Figure V-3 shows the values of completed real estate investment aggregate by these two groups over 2001-2011. The trend line illustrates that since 2009, the real estate investment in HSR cities has been accelerating on average while similar pattern is not identified in the group of non-HSR cities. The average growth rate for cities on Wuhan Guangzhou HSR is 28% before and 31% after the opening of HSR, while that for non-HSR cities remained unchanged at 26%.

Figure V-3 Completed real estate investment in HSR cities vs. Non-HSR cities (2001-2010)
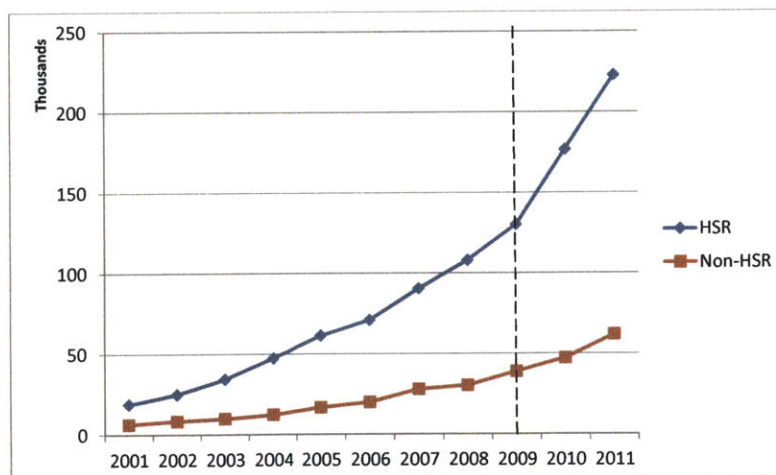
Data source: Chinese city statistical yearbooks.

Variation in the expansion pace of real estate investment also exists within the group of

HSR cities. I replicate the between-group comparison for the HSR cities (Figure V-4). Changsha has experienced a faster pace of real estate development since the opening of the HSR while there was no obvious jump in the growth rate of real estate development in Wuhan (the left chart). After I excluded these two provincial capitals from the sample, Zhuzhou, Qingyuan and Xianning stand out as the cities with step changes in the growth rate of real estate investment. All three cities are within commuting distance to their provincial capitals. The trend lines of real estate development for most cities have a steeper slope after the operation of the Wuhan-Guangzhou HSR. An earlier round of investment boom occurred during 2006-2007 following the inception of the HSR construction in 2005. Unlike the supply of ordinary goods, the construction of new buildings takes years to complete. Therefore, real estate developers often make investment decisions based on expectations. Applying this rule to examine the relationship between urban development and transport infrastructure, analysts find that developers start new real estate projects along new transport facilities when the plans are announced or when they are still under construction (Knaap, Ding et al. 2001; Du and Mulley 2007).

Figure V-4 Real estate investment in the 10 cities on Wuhan-Guangzhou HSR
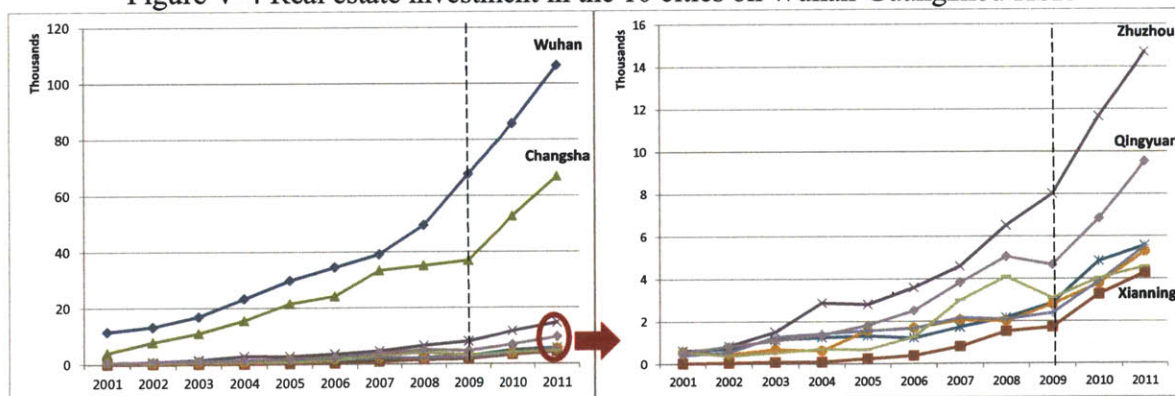
To verify my assumption that one of the reasons for the boom in real estate market in HSR cities is due to the cross-regional investment, I further analyze the location choice of the top real estate developers as they enter a new market. The real estate industry in China is subject to

monopolistic competition among a dozen key players. The major developers initiate new branches and development projects all over the country, yet each of them has a regional focus. Real estate developers that invest in Hunan and Hubei provinces are primarily from the Pearl River Delta (i.e., HongKong, Guangzhou and Shenzhen). I tracked the locations of new projects developed in Hunan, Hubei and Guangdong by five Guangdong-based top developers since 2007. I choose year 2007 because according to existing evidence, developers take actions in advance.

The five developers include the two largest developers in China, Vanke and Evergrande, as well as Country Garden, CITIC Real Estate and Kaisa, which are also among the top 20 largest developers. The geographic focus of business for these developers has long been the cities in the heart of the Pearl River Delta. However, due to increasing competition and shrinking profit margins, the major developers have started to explore new markets in second and third tier cities in Hunan and Hubei provinces. These five developers follow different strategies as they expand their business. Vanke, CITIC Real Estate and Kaisa are more cautious in entering new markets. They restrict new real estate development to provincial capitals and cities in their adjacent locations. In contrast, Evergrande and Country Garden adopted a more aggressive strategy and entered the real estate market of many third-tier cities. It is interesting to note that, in Hunan and Hubei province, the cities they picked for future expansion of businesses do cluster along the HSR, with very few exceptions. In fact, on its official website, Evergrande describes its business strategy as "based in the capital cities and expand along the HSRs."[6] Beside the top developers, major local developers based in Wuhan and Changsha have also expanded their business to third-tier cities, following similar location choice strategies. The first destination of expansion is their next-door minor city connected by the HSR, such as Xianning and Zhuzhou.

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[6] Evergrande http://cs.evergrande.com/about.asp?id=197

Figure V-5 Location of market expansion of five top real estate developers
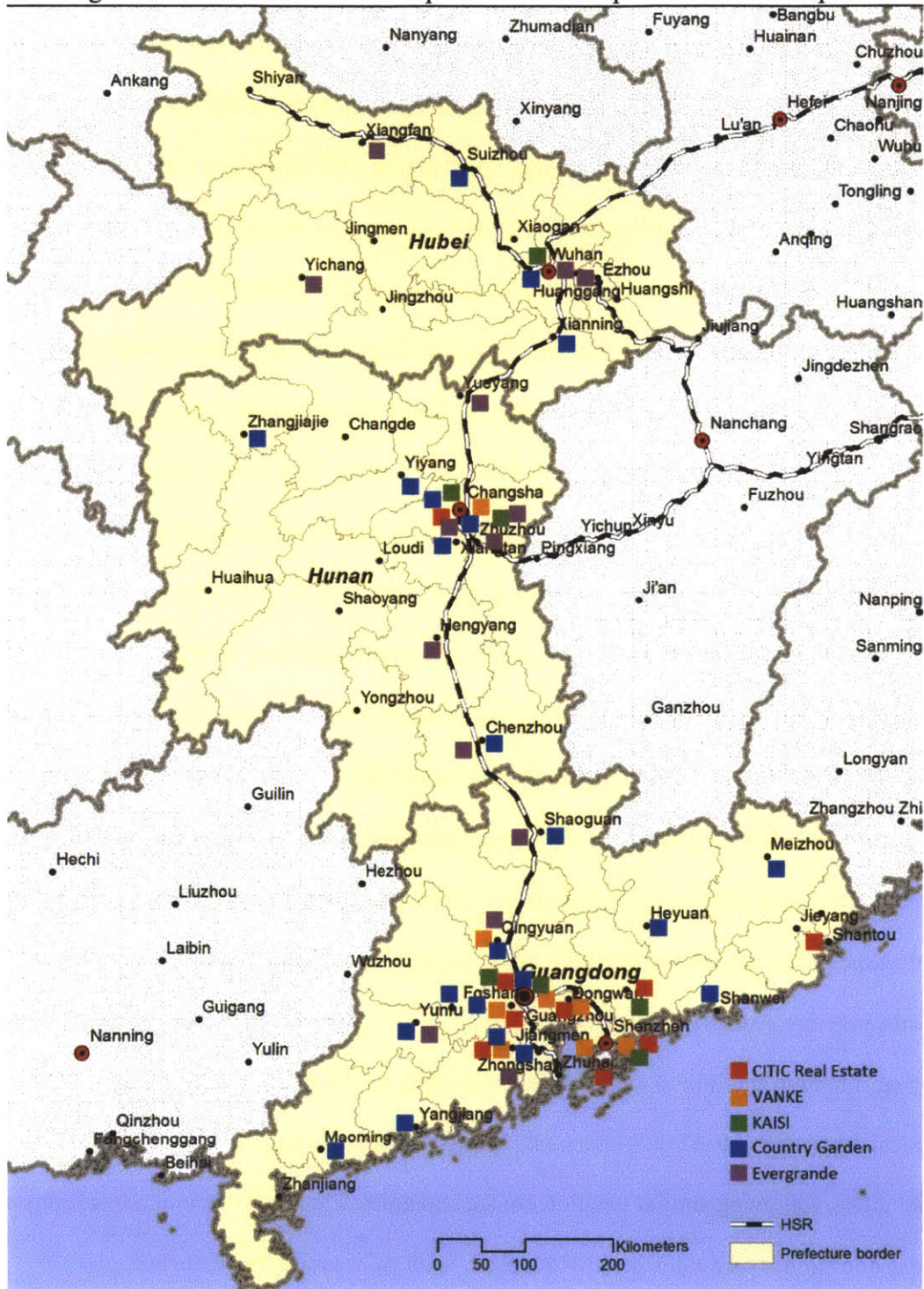
Data source: the official websites of the five developers, author mapping.

Tourism industry

Local authorities have attributed the prosperity of the tourist industry in Hunan and Hubei

provinces largely to the opening of the Wuhan-Guangzhou HSR. To obtain a better

understanding of how HSR influence tourism in HSR and Non-HSR cities, I conduct a

before-and-after analysis using number of tourists and revenues of the tourism industry between

the two groups of cities. The time horizon of the analysis is from 2002 to 2011, which the most

recent available data covers (Figure V-6).

Table V-8 Growth rate of number of tourist and tourism revenue in HSR and Non-HSR cities

	City groups	Pre-HSR average growth rate (%)	Post-HSR average growth rate (%)	Difference in average growth rates (%)
Number of tourists	HSR	14.8	30.5	15.7
	Non-HSR	13.0	27.3	14.2
Tourism revenue	HSR	19.4	35.6	16.2
	Non-HSR	17.8	32.1	14.4

By comparing the pre-HSR and post-HSR average growth rate of number of tourists and

tourism revenue, I find that the Wuhan-Guangzhou HSR has benefited the tourism industry in the

whole study region, not restricted to the locations with HSR connections. The HSR cities slightly

outperformed non-HSR cities, with an extra 1.5 percentage points' growth in number of tourists

and an extra 1.8 percentage points' growth in tourism revenue.

I further analyze which cities on the Wuhan-Guangzhou line benefit most from the HSR

in attracting more visitors. I replicate the between-group comparison for the HSR cities on the

Wuhan-Guangzhou line. Not surprisingly, most cities have experienced higher growth rates of

tourism after the opening of HSR. Among them, Qingyuan, Yueyang, Zhuzhou and Xianning

have witnessed even larger changes than elsewhere. A common feature of these cities is that all

of them are located within half an hour's travel from their provincial capitals by HSR.

Figure V-6 Number of tourists (left) and tourism revenue (right) in the HSR cities
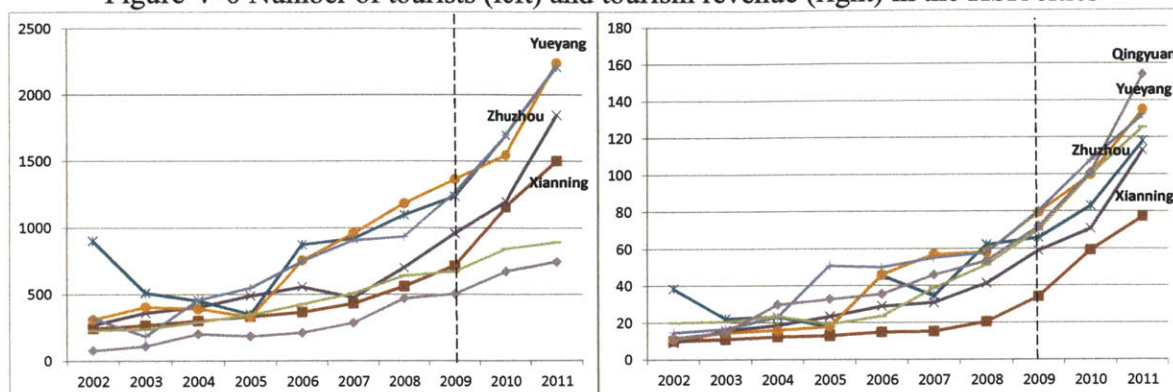
To understand why HSR's beneficial impacts have spread to non-HSR cities and what factors have made these three cities more successful than others, I interviewed several travel agencies[7] based in Guangzhou during my field trip in 2012. The travel agencies have been using HSR as a new promotional strategy. They develop new routes that take good advantage of the Wuhan-Guangzhou HSR in arranging logistics. According to their own-source statistics, the most popular tourism products are the 2-3 day weekend trips to Hunan and/or Hubei province. However, the most popular scenic spots are Wulingyuan in the western corner of Hunan and Shennongjia and Wudang Mountain in the western corner of Hubei. To reach these sites, tourists generally make connecting trips at Changsha and Wuhan. This partly explains why non-HSR cities have also benefited from HSR but not as much as in HSR cities. People from the travel agency told me that they often arrange lodging in third-tier cities close to the provincial capitals, which not only reduces total costs but also adds to the richness of travel experiences. This might explain the huge boom in tourism in Yueyang and Zhuzhou, because the number of tourists is counted based on the overnight stays. For Qingyuan, another very important reason is the fundamental improvement in the rail service by the HSR. As shown in Table V-4 in Section 5.4.1, the number of passengers by rail between Qingyuan and cities in Hunan and Hubei province has

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[7] Travel agencies interviewed include Guangdong International Travel, China Youth Travel and South Lack National Travel.

grown by two to three times after the opening of the Wuhan-Guangzhou HSR. As Qingyuan is a well-known resort of karst landscape and underground water, the removal of the transport barrier has been associated with a significant boom in the tourist sector.

The quantitative expansion of tourism sector is not yet the whole story. There has been underlying change in the composition of tourists and the flow of tourists among destinations. Based on a survey conducted by the travel agencies, tourists arriving by HSR on average spend more time in the destinations, and their per capita expenditure is about 1.5 - 2 times as much as that of people taking buses and regular trains. This finding corresponds to the trend that tourism revenue grows even faster than the number of tourists. In addition, Guangzhou used to be the main origin of tourists. Now it is gaining popularity among people from Hunan and Hubei province as a tourism destination, with artificial landmarks showing the cultural diversity and excitement of urban life. Yet, such a trend is not yet detectable from the aggregate level numbers.

Inter-region transfer of manufacturing

Industrial transfer has become a nationwide economic development strategy in China in recent years[8]. Following the argument of the *Product Cycle Theory* (Vernon 1966) and the *Flying Geese Paradigm* (Akamatsu 1962), the State Council of China has been promoting the relocation of labor-intensive industries from the coastal region to inland locations. The industrial-transfer strategy not only aims to boost economic development in the lagging regions, but also to make room for high value-added industries in the coastal region. This top-down strategy has its micro-level economic ground. Enterprises have strong motivations to avoid the rising wage rates that cut into their profit margins in the Pearl River Delta.

Regarding the study area in particular, a major spatial pattern of industrial transfer has

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[8] Guidelines on accommodating industrial transfer in Middle and Western regions of China by the State Council, http://www.gov.cn/zwgk/2010-09/06/content_1696516.htm

been the relocation of manufacturing enterprises from the Pearl River Delta to the rest of Guangdong province and all the way north to Hunan province. The economic linkage and cultural connection between Guangdong and Hunan has a long history, which makes Hunan a priori destination when the Guangdong-based enterprises make relocation plans. Then within Hunan province, how do the firms choose from among different cities? Does the access to HSR make a difference? My initial observations shed some light on these questions.

The Wuhan-Guangzhou HSR seems to have raised the enthusiasm of transferring manufacturing industry to third-tier cities along this corridor. In almost every HSR city, local authorities have established industrial parks to accommodate the industry transfer from the Pearl River Delta. In October 2011, the National Development and Reform Committee (NDRC) approved the proposal to establish a national-level demonstration district of accommodating industrial transfer in Hunan. The spatial coverage of this industrial transfer district includes three cities in south Hunan: Hengyang, Chenzhou and Yongzhou, the first two of which have HSR access. According to the Commercial Department of Hunan province, during a trade forum held in May 2010, HSR cities in Hunan signed 228 investment memos with enterprises from Guangdong, at a value of 90 billion RMB. In addition, the two largest inter-province industrial transfer projects after 2009 have been the opening of a new manufacturing branch in Hengyang by Foxconn and another one in Chenzhou by Delta Electronics. Foxconn is a top assembler of Apple's products and Delta Electronics is one of the largest supplier to IBM, DELL and HP. These two Taiwanese companies started their business in mainland China in Shenzhen and Dongguan years ago, and both of them are now seeking new development opportunities in inland provinces. The introduction of top enterprise has received wide coverage in the mass media, and

local governments in these two cities attribute the success to the opening of HSR[9]. During the negotiation process, local officials from Hengyang and management staff of the Taiwanese companies made very frequent business trips via the HSR. Mr Zeng, the director of the Baisha Industrial Park in Hengyang, considers HSR to be very important in facilitating the timely communication between the two sides.

However, after a careful scrutiny of other potential influential factors, I find that the contribution of Wuhan-Guangzhou HSR may be overstated. According to (Lin 2010), who analyzed the investment behavior of Taiwanese firms in the IT sector in China, government policy incentive is one of the key determinants of the firms' location choices. Even though favorable policies to attract investment exist universally among locations, the extent to which local governments offer bonuses and credits to external investors varies. In the specific case of introducing Foxconn to Hengyang, the local government went much further in providing policy incentives. The bonus package includes: free land, 50% discount on value-added tax and business income tax for 15 years, co-funding the construction of factory buildings, subsidizing the freight logistics and providing housing for Foxconn employees. Such favorable policies are not available in other third-tier cities in Hunan, nor do they apply to other enterprises located in Hengyang. As to the city of Chenzhou, an important factor that should not be ignored is that, it has the only national-level Export Processing Zone (EPZ) in Hunan province[10]. For export-oriented enterprise like Delta Electronics, the tax rebates to imported materials and tax exemptions on exported final goods in EPZ should be a major consideration in determining the location of factories. In both cases, it is hard to separate the influence of special favorable policies from the potential benefits associated with HSR.

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[9] Shenzhen News Online, Sep 20, 2011. http://sznews.com/zhuanti/content/2011-09/20/content_6067086.htm
[10] The only national-level EPZ in Hunan, A introduction to the Chengzhou EPZ, http://www.czs.gov.cn/sitepublish/site200/zwgk/ztbd/xncjcy/cgzs/content_223114.html

Even so, the micro mechanisms for HSR to be an attractive factor to external investors still exist. For multi-branch firms, HSR does provide a convenient travel option for management level staff to commute among headquarters and local branches, which may improve the efficiency of business management. The actual impacts depend on the specific type of firms. For firms that require huge amount of shipment of raw materials and final goods, the benefits gained from the improvement of passenger travel via HSR may be marginal compared to the costs of freight transportation.

5.5 Summary

My analyses indicate that the Wuhan-Guangzhou HSR has enhanced the competitive edge of the railway sector against alternative transport modes along this specific transport corridor. The interaction among cities is strengthened by growing intercity passenger flows. The shift in travel patterns carries several key features. First, the scale of increase in passenger flows is positively correlated with travel distance, as time savings grow significantly with distance. Therefore, cities close to both ends of this HSR line have experienced the most remarkable growth in railway passenger flows. Second, increase in service frequency also plays an important role in determining passenger flows in addition to travel time savings. Third, the vertical linkages between higher and lower tier cities have been strengthened, as the trips between the three major cities and their subordinates experienced remarkable growth. This has strengthened the existing structure of the urban hierarchy in the study region. Meanwhile, the urban hierarchy is evolving towards a more interwoven structure, with remarkable growth in inter-provincial trips between third-tier cities and the major cities which they do not administratively belong to. In other words, the major cities now reach for overlapped hinterlands and the third-tier cities obtain exposure to multiple external resources for economic development.

The shift in travel patterns is associated with relocation of economic activities. The relationship between enhanced intercity linkage and relocation of economic activities, however, is not straightforward. The time horizon and spatial coverage of HSR's influence on economic activities vary across different aspects of urban economy. Since the Wuhan-Guangzhou HSR line has only been in operation for three years up to the time of my study, it is not yet feasible to identify its influences on aspects of urban economy that take a longer time to response. Therefore, I focus on economic activities that are able to adjust over the short run: (1) real estate development, (2) tourism, and (3) inter-region transfer of manufacturing industries. These three economic activities are also expected to have close relationship with HSR travel according to existing literature (Pol 2007; Masson and Petiot 2009) and the arguments about HSR-induced benefits made by local governments

The opening of the Wuhan-Guangzhou HSR is associated with a faster expansion in real estate investment in HSR cities than non-HSR cities. Among the HSR-connected locations, those third-tier cities in the immediate proximity of the provincial capitals have experienced the most significant expansion of real estate investment. Empirical evidence shows *anticipation effects*, that is, real estate developers began to launch new projects in advance of the opening of the HSR line. The access to HSR makes a difference when they choose from among third-tier cities, but the specific location of the real estate projects does not necessarily fall in the proximity of the HSR stations, as long as the development sites have convenient access to HSR. However, the HSR's impacts on real estate development are likely to be temporary, as the equilibrium stage supply will eventually be determined by the absorption rate at local markets. In fact, the HSR-induced real estate investment has cooled down a bit in 2012, according to recently

released statistics in Hengyang and Zhuzhou[11]. In addition, as the construction of the HSR network goes on, more and more cities will join the club with HSR access, and the advantage of having an HSR station may shrink.

The Wuhan-Guangzhou HSR has brought wide-spread benefits to the tourist industry in the study area. Both HSR cities and non-HSR cities experienced faster growth in number of tourists and related revenue after the opening of this HSR. HSR cities slightly outperformed the non-HSR group. The reason lies in that even though many of the most popular scenic spots are located in non-HSR cities, passengers usually make connecting trips at HSR cities, thus sharing the benefits of reduction in travel time. The Wuhan-Guangzhou HSR has not only accelerated the expansion of the tourist industry but also appears to bring changes to the internal structure of the tourism market. It helps to bring tourists with stronger purchasing power and further increase the revenue base generated out of the tourism industry. In addition, the direction of travel is also changing. The city of Guangzhou, as one of the major origins of tourists, is gaining popularity as a destination offering the modern urban landscape.

HSR's influence on industrial transfer is less tenable. Local development authorities in Hunan have claimed that the opening of HSR also promotes the transfer of manufacturing industries from the Pearl River Delta to the third-tier cities along the corridor. Their argument is based on the facts that the top electronics companies choose to open new branches in the HSR cities. The seeming correlation between HSR and industrial transfer is untenable after a careful scrutiny of other influential factors to location choices. According to my analysis, the extraordinarily favorable policy incentives and the existence of a national-level export processing zone (EPZ) have contributed remarkably to the establishment of new branches at the two HSR cities. It is true that HSR could improve the management efficiency of multi-branch

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[11] http://hn.people.com.cn/n/2012/1016/c336519-17588616.html

firms by saving travel time between the headquarters and the manufacturing plants.

Considering the short-run impacts of HSR all together, I find that within the group of HSR cities, the scale and nature of HSR's impacts on economic performance highly depends on the rank of the city in the hierarchical urban system and the relative location of the city along the HSR line. The most significant HSR-related influence occurs in the third-tier HSR cities in the immediate proximity of the major cities, such as Zhuzhou, Xianning and Qingyuan. My assumption is that the economic performance of the third-tier cities largely relies on their connection with major upper-level economic centers, and the findings confirm this assumption.

The analysis is inevitably subject to limitations. A major concern is the short observation period after the opening of this HSR line. Therefore, the findings from the current analysis are preliminary and are not suitable for evaluating the steady-stage impacts of this particular HSR line. Another limitation lies in the selection of the non-HSR control group. There might be other underlying factors that distinguish these two groups from each other in addition to the HSR. The concern could be partly released as long as the other factors do not experience sudden changes simultaneously with the opening of HSR. Despite the limitations, this analysis shed light on the scale and nature of HSR's channelizing effects on travel patterns and economic activities, which serves as a good starting point of further studies.

HSR access seems to be an attractive to real estate developers. Yet HSR's most direct impacts on urban development often clusters within a certain distance around the station area, thus could not be fully understood by analyzing the aggregate city-level data. In the following chapter, I extend the analysis at an intra-city level, to identify the preconditions for an HSR station to become an engine of urban development and exert influence on the evolution of a city's internal spatial structure.

Chapter VI HSR STATION AS AN ENGINE OF URBAN DEVELOPMENT

For the network and corridor analyses, I treated cities as abstract points in space to focus

on the intercity connections provided by the HSR. Such simplification is not costless. As I have

stated, HSR's impacts on different aspects of economic performance vary in terms of spatial

coverage. Specifically, its influence on urban land development is usually local, clustering in the

proximity of HSR stations. HSR stations bring external stimulus to urban land development, and

potentially have the power to reshape urban structure by shifting cities' path of spatial expansion.

In this chapter, I explore one key research question: in what situation may an HSR station

become an engine of urban development? I hypothesize that the potential for urban development

at HSR station locations is determined by the possibility to match the desire for development

with land available at that specific location, and the involvement of both public and private

sectors is indispensable in materializing the development potential. Public sector's active

promotion can introduce motivations for new development, but without matching responses from

the private sector and the market, the ambitious city-building plans cannot be successfully

achieved. I conduct comparative case studies using the cities on the Wuhan-Guangzhou HSR.

Three major categories of factors jointly determine the demand and supply of land at HSR

station locations: (1) city-specific features, (2) features of the stations, and (3) existing land use

status quo in the proximity of the stations. I identify ten key factors under the three categories

and propose three prototypes of station area development based on different combinations of

these key factors.

The rest of this chapter proceeds as follows: Section 6.1 introduces the motivations of the

city-level analysis of the interaction between HSR station and land development. Section 6.2

reviews relevant studies on HSR station's impacts on urban development, including analytical

tools used and empirical evidence from different contexts. Section 6.3 develops the analytical framework by integrating urban economic perspectives with existing approaches and conceptual models. Section 6.4 explains the criteria I use to select cities for case studies. Section 6.5 contains three case studies representing different prototypes of urban development around the HSR station. Section 6.6 summarizes the findings and policy implications.

6.1 Motivation of research

In this section, I examine the potential of an HSR station to become the stimulus of urban development. Such an analysis is desirable for several reasons. First, the benefits of urban development are not accounted for in the classic NEG models. Scholars have suggested that this missing component represents an important dimension of HSR's indirect benefits on the urban economy in justifying such investments. Local authorities propose to finance HSR with the revenue from land development surrounding the station. Analysts argued that land concession fee can be used to compensate the costs of capital investment and operation (Doherty 2004). In addition, land concession fee has become a major source of municipal finance, and local authorities are interested whether HSR will trigger new development and bring extra sources of fiscal income as they expect. Second, station-area development in China is confronted with opportunities and challenges that differ from their counterparts in the developed economies. In European countries, station area development is often regeneration of declined areas in downtown locations while in China it is the urbanization of undeveloped land in suburbs and rural areas. There is also significant difference in the institutional arrangement that makes the mode of station area development unique in China. Finally, assessing HSR's impacts on urban structure and land development is most relevant to city planners' professional practice and the causal relationship between HSR stations and land development around them is unequivocal and

comparable among different cities in different contexts. Therefore, I dedicate this chapter to the potential impacts of HSR stations on urban development in China.

6.2   Relevant studies on urban development around HSR stations

Empirical research regarding the HSR stations' local impacts on urban development has been built on extensive case studies. Existing literature has made comparison of cities before and after the operation of HSR; between cities with and without HSR services; and among cities in different country contexts (Hirota 1984; Nakamura 1989; Amano 1990; Bertolini and Spit 1998; Pol 2007). To explore what specific conditions have led to the diverse paths of urban development around HSR stations, analysts often group cities or stations into clusters, using different sets of criteria. A common technique they apply is cluster analysis. These comparative, cluster analyses shed light on the influential factors that determine the possibility, path and outcome of HSR station area development. They provide reference for my selection of criteria to categorize the cases in Section 6.4. Another strand of relevant studies is on the transit oriented development (TOD). The TOD literature in general belongs to normative researches, in which the authors discuss how to capture the land value increment generated from transit stations by using pro-active urban planning and city design strategies.

Cluster analysis

Murakami and Cervero (2010) examined the locational characteristics of job and labor markets around the planned HSR stations in California. They compared the Californian case to the areas in the proximity of Shinkansen HSR stations in Japan. They define the units of analysis, namely the "station catchment area", as the 5km radius' buffer from the HSR stations. To build a typology of the 26 HSR station areas in California and 17 Shinkansen station areas in Japan, they applied cluster analysis. The technique of agglomerative hierarchical clustering systematically

combines a number of different station cases into a reasonable set of clusters on the basis of their similarities. The purpose of categorization is to assess how different factors will influence the impacts of HSR on urban development. Based on values of these variables, Murakami and Cervero categorize the 26 Californian cities into five distinct clusters: (1) global and regional business centers, (2) edge cities, (3) aerotropolises, (4) leisure cities, and (5) small intermediate cities.

Hall (2009) stresses the potential advantages of "edge city" station locations (Garreau, 1991), especially where HSR services are directly linked to major international airport terminals. Kasarda (2011) developed the concept of "aerotropolis", consisting of an airport city and outlying high-speed corridors and stretching the clusters of aviation-linked businesses and associated residential development up to 20 miles (30 kilometers) outward from some major international airports. Empirical findings suggest that new HSR project are likely to induce knowledge- and service-based business agglomeration benefits, though these are mostly limited to large, globally connected cities. Growth can also shift from small intermediate cities to HSR-served edge cities, aerotropolises, and leisure-entertainment hubs.

Peter Pol (2007) proposed two archetypes of cities in a European context: Cities in Transition (CiTs) and International Service Cities (ISCs). The former are often old manufacturing or port cities trying to diversify their economic structures through efforts to attract new economic activities and inhabitants, e.g., Liège, Lille, Liverpool, and Rotterdam. ISCs have a competitive edge in the international service and knowledge economy, because of their high grade (international) facilities, attractiveness, and accessibility. Examples include London, Paris, Amsterdam, and Munich.

Sands (1993) comprehensively reviewed early studies on the urban development impacts

of HSR, including empirical evidence from Shikansen in Japan, Train à Grande Vitesse (TGV, meaning high-speed train) in France and Inter City Express (ICE) in Germany. He focused on urban economic impacts, such as, changes in population and employment, as well as station area development and redevelopment. He divided the HSR stations into existing stations shared with regular rail and new station built exclusively for the HSR. He also distinguish the stations served by express high-speed trains that only stop at major cities, versus those served by slower HSTs that stop at every station.

Lin (2011) analyzed 17 HSR stations in China to explore the most influential factors that generate new development. He suggested that existing urban development level, urban spatial structure, function of the HSR station, accessibility of the station and the land use condition in the proximity of the station all contribute to the possibility and scale of new development. Based on a simple correlation analysis of the 17 HSR stations, he concluded that the overall urban development level, distance to urban center and passenger flows are the key determinants of station area development. Lin did not include detailed information about the station-area development, but his study did provide good reference for selecting the influential factors.

Transit oriented development (TOD)

The concept of transit-oriented development (TOD) has been widely used to foster a synergy between the public transport facilities and their adjacent land-use patterns. Analysts have provided a variety of definitions regarding TOD (Cervero, Ferrell et al. 2002). Although the definitions of TOD vary in scope and specificity, most share several common elements: (1) mixed-use development; (2) development that is close to and well-served by transit; and (3) development that is conducive to transit riding. Cervero (2009) also summarizes policy lessons learned about rail transit and urban development, based on the literature reviews and summaries

of relevant case studies. International experience shows that, if they are to have much chance of success, TODs must be proactively championed by the public sector. Among the lessons learned, there are several key messages with respect to station-area development: (1) a prerequisite to significant land-use changes is a healthy regional economy; (2) railways can spur central city redevelopment under the right conditions; and (3) other pro-development measures must accompany railway investments.

The TOD model that has been developed in an intra-city context, however, may not be readily applicable to land development at the HSR stations. Besides the common features of TODs, it is important to have a distinctive treatment among different types of public-transport facilities. The nature and patterns of passenger flows differ depending on the types of transport modes. Different passenger flows generate various demands for land use adjacent to the public-transport nodes, which ultimately leads to different policy implications for urban development practices.

Table VI-1 Types of TODs and demands on land use

Transport node	Typical passengers	Travel distance	Demands on land use
Subway/bus stations	Almost all local residents	Intra-city	Daily life service (e.g., shopping, recreation and restaurant etc.)
Commuter rail	Local commuters	Intra- or inter-city	Office space, daily life service (e.g., shopping, recreation, restaurant etc.)
High-speed rail	Business people and tourists	Inter-city	Office space, hotel, restaurant, trading

Source: author

Different from subways that operate underground without segregating urban districts, HSR plays a dual role in shaping the urban spatial structure. On the one hand, HSR may improve a cities access to external resources and introduce new economic activities; on the other hand, it may also become a barrier that restricts further development beyond the HSR line. It is highly

possible that the land development not take place as planned. The actual development process may be asymmetric, that is, land parcels on the inner side of the HSR stations get developed and merge into the main urbanized area, while it takes much longer time to initiate development projects on the outer side of the HSR. Below I compare the affected zones around a railway station with that of subway stations (Figure VI-1). The potential blocking impacts of the railway on urban expansion implies that, to foster new urban development an ideal location for the HSR station should not be too close to the existing urban center.

Figure VI-1 Differences between affected zones of railway stations and subway stations
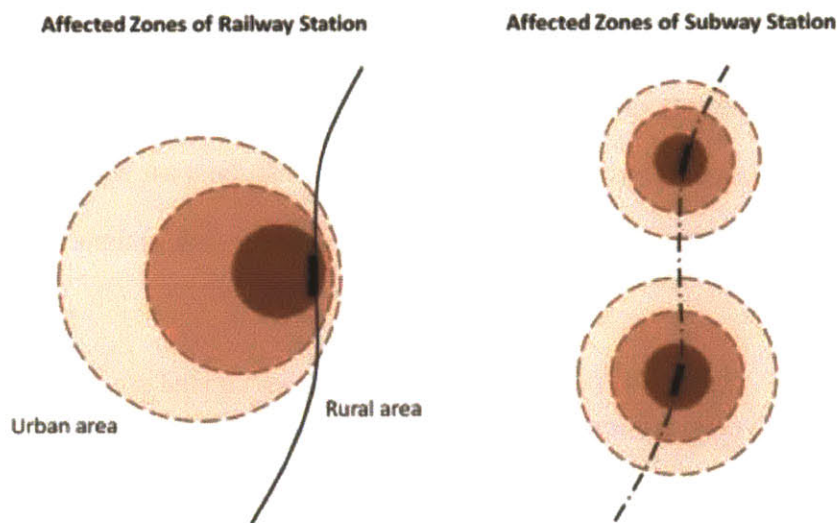
Source: author.

6.3   Conceptual models

In this section I develop an analytic framework by reviewing the widely accepted conceptual model that specifically covered urban development around railway stations, that is, the "node-place value" model. Then I introduce a "demand-supply" model by applying urban economics principles to assess the opportunities for land development around the HSR stations.

6.3.1   The node-place value model

Bertolini's "node-place value" model is among the very few conceptual models that

specifically covered urban development around railway stations (Figure VI-2). According to

Bertolini, station areas are both "nodes" and "places" (Bertolini 1996). They are important nodes

in both transport and non-transport (e.g., business, consumption) networks. Conversely, station

areas also identify a place, both a permanently and temporarily inhabited area of the city, a dense

and diverse conglomeration of uses and forms accumulated over time, which may or may not

share in the life of the node. The node-place value model provides an analytic framework to

penetrate station area development (Bertolini 1999). She builds the model on elaborations of the

"transport land-use feedback cycle" (Badoe and Miller 2000; Wegener and Fuerst 2004).

Figure VI-2 The "node-place value" model
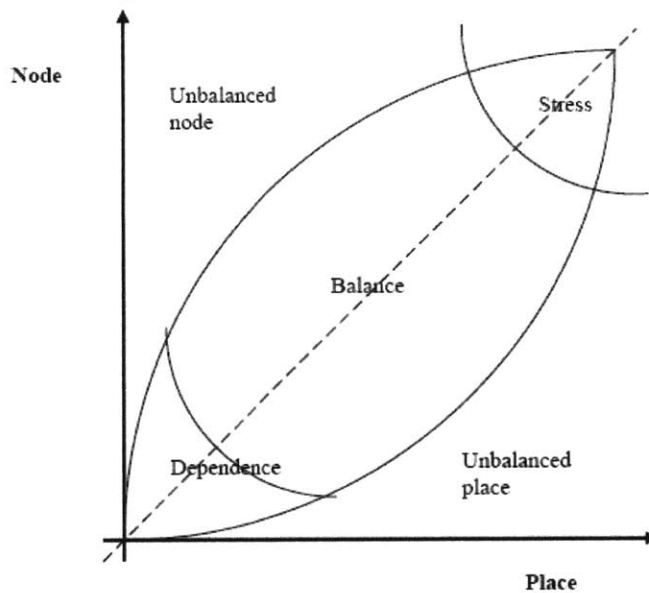
Source: (Bertolini 1999; Bruinsma, Pels et al. 2007)

The underlying idea is that improving transport provision in a location (in the model, its

node-value, the y axis) will, because of improved accessibility, create conditions favorable to the

further intensification and diversification of land uses there. In turn, intensification and

diversification of land uses in a location (or increase in its place-value, the x axis) will, because

of growth in the demand for connections, create conditions favorable to the further development

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of infrastructure there.

Five ideal typical situations are distinguished in the model:

- *Balanced locations* where node and place values are equally strong.

- *Areas under stress* where both node and place values are highest, and there is great chance of conflicts between multiple claims on the limited space where further development might become increasingly problematic.

- *Dependent areas* where the struggle for space is minimal, but the demand for transport service is also low. New development depends on external shocks.

- *Unbalanced nodes* where transportation supply exceeds the actual needs of urban activities (e.g., a newly opened out-of-town railway station).

- *Unbalanced places* where transportation supply does not satisfy the needs of urban activities (e.g., an historic, relatively difficult-to-access urban neighborhood)

Following the "transportation-land-use" feedback cycle, the latter two types show a strong tendency to move towards a more balanced state. Such a tendency is considered an essential factor in the co-evolution of the transportation facility and land use. The "node-place" model provides a useful analytical tool to identify different situations with which a railway station is confronted, but it fails to explain what factors lead to these situations, and how the co-evolution of transport facilities and land use occurs.

6.3.2 The demand-supply model

A limitation of the "node-place" model is that it focuses on describing the outcome of the interaction between the railway station and land-use, while giving little attention to the preconditions that facilitate the convergence of the node values and place values at the station locations. To address this issue, I analyze the conditions for station-area development by

applying urban economics principles. Land development is an economic activity to which the basic market rules apply. In Figure VI-3, I explain the relationships between new development and a set of socio-economic factors. The supply curves (S1, S2) represent land availability, while the demand curves (D1, D2) shows the desire for development on land lots. I model the amount of new land development as a function of the land lot's distance to the city center. I consider a series of factors that may shift the demand and supply curves, for instance, city's rank on urban hierarchy (large vs. small), government involvement and intra-city ground transport, etc.

Figure VI-3 The demand for urban development and availability of land within a city
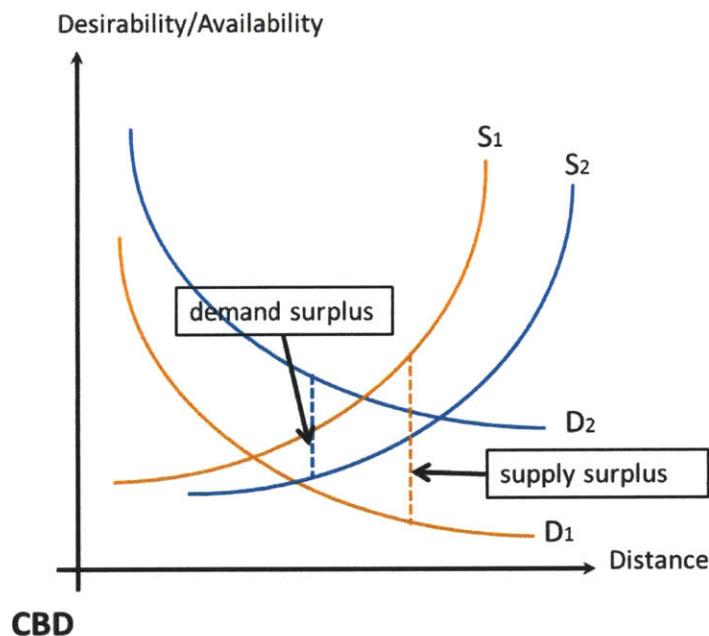
Source: author

Usually, vacant land in large cities is scarcer than in small cities, given the same distance from the downtown. Therefore, I put S2 (land available in a large city) below S1 (land available in a small city). In like manner, the demand for new development is greater in large cities than in small ones, holding the distance to the downtown constant. So D2 lies above D1. In equilibrium, the balanced point in a large city tends to be further away from the downtown than that in a

smaller city. Besides the size of city, many other factors can potentially shift the demand and supply curves. For instance, stronger involvement of local government and extensive public spending can shift both demand and supply curves upwards. Intra-city transport also makes a difference. Improvement in intra-city transport will shift the demand curve upwards, as if the distance to the city center were shortened.

In theory, a possible balance could be achieved when the demand for urban development meets the availability of land at the HSR station area. However, in reality there are often unbalanced situations: either demand surplus or supply surplus. Demand surplus is commonly found in megacities, where land in the proximity to HSR stations has already been surrounded by densely urbanized areas. A typical example is Shanghai South Station (Figure VI-4, left). The cost of redevelopment is high in the area around these HSR stations, so it may not be easy to observe significant changes in land use over a short period.

Figure VI-4 Demand surplus (left: Shanghai) and supply surplus (right: Yangquan)

Source: Google maps.

Supply surplus is normally found in small cities, especially when the HSR stations are located miles away from the existing urban centers. An extreme case is the HSR station in Yangquan city, Shanxi province, which is about 50 km from the city center (Figure IV-4, right). The HSR shortens the travel time from Yangquan to the provincial capital from one hour to 30

minutes, but it takes an hour's drive from the city center to get to the HSR station. The HSR station was built in a remote rural area, and the new HSR station area may remain isolated from the city center for a very long time if not forever. In addition, the remoteness from the downtown exerts strong negative impacts on HSR ridership, which cuts into the "node value" of the station.

6.4   Influential factors and prototypes of station area development

As indicated by existing case studies, a variety of influential factors jointly shaped the development potential of the HSR station area. Some of the factors are city-specific and others are particular to the HSR stations. In addition, the land use conditions and future land use plans near HSR stations also make a huge difference. Below I identify ten key factors that could potentially influence HSR station area development and assess the readiness for development of the stations on Wuhan-Guanghzou HSR accordingly. Some of the factors influence the demand for station area development while others exert impacts on the supply side. For a quick comparison, I use a darker color to represent favorable condition and a lighter color for the opposite. Black shade means the particular standard is not applicable (Table VI-2).

Table VI-2 Influential factors of station area development

Groups	Factors	Wuhan	Xianning	Yueyang	Changsha	Zhuzhou	Hengyang	Chenzhou	Shaoguan	Qingyuan	Guangzhou
City-specific	Rank on urban hierarchy										
	Configuration of urbanized area										
	Proximity to upper-level city(3rd-tier city only)										
Station-specific	Proximity to downtown										
	Proximity to edge of urbanized area										
	Local public transport connections										
	Passenger flow										
Areas around station	Free of geographical constraints										
	Easiness of land acquisition and redevelopment										
	Planning prioritization										

City-specific features

First, the rank of an HSR city in the hierarchical urban system determines its general economic strength thus has a major impact on the scale of demand for land development. It also determines whether the demand comes from within the city or from external sources. For major cities, the driving force for urban development arises from internal needs, whereas for minor cities, the desire for new development may also come from an upper-level city. Second, urban configuration may potentially influence the possibility of concentrated development around the HSR station area. For polycentric cities with a continuous urbanized area, chances may be higher for the emergence of new sub-centers. The selected HSR cities differ in the configuration of existing urbanized areas. For instance, Yueyang expands in a compact, monocentric way. In contrast, Guangzhou, Wuhan and Changsha have a continuous urbanized area with multiple sub-centers. Other cities grow in a more dispersed pattern, expanding along trunk roads and often have discontinuous urbanized areas. Further, for third-tier cities, the distance to upper-level cities determines the opportunity of economic interaction with them. Being close to a major city is not only associated with business opportunities via HSR trips, but also the possibility partly to accommodate urban functions of a major city that grows crowded and seeks structural optimization of land uses.

Station-specific features

The distance from the HSR station to downtown measures its potential intensity of interaction with the existing urban center. All the stations on the Wuhan-Guangzhou HSR are built in a separate location from the regular railway stations in downtown. In the three major cities as well as Hengyang, HSR stations are 15-20 km from the city center, while in other cities the distances range around10 km. Proximity to the edge of urbanized areas is another indicator of

the station's spatial relationship to the existing urban center. It is often easier to initiate new projects at locations close to an urbanized area because urbanization tends to occurs in a continual way, given the scale of economies in the provision of infrastructure and facilities. Furthermore, the local public transport connection determines the time-distance from HSR stations to the destinations in the city. Based on my field observations, all the ten HSR stations offer taxies and buses, though the service quality and frequency vary a lot. Wuhan, Changsha and Guangzhou stations have subway lines in operation or under construction. Wuhan, Yueyang and Zhuzhou HSR stations also provide coach bus service from/to adjacent counties. Finally, passenger flow is a reasonable reference to estimate the size of the market that the station-area development serves.

Land-use status and plans

First, geographical conditions, such as water bodies and hilly terrain, may impose constraints on future urban development. Only in Xianning, Zhuzhou and Guangzhou are HSR stations located on a flat terrain. In other cities the station areas are more or less subject to natural constraints. For example, in Chenzhou and Qingyuan, the stations are located at the foot of mountains thus have limited room for new development. Second, the costs of land acquisition also influence the supply of land. Easiness of land acquisition depends on the current land use conditions. The land acquisition fee increases with the intensity of existing land use. In Wuhan, the HSR station is surrounded by a major steel plant and the cost for redevelopment is higher than new development on farm land. In Guangzhou, the compensation standards for resettlement have already been pushed very high, which may slow the process of new urban development. Finally, whether or not the station area is planned as a prioritized development zone is critical. Sitting on the major direction of further urban expansion significantly increases the opportunity

of new development.

Applying these criteria gives three potential prototypes of station area development ranked by development potential. The first type is a specialized sub-center of business and trading, featured by the clustering of high-end services firms and other activities that require faster travel and benefit from mass passenger flows. I name the second type the backyard of the adjacent megacity. Unlike the first type, the driving force of urban development primarily comes from the next-door megacity rather than the home city where the HSR station is located. This type of station area development is characteristic of land use patterns complimentary to the megacity, ranging from recreational housing to manufacturing land uses. The third type I call "a transport hub and urban gateway". This type of station areas are not endowed with as many development opportunities as the first two, either due to insufficient demand or land-supply constraints. Large scale urban land development is less likely to take place but they could still serve as a gateway to improve urban image if properly planned and managed. Further development may focus on improving local transport connections and improvement of public transit service. It is important to note that the three prototypes of station area development are not mutually exclusive, allowing for certain degree of overlap. I propose the three prototypes to highlight the outstanding characteristics of each and for the convenience of analysis. Even though the potential for development exists, the presence of HSR does not automatically guarantee new development.

Prototypes	Demand for urban development	Potential of development	Cases
Sub-center of business and trading	Internal/external	High	Changsha, Wuhan, Guangzhou
Backyard of the adjacent megacity	External	Medium	Xianning, Zhuzhou, Yueyang, Qingyuan
Transport hub and urban gateway	External	Medium to low	Hengyang, Chenzhou, Shaoguan

6.5   Case studies

In this section, I analyze typical cases for each of the three prototypes of station-area development. I focus on the strategies and actions taken by public and private sectors to foster land development around the station, and the specific institutional arrangement that has been established to allocate responsibility and resources among different stakeholders.

6.5.1   Changsha South: an emerging sub-center of business and trading

An HSR Station area of this type has the potential to evolve towards a sub-center of business and trading that attracts part of the high-end urban services from the existing downtown. The HSR stations in Guangzhou, Changsha and Wuhan belong to this category but the actual possibility for new development varies. I choose to analyze the Changsha South station, which I consider to have greater opportunity of success given the combination of sufficient demand for urban development and matching supply of land. In addition, the area around Changsha South station is where the earliest new development projects broke ground, which itself is an indicator of greater development potential.

Location and land-use conditions

In a regional context, Changsha South Station is located at the intersection of two major HSR lines: the north-south Wuhan-Guangzhou HSR (in operation since 2009) and the west-east Shanghai-Kunming HSR (to be opened in 2014). It takes only 1.5 hours from Changsha to Wuhan and 2.5 hours to Guangzhou by HSR. Upon the operation of the Shanghai-Kunming HSR, the travel time between Changsha and Shanghai is estimated to be 3.5 hours. Within the city, Changsha South Station is located at the southeast outskirts of the urbanized area, about 15 km's path distance from the downtown and takes 30 minutes' drive to reach (Figure VI-5). There are eight bus lines connecting the HSR station with the downtown, the regular railway station and

several coach bus stations that provide connecting service to adjacent counties. In addition, one subway line is under construction and another has been planned to connect the HSR station with other major destinations and transport hubs in Changsha. At the time of my field trip in June 2011, land lots to the north side of the station are occupied by local farmers' self-constructed, single-story buildings. They are either low-quality housing, low-end business (e.g., grocery stores, restaurants, and motels) or cottage factories (e.g., car repairing and accessory manufacturing). Land parcels to the south side of the station remain undeveloped, covered by farmlands and woods. Trunk roads and other urban municipal facilities are under construction.

Figure VI-5 Location of Changsha South station in the city
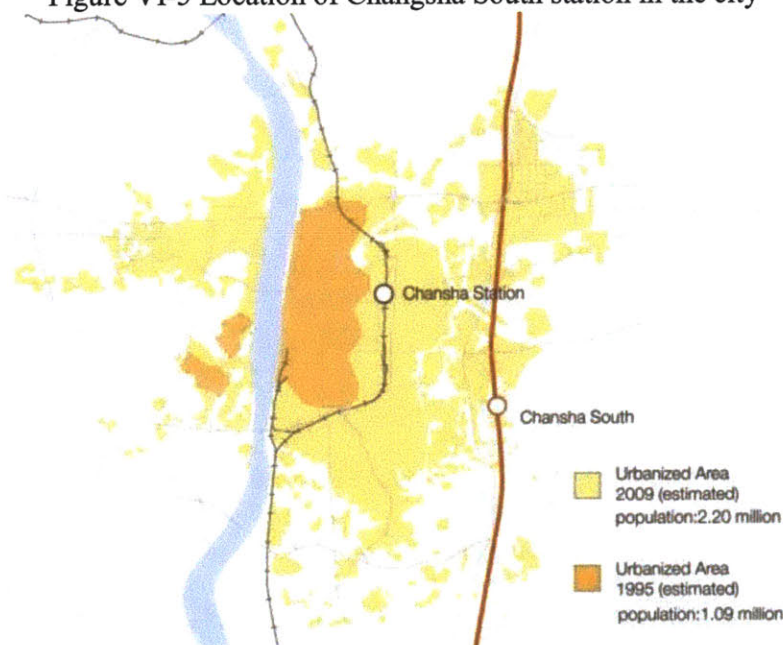
Source: Andrew Salzberg, World Bank 2011.

Government actions

Government officials in Changsha have been active in taking advantage of the HSR-related opportunities for new development. They prioritize the HSR station area for development in the recent version of the city's master plan, by proposing an HSR New Town and holding frequent investment promotion events in megacities.

The planning authority of Changsha revised the city master plan to prioritize the HSR station area for future development. The spatial outlay of Chinese cities is often subject to strong planning intervention. Locations that are prioritized for future development receive fiscal support and favorable land use policy from the government to encourage new development. In an earlier version of the urban spatial structure plan (2001), the main body of Changsha city was defined as an axis connecting the downtown with two auxiliary centers, one to the west and the other to the east. They are the Hexi New Town and Xingma Cluster, respectively. Further development is planned along both sides of the Xiang River. The 2011 city master plan maintained the original structure of the city's major urbanized area but added another axis of future economic development to the southern part of the city, which goes directly through the HSR station area.

Planning authorities not only prioritize the HSR station area development on a strategic level, but also strengthen the feasibility of implementation by proposing an HSR New Town. The proposed New Town is located in *Lituo* Township of *Yuhua* District, between the national expressway G4 and the *Liuyang* River (Figure VI-6). It covers a total area of 18.92 square kilometers, at the core of which will be a business district of three square kilometers. The planning authority listed various projects in the portfolio of investment, including office buildings, hotels, a trading center, department stores, underground shopping malls, pedestrian streets, a waterfront park, and high-grade apartments. Currently, the national expressway G4 separates the HSR station site from the main urban area. The local government has approved a reconstruction plan to put this section of G4 expressway underground, to remove the physical barrier separating the HSR New Town from the existing urban center and facilitate integration between them.

Figure VI-6 Land use plan for the HSR fortune Town at Changsha South Station
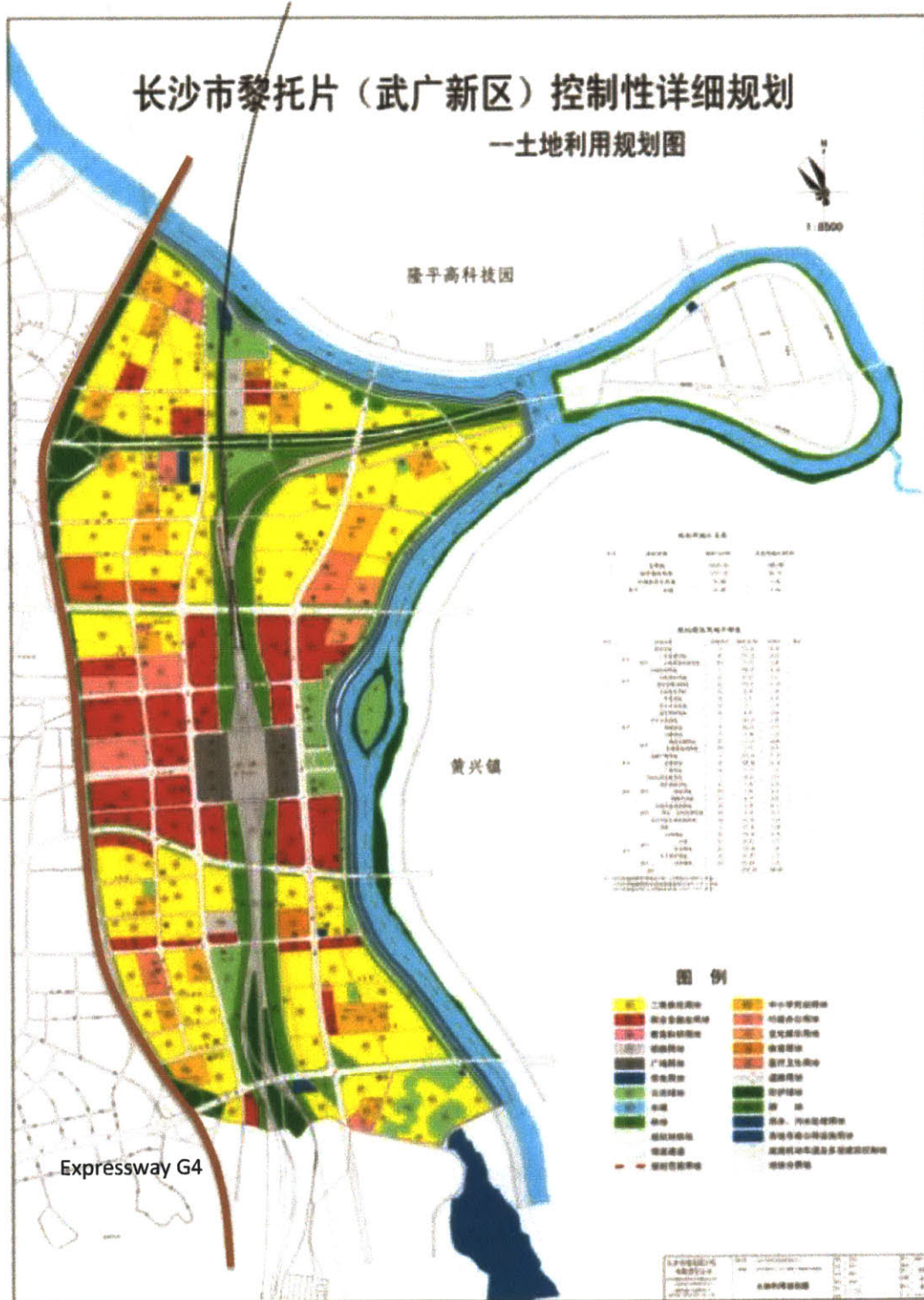
Source: The Planning Bureau of Changsha.

The municipal government of Changsha has made a huge effort to attract external investment, due to the limited local fiscal resources that may be allocated to the construction of the HSR New Town. A specific institutional arrangement has been set up for business promotion. A government-backed company, Changsha Rail Transit Group, is in charge of attracting external investments. At an early stage, this company was also responsible for land acquisition and cleanup, but later on this part of obligation was transferred to Land Reserve Center under the Land Resource Bureau. From 2009 to 2012, the Changsha Rail Transit Group and the government of Yuhua district jointly held four fundraising and investment promotion events in Shanghai, Shenzhen and Hangzhou (Table VI-3).

Table VI-3 Fundraising and investment promotion events held for the HSR New Town

Time	City	Value of contracts (Billion RMB)	Portfolio of projects
9/2009	Hangzhou	12	Housing projects, a press group headquarters, a jewelry exhibition and a shopping mall
07/2010	Shanghai	15	An urban complex integrating transport, business and recreation activities, and a high-end shopping mall
10/2011	Shenzhen	6.9	A business and trading center
04/2012	Shanghai	29.6	First-class office buildings, headquarters, high-end department stores and shopping mall, recreation center and high-quality residential communities

Source: Official site of *Yuhua* Government, Changsha Xingchen News online

These investment promotion events are reported to be fruitful. Local officials in Changsha make an analogy between the Changsha HSR New Town and the *Pudong* New District in Shanghai, which has been seen as a successful sub-center of business and trading. The agendas of these investment promotion events illustrate that the local government of Changsha has a very high expectation for the HSR New Town. Despite the high expectations, it will take years to build up a brand new business center from scratch. Over the long construction term, the fulfillment of the investment contracts is subject to fluctuations in the capital market. The

success of the HSR New Town also relies on concrete investment schemes and detailed construction plans that are yet to be developed.

Private sector involvement

In contrast to the aggressive plans of the government, the private sector is more cautious in making investment decisions. When I conducted the field trip to the station area in June 2011, there were only two residential projects under construction (Figure VI-7).Later in July 2012, a third residential project with total floor area of 1.8 million square meters, Jingtou Global Village was initiated. The ongoing real estate projects share several features in common: (1) invested in by non-local developers that have multiple branches across the country, (2) developed at high density; (3) are the first phase of mixed-use urban development projects and (4) are located to the north end of the planned HSR New Town, where there is good access to the existing city center and the airport. Most urban service facilities are not yet in place and currently these projects are isolated modern communities in a rural context (Figure VI-7).

Figure VI-7 Xinhuadu Wanjiacheng (left) and Evergrande Lvzhou right)

Source: Photos taken by author in June 2011.

The influence of HSR station on urban development reaches beyond the border of the planned New Town. There are dozens of housing projects clustering in the three blocks to the western side of the G4 expressway, between HSR station and the downtown. Most of them have

been newly started during 2009-2011. Among them there are low-density residential projects as well as a huge commercial complex. Even though these projects are not officially located within the border of the planned HSR New Town, developers are using the HSR as a marketing strategy in promoting sales. Most projects are located within 3 km's radius of the HSR station, within about a 10 minutes' drive from the station.

To the developers HSR is one of the many factors that influence site selection of development projects. Land parcels that are closer to the current city center are more favorable to them, especially at an early stage of the New Town development. Besides, access to other transport facilities adds attractiveness. This trend can be identified from the fact that the earliest development happened in the northwest corner of the planned New Town, where both favorable conditions are met. According to my observation, residential projects are the pioneers among all development types, because of a shorter construction period and less risk associated with uncertainty in the market. Commercial buildings only emerge as the total number of residences in the area reaches a certain threshold. They usually take a longer time to build and to attract sufficient tenants, therefore are subject to higher financial risk than non-commercial buildings.

The market shows a positive feedback on the concept of HSR real properties. According to my investigation with local residents and real estate agencies, most residential properties are sold out even before they are put into use. The transaction prices for housing units that belong to the same project are always rising at a faster speed than average. For instance, the unit price of the *Evergrande Lvzhou* apartment was 6,000 yuan/m^2 in January 2010 when it was first opened to market, and the price has reached 8,000 yuan/m^2 as of July 2011, an increase of 25%. During the same period, the average appreciation in housing price in Changsha is about 8%[12]. People are buying these HSR properties mainly for the purpose of investment rather than for living. Among

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[12] This is estimation by local real estate brokers I talked to in Changsha.

them, there are a significant proportion of non-local buyers, who enter the market for speculation

opportunities.

A government-led mode

The Local government of Changsha has been playing a dominant role in the urban

development process around the HSR station (Figure VI-8).

Figure VI-8 The government-led mode of HSR station area development

Involved Agent	Development process

```
                              ┌──────────────────────┐
         ┌──────────────────┐ │   City Master Plan   │
         │ Planning Authority│──▶│ The HSR New Town Plan│
         └──────────────────┘ │    Urban design      │
                              └──────────────────────┘
                                         │
         ┌──────────────────┐ ┌──────────────────────┐
         │Land Resource Authority│ │  Land supply quota  │
         ├──────────────────┤ │  Land acquisition    │
         │Land Reserve Center│ │ Utility/road construction│
         └──────────────────┘ └──────────────────────┘
                                         │
         ┌──────────────────┐ ┌──────────────────────┐
         │ Rail Transit Group│ │    Fund raising      │
         ├──────────────────┤ │  Business promotion  │
         │District Government│ └──────────────────────┘
         └──────────────────┘
```

Public sector

Land concession fee and taxes

Land supply and policy support

Private sector

Planning Authority

City Master Plan
The HSR New Town Plan
Urban design

Land Resource Authority
Land Reserve Center

Land supply quota
Land acquisition
Utility/road construction

Rail Transit Group
District Government

Fund raising
Business promotion

Developer
Entrepreneurial investor

Real estate project

Business / trading activities

Residents

Housing   Urban services

This government-lead development mode is a proper choice when the expected station

area development takes place on a large and over a long period of time. It requires high capacity

of local government and sufficient administrative resources. The high capacity of local

government is a result of effective coordination horizontally among different professional authorities and vertically among different levels of government. In the case of Changsha, the regulatory role of government is strong in that it manages an integrated plan for the HSR station area and introduced investment and development projects that fit well with the overall agenda.

Following this type of HSR station area development, the growing demand of an expanding urban economy for new development is sufficient to support the formation of sub-centers. The HSR station area stands out as a clustering location for urban economic activities that requires fast and convenient connections with other cities. A key challenge is to avoid rat race among different potential sub-centers. In Changsha, even though the plan of an HSR New Town sounds very promising, there are several other planned New Towns on the outskirts of the city, which may lead to repeated investment and unnecessary competition. For instance, the government planned a New Town around the *Huanghua* Airport, and another one at the new site of the provincial government. These New Towns have very similar portfolios of urban development projects due to lack of interdepartmental coordination. The local government should develop diversified strategies for each of the sub-centers.

6.5.2 *Xianning North: the backyard of the adjacent megacity*

The second type of development takes place when HSR stations are located in third-tier cities, and the main driving force of station area development comes from the adjacent megacity. Being different from the first type of station area development, this backyard-style development is primarily a result of economic integration with the adjacent megacity, the success of which depends not so much on the strength of the local economy. Urban development is likely to occur when the following conditions are met: (1) the third-tier city is within 30 minutes' commuting distance of the megacity; (2) it is rich in resources that are scarce in the megacity, such as, good

environment quality, cheap land or unique recreational resource; (3) its industrial structure and urban functions are supplementary to that of the megacity. The HSR station areas in Xianning, Zhuzhou, Yueyang and Qingyuan generally belong to this category. During my field trip I found that the HSR station area in Xianning fits best with the three conditions: it is 24 minutes away from the provincial capital Wuhan and well known for its beautiful living environment and hot spring resorts. In addition, local authorities of Xianning have been eager to accommodate manufacturing plants that are moving out of the megacities, especially those in the IT and biotech industries. For these reasons, I use the Xianning North station for the analysis of the second type of station area development.

Location and land-use conditions

Xianning North station is the second stop on the HSR that departs from Wuhan. With HSR, it takes 25 minutes to reach the provincial capital Wuhan, 55 minutes to Changsha and 3.1 hours to Guangzhou, according to the 2010 train schedule. The HSR station is located on the north edge of the urbanized area of Xianning, about 10 km's route distance from the city hall. The Wuhan-Guangzhou HSR passes by the city at its northwest fringe. The conventional rail runs in parallel with the HSR but is closer to the city center and cuts through the urbanized area. There is a large freight yard on the regular rail, about 1km to the south of the Xianning North station. The core urbanized area of Xianning follows the shape of outstretched fingers along major roads, the boundary of which is defined by a river and several small hills. To the northeast side of the existing city, the local government has planned a huge industrial park, about half the size of the current urbanized area.

Government actions

In the 2010 version city master plan of Xianning, the planning authority stated that future

urban expansion will give priority to the northeast and north directions. The Wuhan-Guangzhou HSR is considered as the northwest border of the planned urbanized area for the coming decade. The statement implies that in the near term urban development is unlikely to occur beyond the HSR line and the station area development is most likely to be single-sided. According to the arrangement for short-run construction in the city's master plan, the planning authority has identified the HSR station area as one of the three prioritized zones for new development. The HSR station area is expected to become a cluster of mixed urban activities, which the planning authority hopes can contribute to the provision of comprehensive urban services. Even though the planning authority strategically selected the area around Xianning North station as one of the prioritized zones for new development, no concrete plan with implementable details is in place.

The government of Xianning has not proposed any ambitious New Town plan for the station area that I have seen in Changsha and many other HSR cities. A key reason is the unfavorable land use condition in the proximity of the station. The Xianning North station has entrances and exits only to the southeast side of the line, that is, the side facing the urbanized area. Naturally, new development will take place on the southeast side of the station. However, the old regular rail sits between the HSR station and the city center, blocking the opportunities for further development. This specific land use situation leaves a narrow strip of developable land stuck between two railway lines. The local government has proposed a solution to relocate the freight yard northwards to remove barriers to the HSR station area development. However, the implementation of this relocation plan is still pending. The reason is that the regional Railway Bureau of Wuhan is responsible for the management of the freight yard, and the negotiation between the railway bureau and local government is time-consuming. As a result, limited availability of land has discouraged the ambitious development plans at the HSR station.

Instead, local officials at Xianning are more enthusiastic about using the HSR station as a bargaining chip to attract investment to the planned industrial park, the border of which is within 2 km's radius of the HSR station. The business promotion actions have been effective in attracting top companies, including famous brands in food and beverage, textile, IT and energy industries. The establishment of new firms and plants surely will lead to urban development, but not at the heart of the station area.

Private-sector involvement

Despite the unfavorable land-use conditions, urban development still occurs around the Xianning North station, in a different way from what I found in Changsha. In the case of Xianning, the real estate developers play a more active role. New development around the Xianning North station has been processed under a single mixed-use project called *One Future* (壹•未来). This project was financed by Evergreen Real Property Ltd., a joint venture of two major real estate developers from Wuhan. One developer is the Wuhan Urban Development and Investment Company (UDIC), and the other is the Goodwill Group based in Wuhan, which has multiple branches in many other cities all over China.

The One Future project is located between the new HSR line and the regular rail, taking up a total area of 87 hectares. The planned floor areas of all buildings add up to two million square meters upon completion. This project is a mixture of residential, commercial and industrial land uses. The site plan below illustrates the spatial arrangement details of different land uses (Figure IV-9). The land parcel immediately to the western side of the station square has been allocated to a pedestrian-oriented commercial street, which is the first phase development of the whole project. A land parcel on the other side of the station square has been planned as an industrial park to accommodate innovative startups. To the south of the station square are two

business and trading districts filled with high-rise office buildings. The two wings further away are assigned to residential development, though they differ in density and the style of design.

Figure VI-9 The Site plan for *One Future* project at the Xianning North station

Source: brochure of the One Future project

As of my field trip in April 2012, the first phase of development, the commercial street project, was partly built and was put onto the market for sale. It consists of retail shops on the first three floors and compact condominiums on the upper floors. According to a market analysis report released by a local real estate consulting firm, 60% of the first-floor retail shops and 30% of the second- and third-floor shops have been sold. The sales ratio of the condominiums reached as high as 80% as of July 2012.

An all-round developer mode

Unlike the case in Changsha where the local government leads urban development in the HSR station area, in Xianning the local government's influence on station area development is regulatory, without much fiscal or administrative resource directly allocated to the projects. In contrast, real estate developers have been playing a central role, being responsible for financing and construction of all the urban development projects (Figure VI-10).

Figure VI-10 The all-round developer mode of station area development

Involved Agent	Development process

Public sector

Planning Authority → City Master Plan / Zoning regulation / Urban Design

Land Resource Authority → Land supply quota

Land concession fee and taxes

Land supply and policy support

Private sector

Developer → Land acquisition / Utility/road construction / Real estate development / Business promotion

Entrepreneurial investor → Business and trading / Manufacturing

Housing and urban services

Residents

The developer is deeply involved in the process, from land acquisition, raw land development and facility provision, to real estate development and business promotion. This "all-round developer mode" functions well when the total scale of development is manageable under a single portfolio of mixed-use projects. The local government of Xianning is even less financially capable than its counterpart in Changsha. The government solved the issue of financial constraints by entrusting the development to a major real estate developer from Wuhan. The Wuhan-based developer not only brings funds needed to initiate development, but also experiences in managing complex mixed-use urban development projects as well as buyers from Wuhan who trust the brand of the company. This appears to be a win-win solution where the

government receives land concession fees and witness new development, and the developer makes profit from the portfolio of development projects.

Still the station area development is not free from challenges. This backyard-type development is very sensitive to the transport connection with the megacity. During my field trip, a light rail between Wuhan and Xianning was under construction and was scheduled to be in operation in June 2013. Two light rail stations have been planned in the urbanized area of Xianning. These two light rail station locations also have the advantage of convenient access to the provincial capital Wuhan within half an hour, and are probably in an even better position because of higher service frequency and multiple stops at both ends of the light rail. The light rail stations may become competitors in attracting investment from Wuhan in urban development, especially the Xianning East station which is located in the southeast corner of the industrial park and surrounded by large parcels of developable land. Even though the station area development in Xianning is dominated by a real estate developer, the opportunity for new projects still depends on how local government allocates priority among different station sites.

6.5.3 Chenzhou West: The transport hub and urban gateway

The third type of HSR station areas are less favorable locations for urban development compared to the first two. The home city does not generate sufficient demand for a new sub-center, and it is not within the commuting distance of any megacity. In this case, however, it is still possible to initiate urban development projects, but the nature and scale of development is different from the first two types. The priority of development is given to transport-related land uses, and the HSR station area serves as a gateway to show modern urban images to visitors and potential investors. The HSR station areas in Hengyang, Chenzhou and Shaoguan more or less fit into this category. However, the stations in Hengyang and Shaoguan are too far away from the

edge of urbanized areas, and no urban development was taking place when I conducted the field research. Instead, urban development projects are under construction in the area around Chenzhou West station, so I choose it for the analysis of the third type station area development.

Location and land-use conditions

Regionally speaking, Chenzhou West station is at the middle point on the HSR between Changsha and Guangzhou. It takes about 1.3 hours to its provincial capital Changsha and 1.2 hours to Guangzhou via HSR. The north-south HSR line passes by the western side of Chenzhou, with the station located at the southwest corner of the urbanized area. The station is within walking distance to Chenzhou Industry and Technology Park established in the early 2000s. This industrial park is relatively small and is occupied by a major pharmaceutical factory and several other manufacturing plants. It takes 15 minutes' drive from the HSR station to the City Hall at *Wuling Square*, the emerging new urban center and 20 minutes' drive to the old downtown in the northern part of the city. There are two bus lines connecting the HSR station with the old railway station and the City Hall respectively. The station is located in a valley between two hills, with exits and entrances only on the eastern side of the station. In the immediate adjacency of the station (less than 2kms' radius), flat land available for development is very limited as the hilly terrain frames the wedge-shaped narrow land parcels. When the HSR was first in operation, 90% of the station area was covered by woodland, with sporadic farmhouses hidden in it. Only a small proportion of the land at the northeast corner was occupied by factories.

Government actions

In the 2009 version of the city master plan, the Chenzhou planning authority proposed to expand the urbanized area in both south and east directions. In the past few years, the city has relocated economic activities from the old downtown southwards to *Wuling Squre* next to the

city hall. It has become a popular spatial strategy to relocate the government center to new districts in order to induce further development to the targeted areas. The spatial expansion in the southwest indicates that the HSR station area is on the prioritized axis of future development.

The local planning authority has proposed an HSR *Fortune Town* at the station area (Figure VI-11), covering a total area of 5.2 square kilometers. It is expected to host 80,000 people upon completion. The planned HSR Town takes a U shape, because a small hill separates the two parts of developable land parcels. The station area is designed to be a hub for passenger transport and a mixed-use community with business, tourism and high-end residence. The core station area is reserved for transport facilities and office buildings. A coach bus station next to the HSR station has been planned to serve local connecting trips to adjacent counties. The north wing of land is expected to accommodate tourism-related industries, manufacturing and housing. The south wing of land is allocated to recreational facilities and housing.

Due to local government's emphasis on building a transport hub, the connection between HSR and different local transport modes is smoother at Chenzhou West station, compared to other third-tier cities I visited on this HSR line. Parking lots and routes for private cars, taxies and buses are well organized via horizontal and vertical separation. Parking lots for private cars are further away from the station as cars are allowed to access the entrances and exits of the station on the second floor level. Buses and taxis are operating on the ground level closer to the station, with well-designed waiting area to channelize passenger flows (Figure VI-12). Although buses and taxies are available at almost every HSR station I visited, the quality of service varies. At Chenzhou West station, buses arrive with high frequency that significantly reduces waiting time. In addition, taxi service is charged by mileage of trips, while in other HSR cities, taxi drivers refuse to use the taximeter and charge for prices that are 2-3 times higher than normal.

Figure VI-11 Land-use plan for the HSR fortune Town at Chenzhou West Station

武广铁路客运专线郴州站片区控制性详细规划（2009年版）

05　土地使用规划图　　　郴州市城市规划设计院　2009.12

Source: The planning bureau of Chenzhou city.

Figure VI-12 Parking lot for private car (left) and waiting area of taxi (right) at Chenzhou West

Source: photo taken by author in April 2012.

Local development authorities in *Chenzhou* are not as aggressive as their counterparts in *Changsha* in attracting external investment for the HSR town. So far, they have not held any business promotion or fund raising in megacities to attract investment for the station area. The Land Reserve Center under the municipal Land Resource Bureau is in charge of raw land development, including land acquisition, resettlement and construction of roads and urban utilities. It is not yet very clear which agency is financially responsible for the station area development, which differs from the institutional arrangement in either Changsha or Xianning. A non-government organization, Chenzhou Chamber of Commerce, has been marketing a variety of development projects in Dongguan, a major manufacturing city in Guangdong province. The list of key projects they provided shows that a furniture exhibition and trading center and a medium-size hospital are expected to be built in the HSR town. In addition, chain hotels and retail stores are especially welcomed to locate in zones planned for commercial uses.

Private sector involvement

As of the time of my field trip in April 2012, only one residential development project named *Huasheng Century New Town* (华盛世纪新城) was under construction (Figure VI-13). The real estate developer *Husheng Yuefeng* is based in the provincial capital Changsha. The first

phase of development with floor area of 257,214 square meters is sold exclusively to the employees of the local Tobacco Bureau at below a market price. Even so, the first phase of the project was profitable to the developer because the employer will subsidize the gap between the market price and the discounted sales price. In addition, the sales are guaranteed by an upfront contract signed between the developer and the Tobacco Bureau. The strategy to subsidize the buyers not only shifts outwards the demand curve on housing, but also reduces the risk of the uncertainty in the market when the development is at very early stage. According to Mr. Shen, the vice president of *Huasheng*'s branch in Chenzhou, the second phase of development will be commodity housing for market sale. A HongKong-based company, Qianjing Investment Group, has expressed interest in building a mixed-use project consisting of an office building and hotels. The total floor area of this project will be 858,000 square meters, and the investment is estimated to be 0.9 billion RMB.

Figure VI-13 Site plan of Chenzhou Huasheng Century New Town (华盛世纪新城)

The development in Chenzhou West station area follows the government-led mode in Changsha, even though the detailed assignment of responsibility among government divisions is slightly different. The local government of Chenzhou, however, is facing more challenges from

natural constraints on land supply and lower availability of fiscal resources. As a result, local

government is eager to attract external start-up funding. The underlying risk might be

introducing a collection of economic activities bidding high prices but are not compatible with

each other. This is possible especially when the agency in charge of development does not have a

clear vision of the composition of projects. Urban development entails a certain degree of *lock-in*

effects, that is, the construction styles and activity types today determine the land-use pattern

tomorrow. In this case, there needs to be a consistent business promotion plan to make sure that

investment in different projects at each stage of development can generate synergy as much as

possible, rather than leading to conflicts and negative externalities. Land-use types that do not fit

well into the overall quality of development should not be introduced. Fiscal instruments, such as

tax credits and density bonus could be used to regulate the type of development.

6.6   Summary

The first key finding from the case studies is that, for the HSR station to become an

engine of urban development, the demand for new development needs to match the supply of

land at the station location.

Among the demand-related factors listed in Section 6.4, I find that proximity to the edge

of urbanized areas rather than the distance to the downtown--as predicted by existing

literature--to be an essential condition to initiate station area development. All three HSR stations

with urban development projects in process are located at the fringe of the urbanized area. The

underlying reason is that urbanization is often a spatially continuous process. From the

developer's point of view, it is wise to share facilities with the existing urbanized areas due to

increasing return to scale in the provision of urban infrastructure. As to potential buyers, an

isolated development project lacks the atmosphere of urban life and the sense of safety. In

contrast, other factors exert a relatively weaker influence on the opportunity for station area development. Higher rank on the urban hierarchy and proximity to upper-level city in theory increase the probability of new development but fail to bring real change if the station is too far away from the existing urbanized area. The configuration of urbanized areas is not a determinant factor. The three cases I analyzed have different shapes of urbanized areas, from compact monocentric pattern to dispersed expansion along major roads. Proximity to downtown is not that important as predicted by existing literature. Instead, for the first type of development---the sub-center of business and trading, a certain distance from the old urban center is favorable to avoid unnecessary competition. Convenient local transport connection to the station has a favorable impact on HSR ridership, but not necessarily on the development at the core station area. Easy access to the HSR spreads the opportunity of development over a broader space. In an extreme case when all passengers traveling to the HSR cities pass by the station area very quickly, there is little chance for urban development at the station location. Finally, large passenger flow does not guarantee urban development--a typical case is the station area in Hengyang; but a small passenger flow does hamper development as is the case in Qingyuan.

Among the factors shaping supply of land, I find that the route selection procedure of HSR dominated by the railway bureaus with engineering principles often constrains the urban development potential at the station locations. Geographical constraints play an important role. They frame the boarder of HSR station area development, from the river in *Changsha*, the old rail and the freight yard in *Xianning*, to the hills in *Chenzhou*. Cost of land acquisition does not seem to be a vital factor at this moment as most HSR stations are located in undeveloped rural areas. Planning prioritization matters as sitting on the direction of future urban expansion increases the chance of station area development. The prioritized zones not only receive

favorable policy from the government but also enthusiastic investment from developers. But still, planning prioritization will not work if the station is located too far away from the urbanized area. It will take many years to fill in the undeveloped lands in between. This is exactly the case in Hengyang and Shaoguan, where there is little development in process even though there are ambitious New Town plans.

It is worth mentioning that the factors are not static. For instance, the distance to the edge of urbanized area is shortened as the city expands. Therefore, the chance for new development at the station areas is increasing over time. Passenger flow generally increases over time, and the possibility for development goes up accordingly. Economic and social costs of land acquisition will be higher in the future than at present. From this perspective, development may be even harder to initiate if the government and developers do not take action now. As a result, the demand and supply factors determine the possibility of urban development at HSR station, with the potential of station area development changing over time.

Another important finding is that, active involvement of both the public and private sectors is necessary to make the HSR station an engine of urban development, though the role of each party may differ across cities. The development process could be dominated by government, with close cooperation among planning, land resource, transport and business promotion divisions of the local government. This strategy is adopted in Changsha and Chenzhou. An alternative is to have an all-round developer that is involved from very early stage of development, taking a variety of responsibility from infrastructure provision, building construction to business promotion. The development in the station area of Xianning is an application of this mode. No matter which mode is applied, for the success of station area development, the joint efforts of both the public and private sectors are indispensable. Then it

comes to the definition of successful development. The speculative investment using HSR as a marketing strategy to build and sell real property is off the right track of HSR station-area development. The ultimate goal of development should be integrating the new pieces of development as an organic part of the city in which the HSR station is located. To achieve this goal, local development authorities need to promote industrial activities that fit well with the local economic base in parallel with the land development plans.

Government involvement has been considered essential in spurring station area development, particularly in China. A capable local government could simultaneously push up demand and supply of land. On the one hand, the government generates extra demand for land development by introducing business investors from outside the city; on the other hand, it accelerates the supply of land by revising city master plans and land use plans. One major motivation for local government to promote urban development is to increase fiscal income from land concessions. As a result, local authorities tend to augment the supply of land for development. It is worth noting that except for office space, most of the potential land use types are consumption-based rather than production-based, and therefore the profitability of these development projects depends on the purchasing power of local residents. Up to the time when I conducted my field trip in April 2012, the ongoing projects the HSR New Towns are were residential development. No firm has located in the HSR station area yet. It will become increasingly hard to absorb newly built housing in the HSR station area as the market gets saturated. Therefore, the sustainability of the current mode of urban development is questionable. Without economic activities that provide jobs, the New Town plan may end up being just a sleeping town, or even worse, a ghost town, as has occurred in other fast-expanding cities.

I also find that a common challenge in the station area development is to match the

development portfolio with the composition of potential users' needs. To improve the feasibility of the HSR New Town plan and to avoid wasteful construction, planning authorities and developers need to conduct in-depth market surveys to get a clear understanding on the detailed composition of the demand for different types of land uses. It is wise to allocate the land near HSR station to a portfolio of development projects based on the knowledge of the detailed composition of sub-markets. The HSR has changed the transport condition of a city mainly from three perspectives. First, improved accessibility to a megacity brings more inbound and outbound business trips. Second, improved accessibility to adjacent cities leads to integration of labor markets and brings more commuting trips. Third, HSR also induces non-regular trips by making it easier to see tourism sites or visit family and friends in the city it connects. The sub-market consists of several groups of people who make HSR trips at various frequencies and for different purposes, and imposing unique demand for land uses (Figure VI-14).

Figure VI-14 Demand for land use generated by different groups of HSR passengers
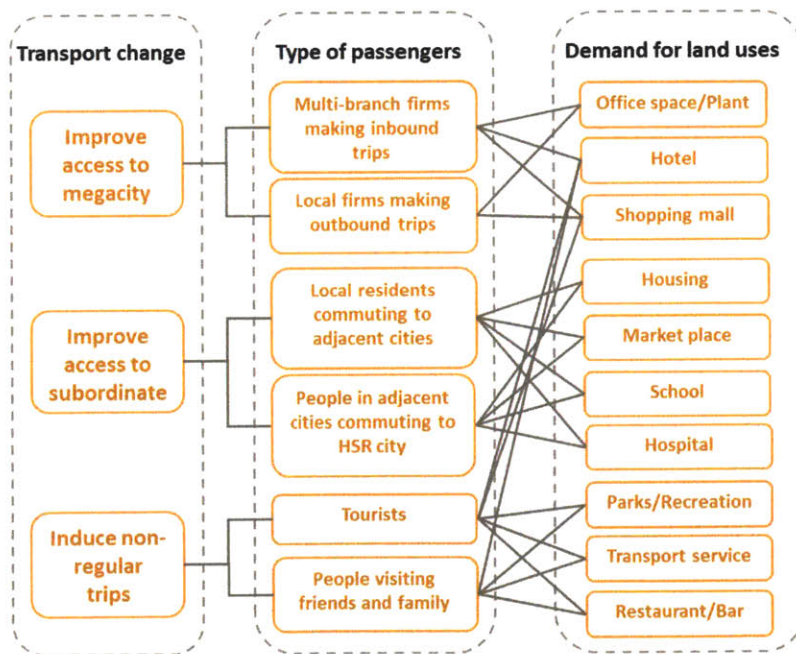
Source: author

To achieve the goal of matching the project portfolio with composition of demand requires further cooperation among different government agencies. In China, the rail passenger data are normally collected by railway bureaus and are seldom shared with local governments. The research institute under the Ministry of Railways has conducted surveys on the composition of passengers by purpose of trips and demographical features. The research by Li (2011) on the Wuhan-Guangzhou HSR is informative for local authorities to develop land-use plans. The chart below shows part of the findings from his survey conducted in December 2010 (Figure VI-15).

Figure VI-15 Percentage of passenger by purpose of trip on Wuhan-Guangzhou HSR
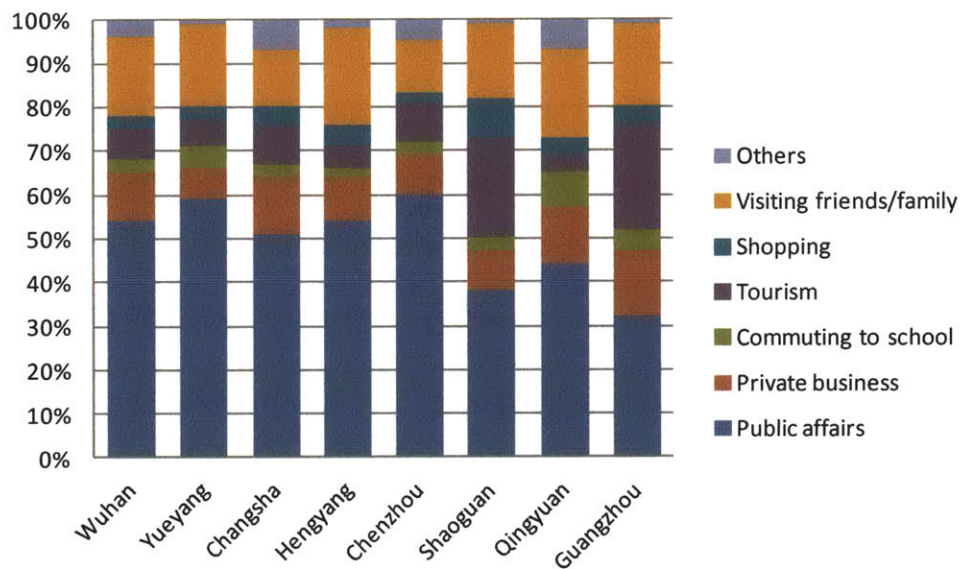
Data source: Li (2011), author revised.

Lastly, under the current framework of institutional arrangement, the possibility of financing HSR projects with profits from land development in the station area is very low. The reasons are as follows: the MOR and its affiliated agencies are responsible for the construction and operation of the HSR lines, but they seldom get involved in the station-area development. Local authorities normally hold about 30% of the equity, or about 15% of total assets, but often

provide land needed for route construction in lieu of monetary investments[13]. Local authorities

initiate station area development and collect revenues from land concessions. Therefore, the

costs incur mostly in the railway department, and the revenues go to local governments.

Currently there is no fiscal scheme to share or transfer funds between the railway bureaus and

local government authorities. In addition, even with an effective transfer scheme, land

concession fees may not be a good source to finance HSR operation because of their one-time,

unsustainable nature. Local authorities need to develop policy instruments to capture the

long-term increment in land value around the HSR station. This is beyond the scope of my study

but leaves opportunity for further research.

In sum, HSR stations introduce external driving force for urban development, in addition

to the intrinsic demand for development from the existing CBD. The station could be considered

as a projection of all other cities' influence that spreads though the HSR network. HSR stations

bring potential opportunities to promote a compact mode of urbanization around the transit

facilities. However, during my field trips, I observed signs of land speculation (e.g., non-local

buyers, high vacancy rate, etc.) in the station-area development. To mitigate the risk of land

speculation and avoid inefficient land concession in the name of HSR station-area development,

there should careful assessment of the scale and composition of demand for development and

phased construction plans to match the changing needs over time.

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[13] According to an personal interview with an MOR official in 2011

Chapter VII CONCLUSION

In this study, I examined the correlation between transport infrastructure, accessibility and urban economic performance, with a tentative assessment of the role of HSR in accessibility of selected cities and their economic and spatial development. This chapter summarizes my main findings, and draws implications for policy-makers in central and local governments. It also discusses the limitations of my study and identifies opportunities for future research.

7.1 Findings

Different from most existing empirical studies in this area, my study does not relate urban economic performance directly to transport investment. Instead, I introduce an intermediate variable, accessibility, which implicitly includes a spatial dimension, and treats transport infrastructure differently from other types of public investment. I conduct the research in two steps: (1) evaluate the impacts of transport investment on intercity accessibility patterns; and (2) identify the influence of accessibility on economic performance at different spatial scales.

7.1.1 From transport investment to accessibility improvement

The relationship between transport investment and accessibility is not self-evident. The improvement in accessibility is not necessarily proportional to the amount of funds allocated to the transport sector. Rather, it depends on the particular type and the location of transport projects, as well as the relationship between new and existing transport facilities.

In China, the central government has adopted a sequenced policy for constructing transport infrastructure. In the first two decades after China's reform and opening (i.e., 1980-2000), coastal regions received the major share of investment in transport infrastructures. After 2000, the central government has channelized huge amount of transport investment to the western and middle regions of China, aiming to close the gaps in intercity accessibility. My

analyses of the evolution of accessibility patterns indicate that:

- The shift in transport investment strategy was effective in reducing disparities in accessibility, and the findings are consistent across different accessibility indices.

- Transport infrastructure's impacts on accessibility differ by type. Airlines greatly distort accessibility patterns on a national level, but its impacts are spatially restricted to a small number of cities at the top of the urban hierarchy. Expressways mainly influence the pattern of local travel within prefectures. HSR primarily reshapes connectivity at a regional level, which dominates the economic interaction among prefectures at the lower tiers of urban hierarchy.

- HSRs that brought fundamental improvement in accessibility share two features: (1) building connections between megacities and lower-tier cities instead of among a cohort of lower-tier cities; (2) adding new fast travel options to cities that are not conveniently reachable instead of introducing overheated competition with existing modes. Typical examples are the Wuhan-Guangzhou HSR and the coastal HSR.

- HSR has a potential to dominate the niche market for medium-to-long distance travel of 300-1000 km. The centroids of major urban clusters are about a thousand kilometer from those of their closest neighbors. As a result, HSR is potentially a suitable transport option to enhance economic integration within the urban cluster as well as to facilitate cooperation among different urban clusters.

7.1.2 From accessibility improvement to economic performance

Recent development in information technology, characterized by the prevalence of personal computers and internet access, has cast doubt on the importance of geographical locations and transport costs in shaping economic landscapes. Friedman (2005) argued that "*The*

World is Flat" as globalization has removed major barriers to international trade and inter-region cooperation in production, and put individuals and countries on a level playing field. Florida (2005) raised exactly the opposite argument saying "*The World is Spiky*". He shows how much economic activities still cluster selectively and exclusively in favorable locations by mapping the distribution of population, light emissions and innovation.

As part of the debate over the divergence versus convergence of locational advantages, it has long been argued that the invisible force that ties up economic activities at urban locations are the agglomeration benefits. Glaeser (2011) considers the city as the greatest invention of human civilization and claims the "*Triumph of Cities*" over other locations in generating economic prosperity. In this research I follow the assumption regarding the importance of agglomeration, yet I extend the scope of agglomeration to include the excess to external production factors. Agglomeration economies emerge not only when production factors cluster within a city but also when they are able to transfer smoothly among urban locations. In other words, a city's access to external production factors is partially substitutable for its own resource endowment, even though these two sources of economic growth are not exactly interchangeable regarding reliability and quality.

Network analyses

My network-level analyses examine the correlation between a city's access to external production factors and its own urban economic performance, focusing on two major inquiries: (1) whether the economies/diseconomies associated with accessibility are generative or redistributive; and (2) whether the agglomeration effects diminish as accessibility level increases.

(1) Generative vs. Redistributive

I illustrate that the influence of intercity accessibility on urban economic performance

consists of both generative and redistributive components.

- The positive correlation between productivity and accessibility indicates a generative nature, as cities, on average, witness a rise in wage rates with improved accessibility in inland regions. Given that the most significant accessibility improvement also occurred in the inland regions, these findings imply a closing gap in productivity between the developed coastal region and lagging inland regions.

- The impacts of accessibility improvement on employment and capital investments are mostly redistributive. The impact on employment is divergent, because accessibility improvement attracts more workers to large cities, particularly to the private sectors. However, the impact on FDI is likely to lead to convergent outcomes, because Middle China becomes a favorable destination for investments.

- Accessibility's influence on the employment of the high-end service sector is generative and remarkable. The employment of IT and finance industries shows positive correlation with accessibility but such correlation is not stable, varying across regions and city sizes.

- No evidence supports the argument that accessibility improvement leads to prosperity in real estate market. On the contrary, I identified negative correlation between property price/amount of real estate development and accessibility.

- The tourism industry shows strong positive correlation with accessibility. The accessibility-related prosperity in the tourism industry is of a generative nature because most subgroups of cities are benefited.

(2) Saturation effects

Empirical evidence does not show a diminishing trend in the elasticity of urban economic

performance with respect to the level of accessibility.

- The correlations between wage rate, IT and finance sector employment, FDI, tourism revenue and accessibility are positive and stable across different levels of accessibility.

- The negative correlation between population, employment and accessibility only exists in the medium to high accessibility groups.

Corridor analyses

The corridor analyses indicate that HSR has significant impacts on travel patterns. The shift in travel patterns is associated with a restructuring of the regional urban hierarchy and relocation of economic activities along a transport corridor.

- The Wuhan-Guangzhou HSR has significantly improved the competitiveness of the railway sector against alternative transport modes along this specific transport corridor. The most remarkable growth has occurred in inter-provincial trips.

- The time-space along the Wuhan-Guangzhou transport corridor has shrunk significantly after the introduction of the HSR. Yet, the impacts on the regional urban hierarchy are mixed: on the one hand, the existing urban hierarchy has been strengthened by increasing passenger flows between major cities and their subordinates; on the other hand, the urban hierarchy is evolving towards a more interwoven structure, in which higher-tier cities reach for overlapped subodinates and lower-tier cities obtain exposure to the influences from multiple megacities.

- HSR's impacts on different aspects of economic performance vary in terms of time horizon and spatial coverage. In the short run, I identify changes in real estate development, tourism and inter-regional industrial transfer.

- Third-tier cities with HSR connections have become favorable locations to external real estate developers and the new development are mostly clustered at locations with convenient access to the HSR station.

- In contrast, the HSR has brought more wide-spread benefits to tourism not restricted to HSR cities. Non-HSR cities are able to partly share the time savings because travelers make connections at the HSR cities. Moreover, HSR has also introduced passengers with higher purchasing power and changed the internal structure of tourism markets.

- The expected correlation between HSR and inter-regional industrial transfer is less tenable. My analyses find that the extraordinarily favorable policy incentives and the existence of export processing zone (EPZ) could be more important determinants of industrial transfer. Yet, HSR could improve the management efficiency of multi-branch firms by saving travel time between the headquarters and the manufacturing plants.

- Within the group of HSR-connected cities, HSR's impacts on economic performance vary by the city's rank in the urban hierarchy and its location on the HSR line. Third-tier cities next to a megacity seem to experience greater changes in the examined economic activities than elsewhere.

Node/city analyses

The node/city analyses focus on HSR's impacts on the immobile factor--land. I find that for HSR stations to become an engine of urban development, the demand for new development need to match the supply of land at the station location. I identified ten city-specific, station-specific and land condition factors that jointly determine the demand and supply of land

in the HSR station area.

- Cluster analysis of key factors generates three prototypes of station area urban development: (1) the sub-center of business and trading, (2) the backyard of the adjacent megacity, and (3) the transport hub as an urban gateway. The driving forces and potential for urban development vary among these three prototypes.

- Active involvement of both the public and private sectors is necessary to make the HSR station an engine of urban development, even though the institutional arrangements and the role of each party may differ across cities.

- Proximity to the edge of an existing urbanized area is essential to make station area development possible among other demand-related factors, and geographical constraints play an important role in determining the supply of land.

- A common challenge in the HSR station area development is to match the development portfolio with the composition of potential users' needs. To complete this task requires further cooperation among different government agencies.

- In the current framework of institutional arrangements, the possibility of financing HSR projects with profits from land development in the station area is very low. Institutional reforms that generate revenue sustainably and transfer funds between the national railway department and local governments are needed.

7.2 Policy implications

Based on these findings, I draw key implications for policy-makers in China, with respect to: (1) the investment-led economic growth mode, (2) inclusion of wider economic impacts in the appraisal of transport investment and (3) the future path of urbanization.

7.2.1 Revisiting the investment-led economic growth mode

During the 2000s, China's growth model has become more reliant on investment,which has contributed about one-half of China's GDP growth (Ashvin Ahuja 2012). The expanded contribution of investment to growth in recent years reflects the step increase in infrastructure investment during the 2008-2010 stimulus response to the global financial crisis. Investment as a share of GDP increased by nearly 6 percentage points over this period (relative to pre-crisis), accounting for 48% of GDP growth in 2010 (Figure VII-1).

Figure VII-1 Contributions of investment, export and consumption to China's GDP growth

China GDP: Contributions to Growth
(in percentage points)
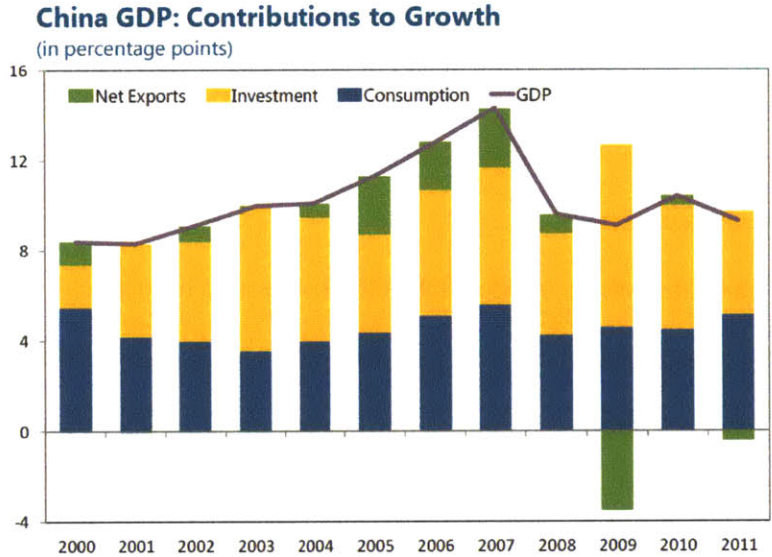
Source: (Ashvin Ahuja 2012)

In the 12th Five-Year Plan for National Economic and Social Development, the central government of China proposed a structrual shift from the investment-led development mode toward a more balanced one, with domestic consumption making a greater contribution than before to GDP growth. However, the proposed structural change does not seem feasible over the short run. As a recent *Wall Street Journal* article pointed out: "For now, the main catalyst for growth is an increase in investment in infrastructure, especially public-transport projects."(Tom Orlik 2012)

To what extent should policy-makers in China be concerned about the investment-led growth model? Economists and scholars have not reach any concensus. In his recent book "New Structure Economics", Justin Lin (2012) arrgues for the necesscity and importance of state-dominated investment in infrastructure:

Physical infrastructure in general is a binding constraint for growth in developing countries, and governments need to play a critical role in providing essential infrastructure to facilitate economic development. [...] Such investments boost short-term demand and promote long-term growth. (Page 30)

Liu (2012) raised an opposite point of view, argueing that in China infrastructure is no longer a bottleneck to economic development; in fact, in some regions, infrastructure has already been overbuilt and under-utilized.

Even though such discussion is around the effectiveness of infrastructure investment in general, the logics apply to transport infrastructure as well. According to my research, with regard to the wider economic impacts on productivity, transport infrastructure investment in China has not reached the level at which marginal contribution from accessiblity to economic performance is diminshing. In other words, saturation effect is not yet a major concern. Differently, Graham (2006) reported that diminishing returns to agglomeration are evident in some industries in the United Kingdom, causing the magnitude of aggolmeration elasticity to dip as effective density (i.e., economic potential) increases. The differences could be explained by the vast disparities in economic development and market segregation among regions in China. When there is a huge gap in economic development and significant diversity in natural and human resource endowment, the benefits from enhanced connectivity and market integration are often expected to be greater (Fujita and Mori 2005).

Based on my analyses, I agree with Lin that China as an entire nation still has not

exhausted the agglomeration benefits and growth potential from investing in infrastructure.

However, regional disparities do exist and such development strategy requires adaption

accordingly. The reliance on infrastructure investment is justifiable to the extent that its marginal

contribution to economic performance is not saturated. From an economic development

perspective, HSR lines connecting coastal megacities with lagging inland cities are effective in

reducing disparities in accessibility and should be encouraged.

Yet it remains a challenging task to allocate funds effectively among transport and other

public infrastructurre, and among different types of transport infrastructure. Huang (2011) found

that the investment in HSR often crowds out other transportation investments according to

international experiences. For project prioritization among different types of transport investment,

analysts need to assess the wider economic impacts that alternative transport investments create

by changing the accessibility among different localities.

7.2.2   Including wider economic impacts in transport project appraisal

The Department of Transport (DFT) in London, U.K., has developed pilot methods to

include the wider economic impacts in transport project appraisal (DFT 2005). Given the

elasticity and changes in accessibility measured by economic potential, they propose to calculate

the agglomeration benefits using the following formula. For simplicity, I use the version from

(Jenkins, Colella et al. 2011), rather than the more complicated original version by DFT.

$$Aggolemration = \{(\frac{d_i^a}{d_i^b})^\rho - 1\} * GDPW_i^b * E_i^b \qquad \textbf{Eq. VII-1}$$

Where d_i^a and d_i^b stand for the economic potential of region i after and before the

improvement of transport infrastructure; ρ is the estimated elasticity of productivity with

respect to economic potential; $GDPW_i^b$ and E_i^b are the per worker GDP (as a measurement of productivity) and employment in region i before the improvement of transport infrastructure.

Jenkins, Colella et al. (2011) pointed out that this formula provides a static picture of agglomeration without considering accessibility's consequential impact on land use. Yet this is not the only limitation of the calculation formula. The underlying assumption of the calculation is that region i only experiences improvement in productivity without changes in the size of labor pool. The second condition, according to my analyses, is seldom met in reality. For a particular city, it often witness qualitative change and quantitative change in production factors at the same time, the influence of which on economic performance may offset each other. For instance, in this research, cities in China mostly experienced enhancement of productivity along with accessibility improvement. However, accessibility improvement is also associated with job losses in most cities, and these two effects partially cancel out each other and leave barely detectable net contribution to GDP or total labor payment. Even with such caveats, this formula is still very useful when applied properly. It is capable of assessing the wider economic impacts to specific industrial sectors that primarily experience generative benefits from accessibility, such as the tourism industry and high-end service sectors.

An important component of transport infrastructure's wider economic impacts is the change of land-use patterns and land values, which is even harder to assess. Despite that analysts could estimate hedonic price models to determine the spatial decay of HSR stations' impacts on land values, it remains unclear which proportion of the benefits could be attributed to the existence of the new transport option. To analyze HSR's impacts on land value requires further research efforts and longer observation periods.

7.2.3 *Reshaping the path of urbanization*

Like other regional transport infrastructure, HSR not only increases the mobility of

production factors, but also exerts impacts on the hierarchy of the urban system and the

configuration of cities. In the coming two decades, the scale and pace of China's urbanization

will continue at an unprecedented rate (Jonathan Woetzel 2009). Meanwhile, transport

infrastructure is a durable asset and its influence on urbanization will last for decades. Such a

lock-in effect is an important factor to consider when making infrastructure investment decisions.

Urban Hierarchy

In the classical paradim of urban hierarchy based on the Central Place Theory by

Christaller (1933), a dominant relationship is established between several orders of the hierarchy.

Transport infrastructure can alter the structure of urban hierarchy by changing the strength of

linkages between different tiers of central places. Pred (1977) adpated the original Christaller

model to accommodate more complex and a less rigorous urban hierarchy by introducing

interdepency and complementary relationships among central places (Figure VII-2).

Interdependency implies that central places can exchange similar goods and services.

Complementarity enables several centers of a similar order to specialize in specific activities and

supply themselves with goods and services they do not have from other centers. Christaller's

model is a better proximiation of the pre-industrialization economy, when regions are relatively

isolated and administrative relationships dominate the urban hierarchy. Pred's model better

explains the post-industrial world with regional transport network in place.

My research illustrates that, HSR contributes to the evolution of urban hiearchy from a

tree-shaped structure towards an interwoven structure, in which higher-tier cities reach for

overlapped subodinates and lower-tier cities obtain exposure to the influences from multiple

megacities, or even merge into them. As this trend goes on, it may eventually raise the need for

adapting administrtative structure to fit the actual structure of economic linkages.

Figure VII-2 Urban hiearchy: Christaller model vs. Pred model
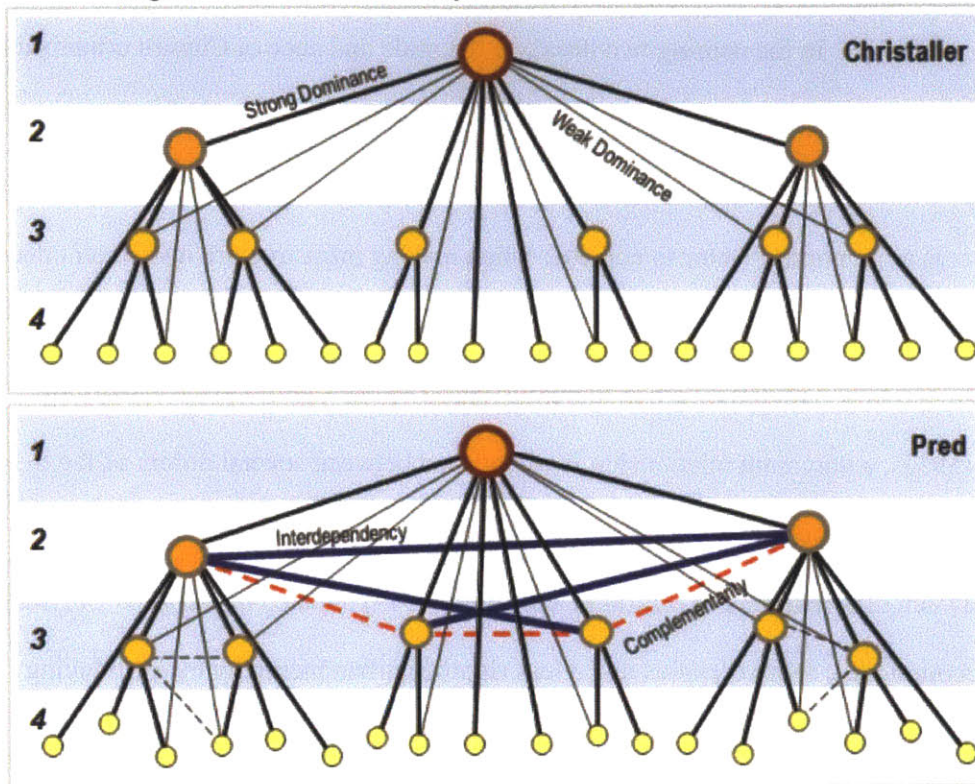
Source: Rodrigue (2013)

Urban configuration

The correlation between different types of transport infrastructure and the urban
configuration is well documented. Empirical evidence from the United States has shown that the
expansion of the highway system is strongly associated with urban sprawl (Baum-Snow 2007;
Wassmer 2008). In contrast, analysts find that a railway-based regional transport network tends
to encourage compact, transit-oriented urban developments around station locations(Amano
1990; Pacione 2009)

My study shows that an HSR station has the potential to grow into a new sub-center of
employment and residence, turning a monocentric city into a polycentric one. This could be a

favorable factor especially when the existing center is suffering from congestion or unregulated urban sprawl. Yet, an HSR station alone does not make a sufficient precondition for urban development to occur. The evolution of land use patterns is the outcome of induced investments from public and private sectors. In this process, HSR serves as a catalyst rather than a real input to the land use changes. But still, HSR stations concentrate people and economic activities in their proximity, and create necessary density and scale of economies for effective urban development. In addition, with HSR it is easier for transport planners to coordinate the inter- and intra-city public transit facilities, and reduce a city's dependence on automobile travel.

7.3   Limitations and future research

Although my resarch extended the empirical studies on the wider economic impacts of major transport infrastructure investment, it is inevitably subject to limitations and the findings need to be interpreted with caution.

Measurement of accessibility

My research uses economic potential based on minimum travel time as a proxy for the strength of economic interaction among cities. Such a measurement has several limitations. First, freight transport is not accounted for because the most direct impacts of HSR occurs in passenger transport market, but in reality the flow of cargo represents an important aspect of intercity economic linkages. However, the data for the costs of freight transport are not available at intercity level for my study period. Second, ideally the travel cost should be an average travel time weighted by the market share of each transport mode. Moreover, it is better to account for the monetary cost by constructing a generalized transport cost.

Exclusion of the lowest-tier urban localities

Another limitation of my research is that the analyses focus on prefecture-and-above

level cities, excluding the lowest-tier urban localities, namely, counties and towns. There are two major reasons for not including counties and towns in the analyses. First, socio-economic data that match with the statistical caliber of cities are not available at county and town level. Second, the travel matrices would become too big to handle with thousands of administrative units, and it is impossible to track the change of travel time among them during the study period.

Using aggregate level data

The spatial unit of data I collected for the econometric analyses is the urbanized areas of prefecture-level cities. This is not necessarily an ideal scope of observation given that data on the aggregate level lose detailed variations. In a similar study, Rice, Venables et al. (2006) used firm-level data, making it possible for more precise estimation of the elasticity of productivity with respect to economic potential.

Short observation period

The case studies at the corridor and node level have a relatively short observation period after the opening of HSR. The reported changes in economic activities and land development are preliminary findings and do not imply any long-term trend. However, for a specific transport corridor where HSR is becoming a dominant travel option, it is reasonable to expect that certain aspects of economic activities could adjust very rapidly, as I reported in my analyses.

Future research opportunities

The limitations of my research also open up opportunities for future research. The first possible direction is to improve the measurement of accessibility by using weighed average travel time among three modes and by including the monetary costs. The generalized travel cost can also be represented by a logsum function of utility measurement, with parameters estimated by discrete choice models. A second potential improvement is to use disaggregate data either by

including lower tier administrative units or by using firm-level observations. The third opportunity for future research is to follow up the medium-to-long term economic impacts along the Wuhan-Guangzhou HSR corridor, and make a comparison with other HSR corridors in China. Finally, the methodological framework could also be applied to conduct ex ante analyses for proposed regional transport infrastructure investment, or to evaluate the impacts of different investment alternatives.

7.4   Concluding remarks

If the construction of the four-vertical-four-horizontal trunk HSR lines is completed as scheduled in 2015, China will have the largest HSR network in the world. Doubtlessly, this will bring changes not only to people's travel patterns, but also to the location choice of economic activities and efficiency of production. It is of great policy significance to evaluate how much China's economy could benefit from the trillion yuan investments. It is equally important to be aware of the potential downsides of regional integration due to accessibility improvement. My research is among the first studies that seek to understand the nature, magnitude and distribution of HSR's spatail economic impacts in a Chinese context.

Even though China has not yet exhausted the potential from investing in transport infrastrucuture, continuing the on-going trend will eventually encounter a saturation point. In addition, the costs of maintaining such a huge transport infrastrucutre stock will augment enormously. The State Council of China has approved unprecedented development plans for expressways and airports in parallel with the contruction of the national HSR system. Unfortunately, these plans have been developed by seperated trasnport ministries without much consideration about the inter modal competition or integration, which very likely will lead to replicated investment and ineffective use of public funds.The good news is that, the State

Council of China has announced a plan for institutional reform in March 2013. A key action is to dismantle the Ministry of Railways (MOR), with its administrative powers and planning obligations incorporated into the Ministry of Transport (MOT) and the National Development and Reform Commission (NDRC) (Xinhua 2013). Such institutional integration may lead to more comprehensive national plans of transport investment than currently exist. The method developed in my research is applicable to assess the potential impacts of proposed transport investment, not necessarily for the HSR system in particular.

Finally, investing in HSR or other regional transport infrastructure is not a purely economic decision. For instance, energy security is also a very important consideration. As a country that is not self-suffcient in fossil fuels, China can not afford the luxury of a automobile-dependent economy as the United States does. HSR is an ideal alternative to expressways as it is powered by electricity. Using electricity is not necessarily environmental friendly or carbon neutral as analysts argued (Álvarez 2010; Chester and Horvath 2010), particularly in China where nearly 80% of electricity is generated from coal. But shifting towards a railway-dominated inter-regional travel mode gives the flexibility of choosing from multiple energy resources, and makes room for future optimization of energy consumption structure.

My study contributes to wise decision-making in emerging economies, by conducting systematic assessment of the wider economic impacts of transport infrastrucutre investments. The findings from my research may also serve as a reference of comparison when similar studies are conducted in different contexts.

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Appendix A MAPS

Figure A-1 Proposed High-Speed Passenger-dedicated Lines in P.R. China (2008 version)

Source: The Medium-to-Long-Range Plan of Railway Development in China, 2008 version

Figure A-2 China's Railway Network 2001

Legend
- ----- Conventional Rail 2001
- Provinces
- Nationbound

Kilometers
0   250   500   1,000
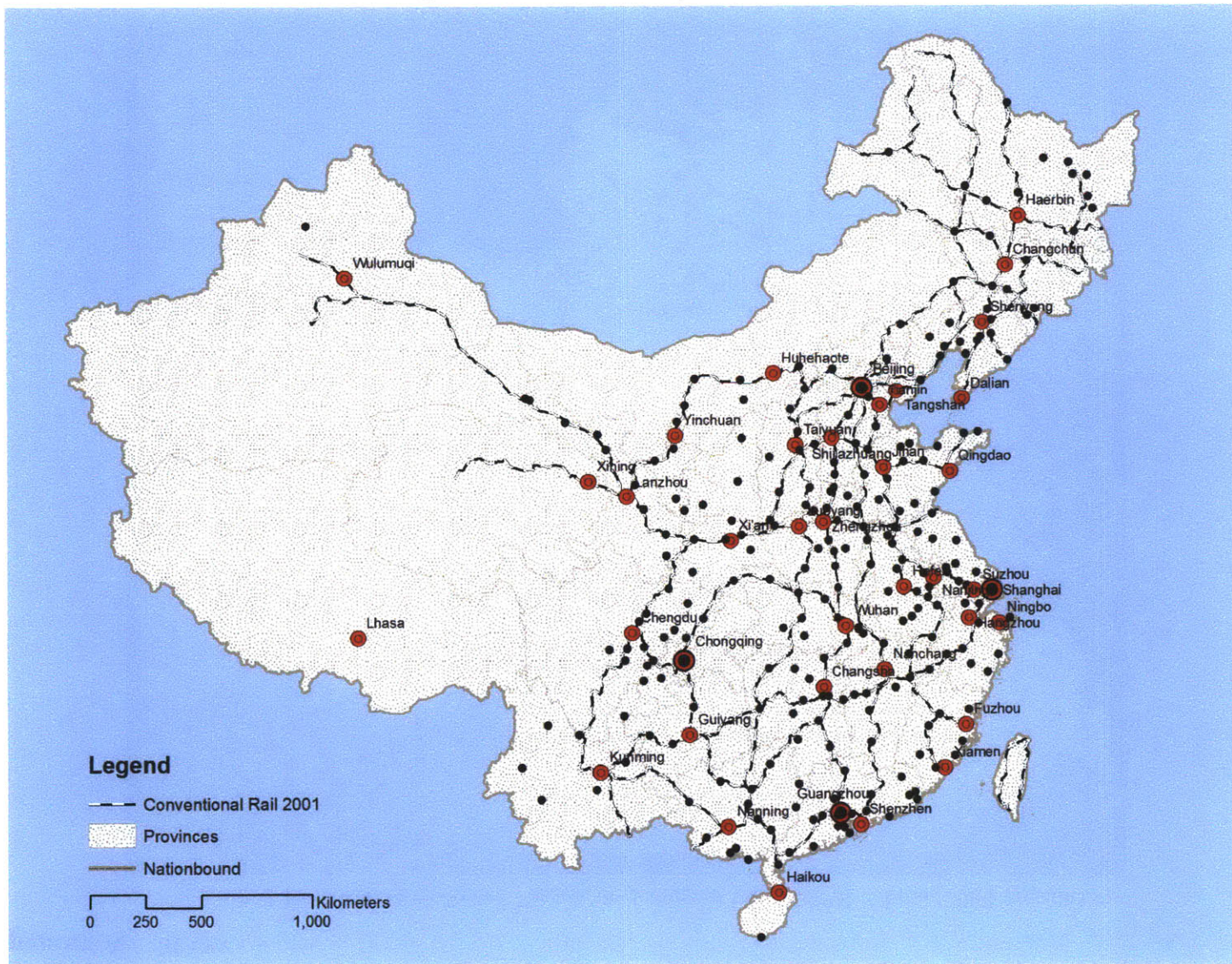
Figure A-3 China's Railway Network 2010
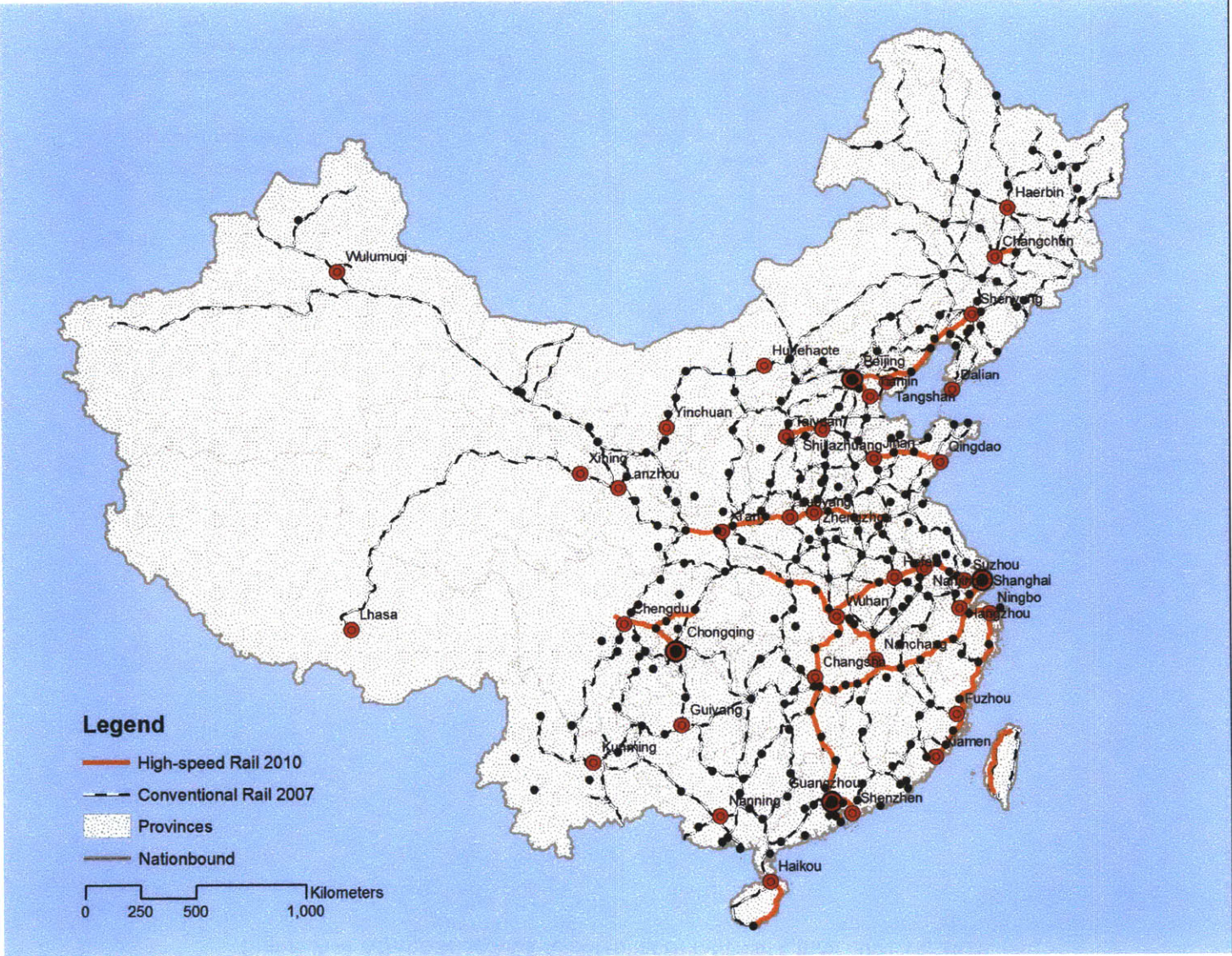
Figure A-4 All-mode economic potential of cities in China 2001 vs. 2010

Legend

—— High-speed Rail 2010

● Economic potential 2001

● Economic potential 2010

Provinces

—— Nationbound

| | | | | Kilometers
0   250   500   1,000
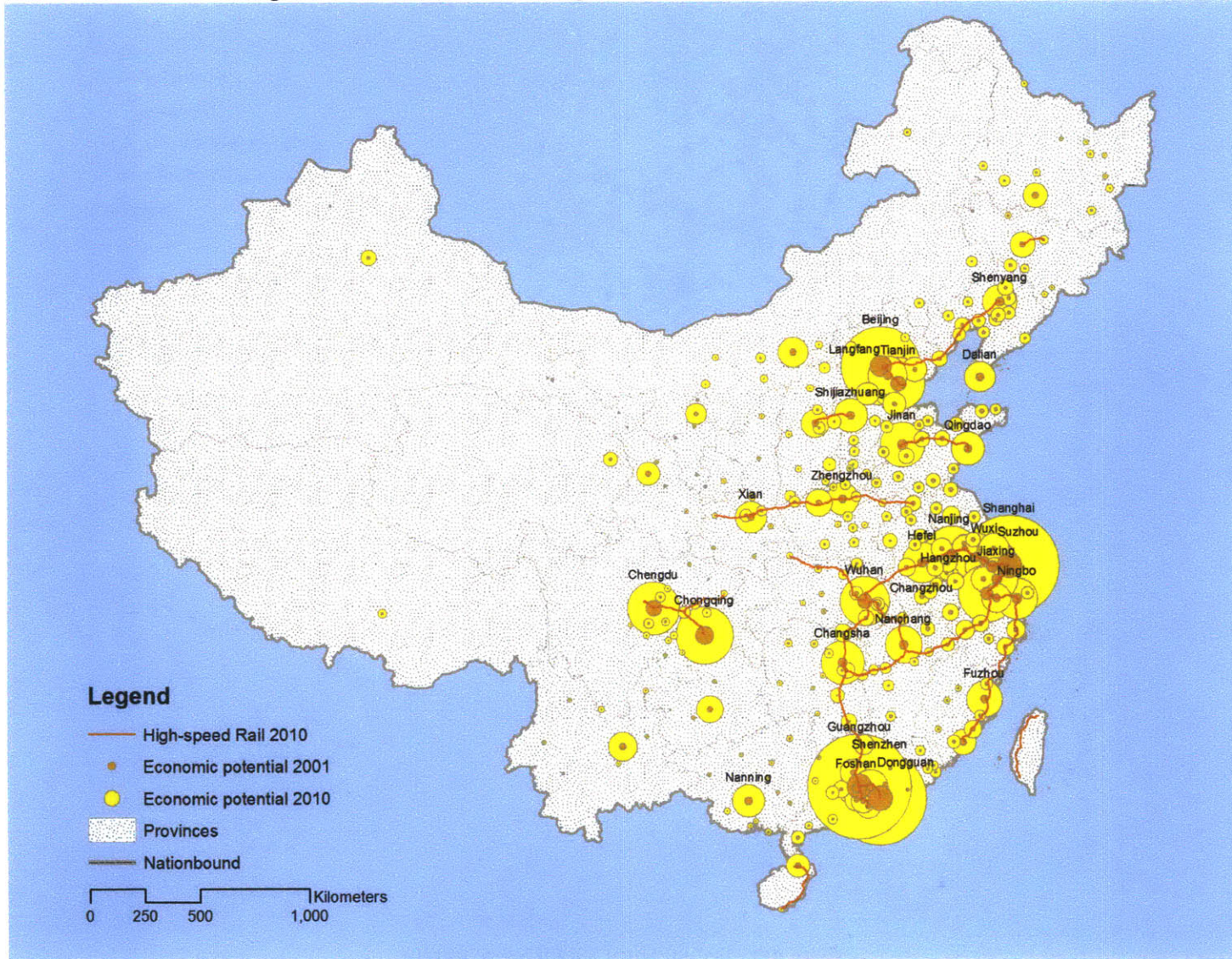
Figure A-5 Railway-based economic potential of cities in China 2001 vs. 2010

Legend

— High-speed Rail 2010

• Economic potential_Rail2001

⬤ Economic potential_Rail2010

▨ Provinces

— Nationbound

Kilometers
0 250 500 1,000
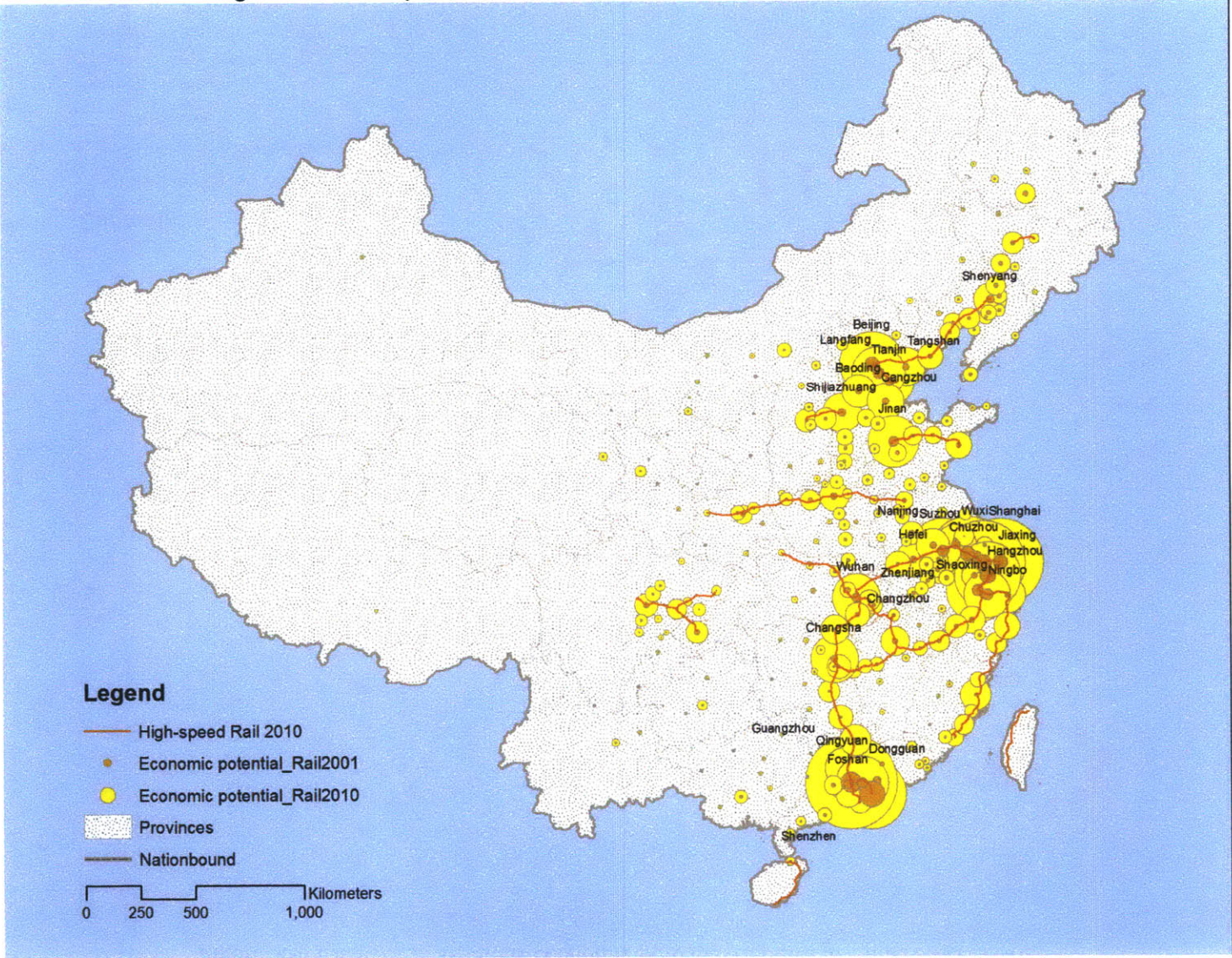
Figure A-6 Changes in all-mode economic potential of cities in China 2001- 2010

Legend

—— High-speed Rail 2010

● Change of economic potential 2001-2010

▢ Provinces

—— Nationbound

Kilometers
0   250   500   1,000
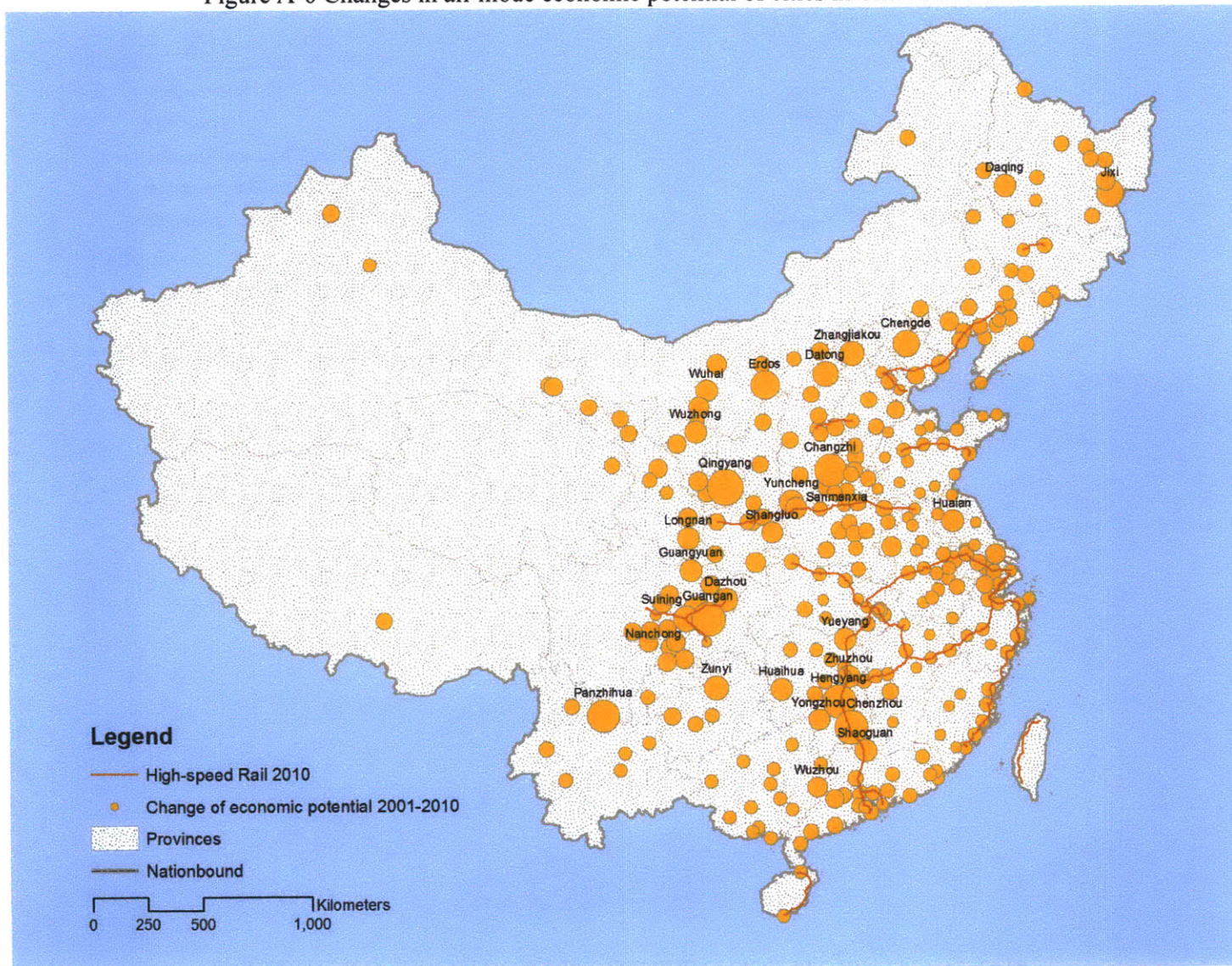
Figure A-7 Relative changes in rail-based economic potential of cities in China 2001- 2010

Legend

— High-speed Rail 2010
● Change of railway-based EP 2001-2010
▫ Provinces
— Nationbound

| | | |
| 0 | 250 | 500 | 1,000 | Kilometers |
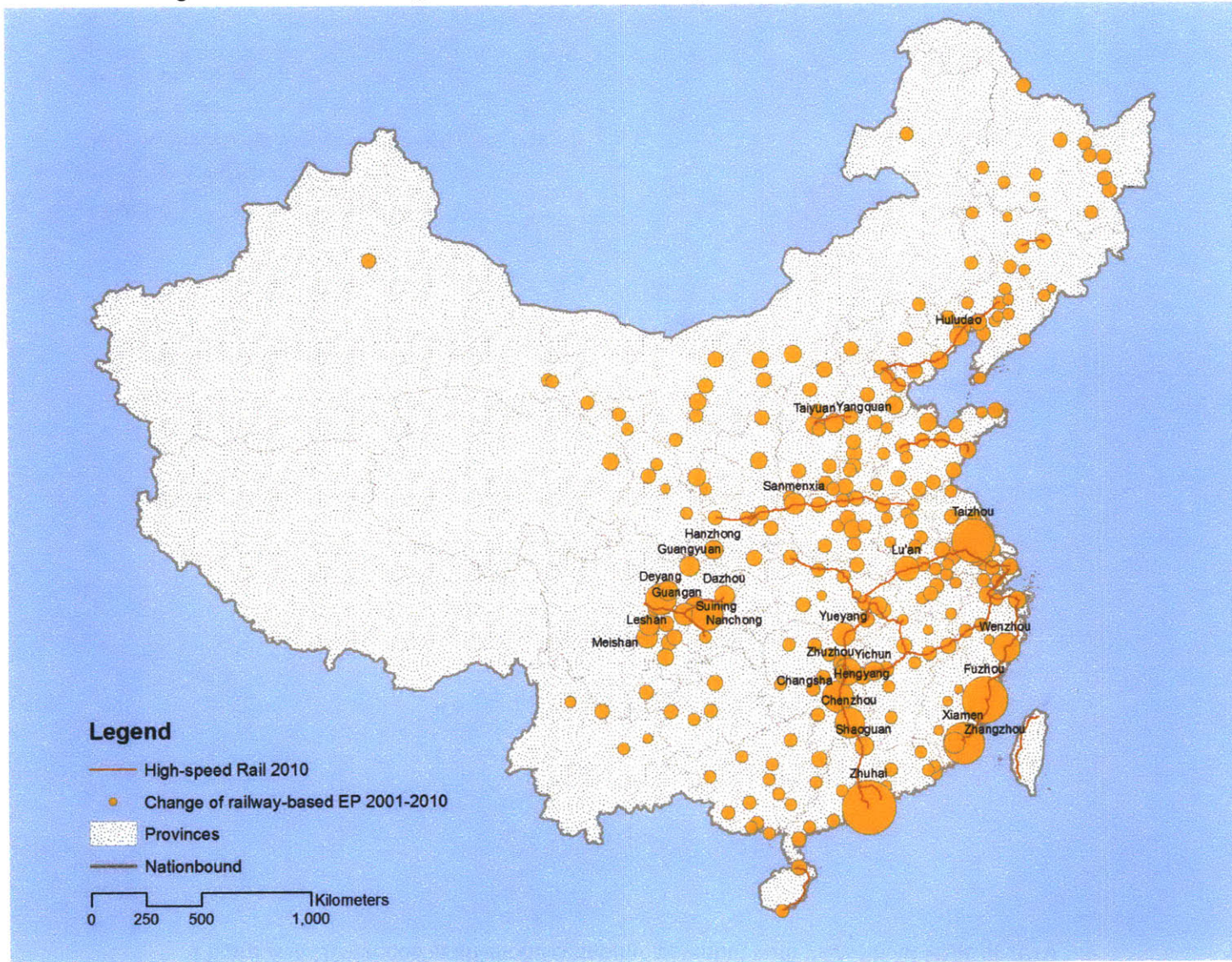
Figure A-8 Difference in all-mode economic potential with vs. without HSR in 2010
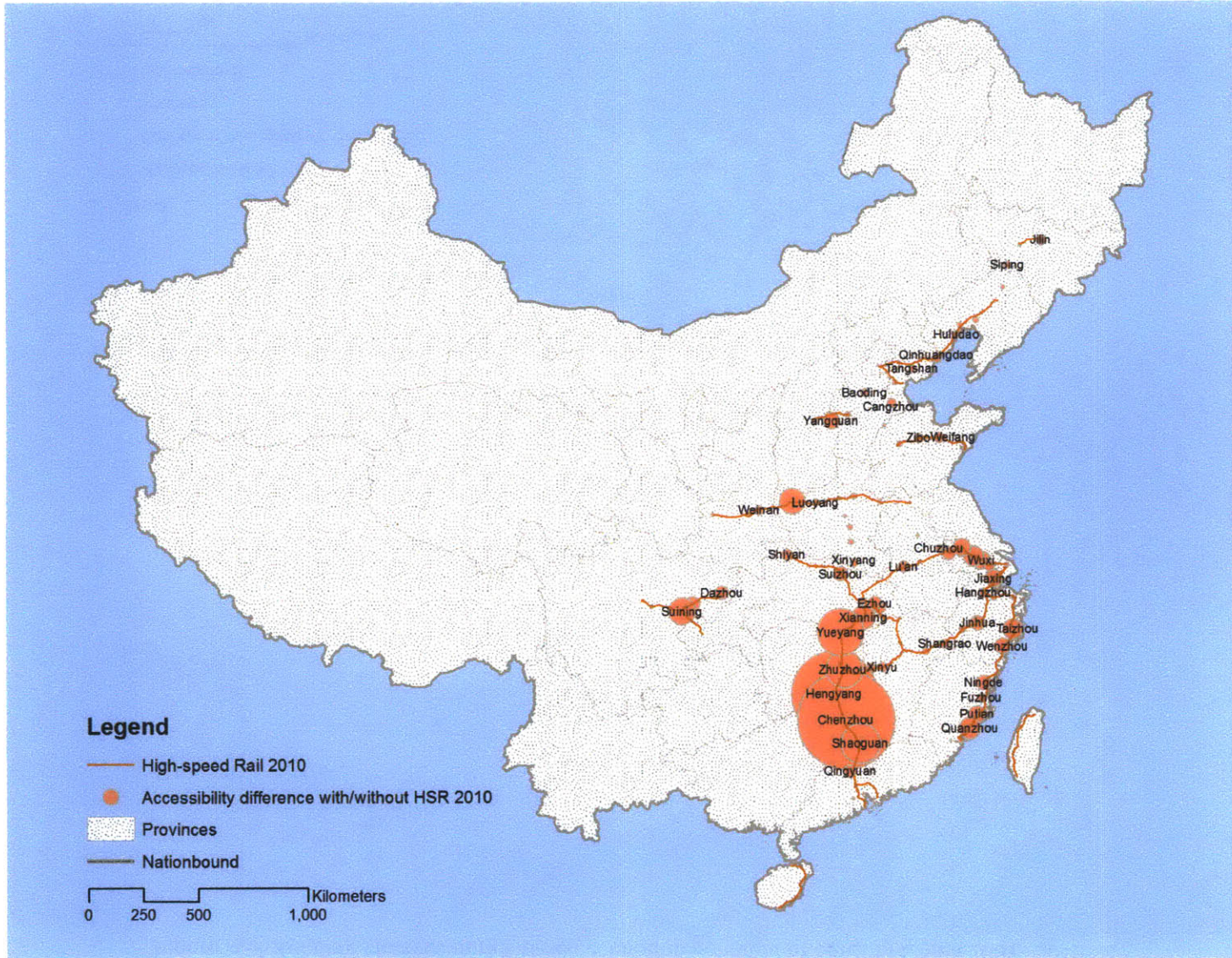
Figure A-9 All-mode daily economic potential of cities in China 2001 vs. 2010

Legend
High-speed Rail 2010
Daily all-mode EP2001
Daily all-mode EP2010
Provinces
Nationbound

0   250   500   1,000   Kilometers
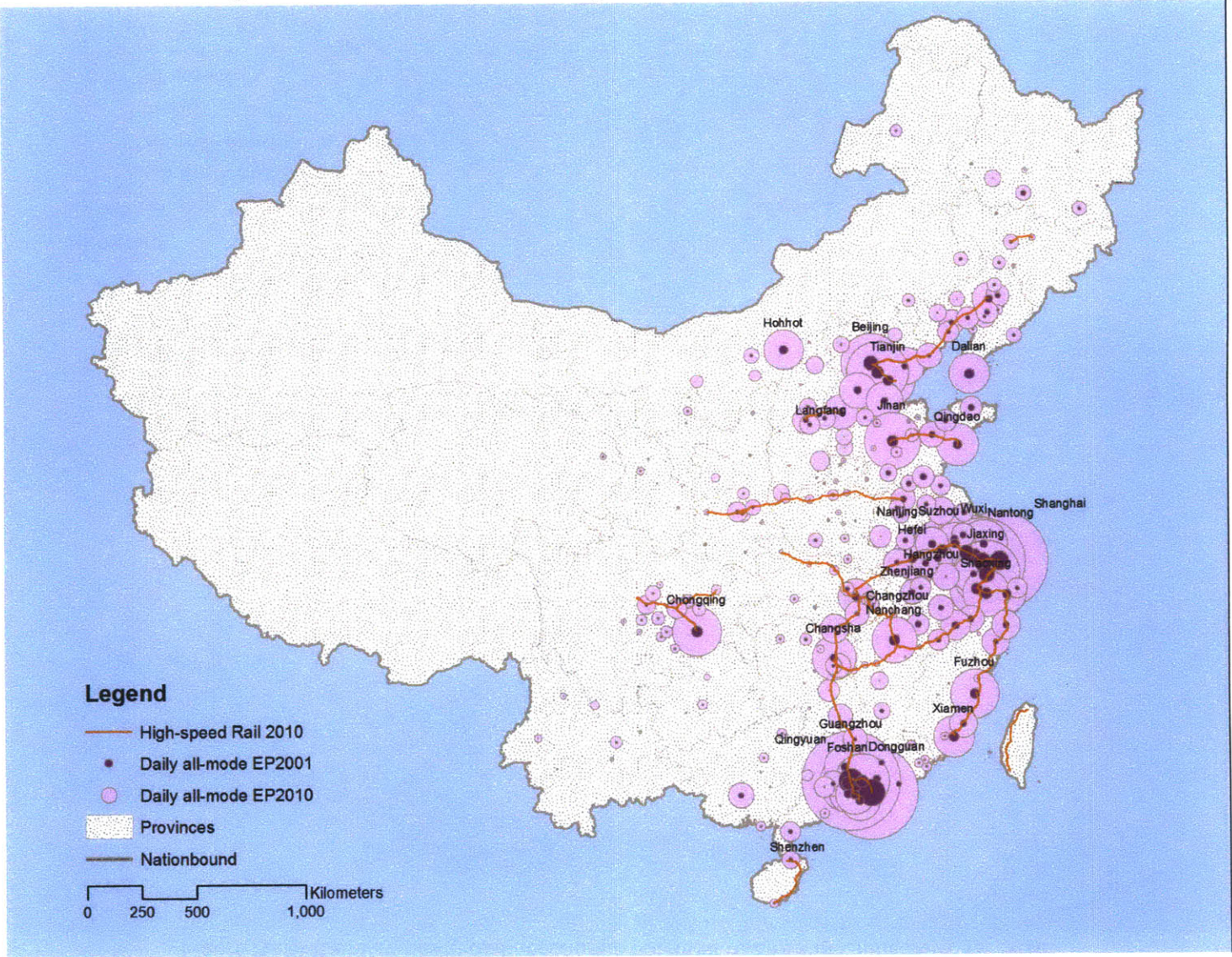
Figure A-10 Railway-based daily economic potential of cities in China 2001 vs. 2010

Legend

— High-speed Rail 2010

● Daily Rail-based EP2001

○ Daily Rail-based EP2010

▦ Provinces

— Nationbound

0 250 500 1,000 Kilometers
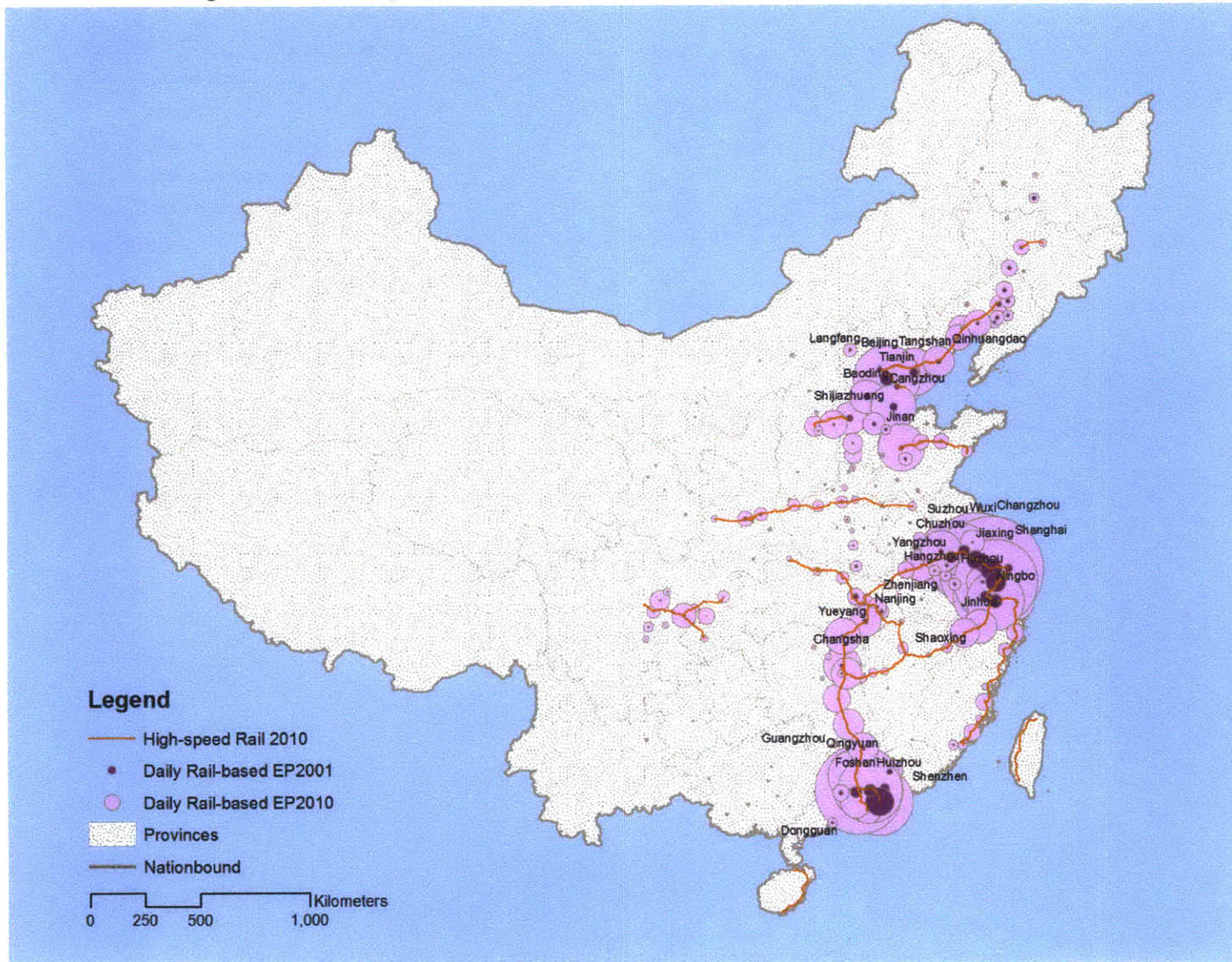
Figure A-11 Changes in daily all-mode economic potential of cities in China 2001- 2010
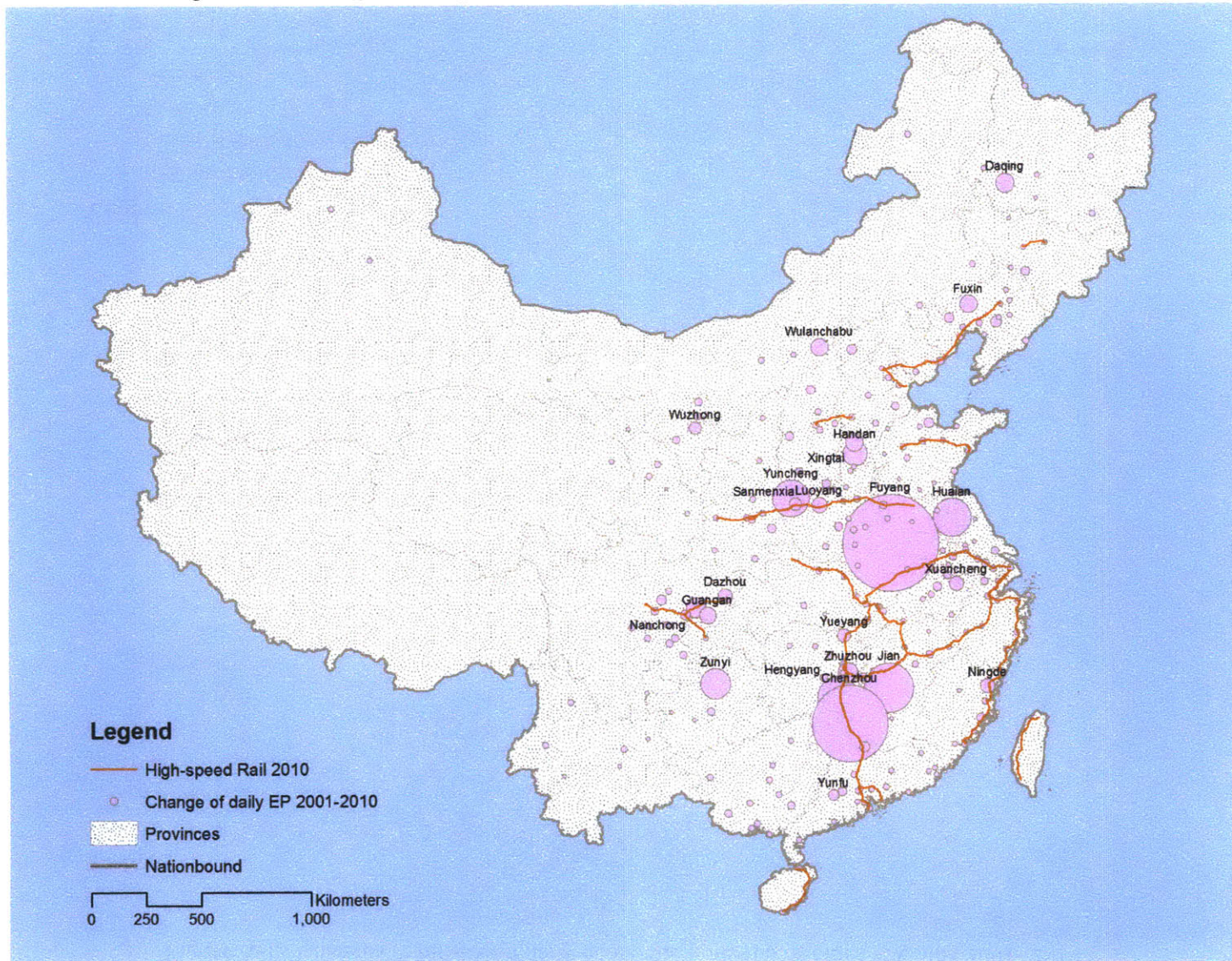
Figure A-12 Changes in rail-based daily economic potential of cities in China 2001- 2010
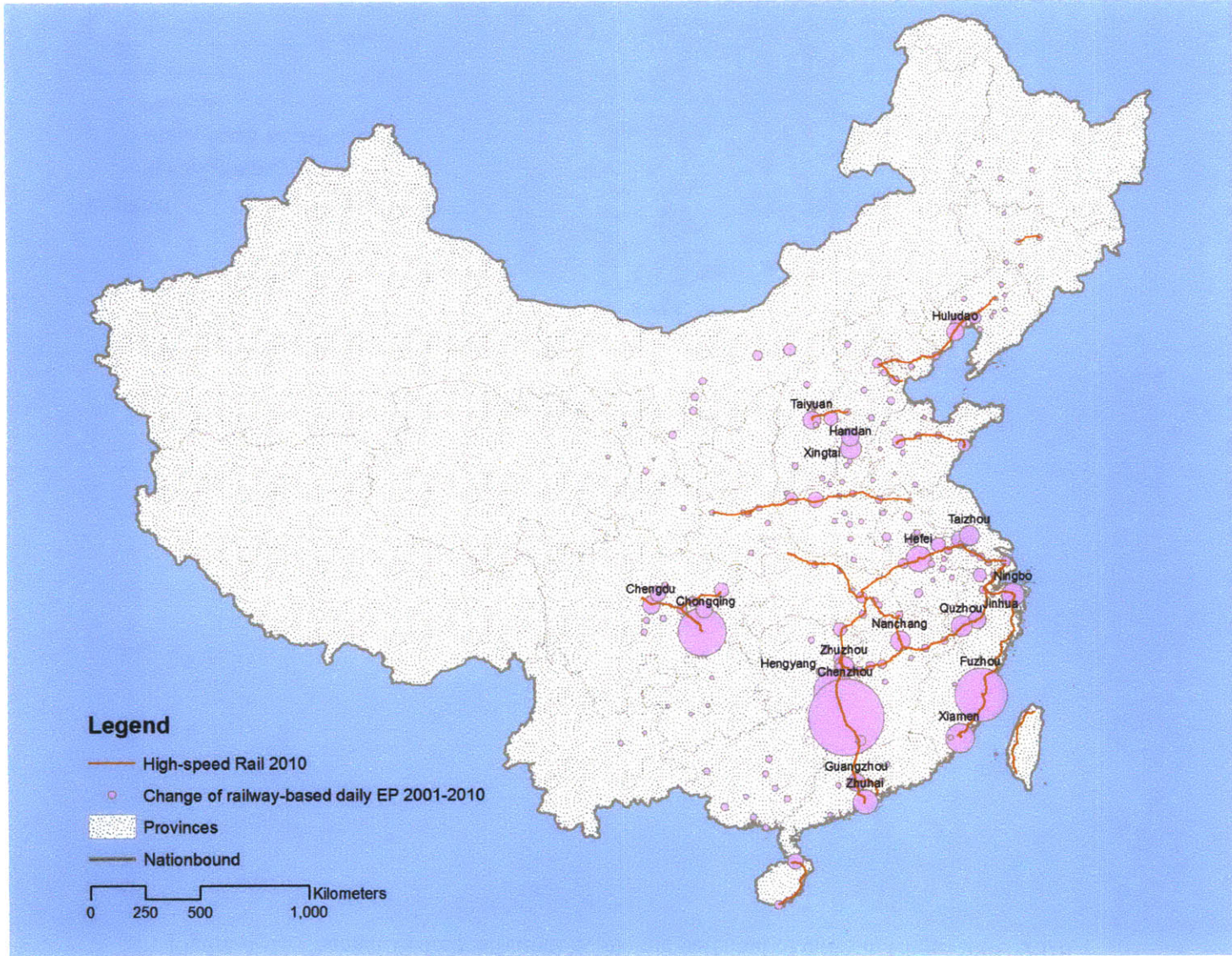
Figure A-13 WATT by all modes(top) and by railway(down) in 2001(left) vs. 2010(right)
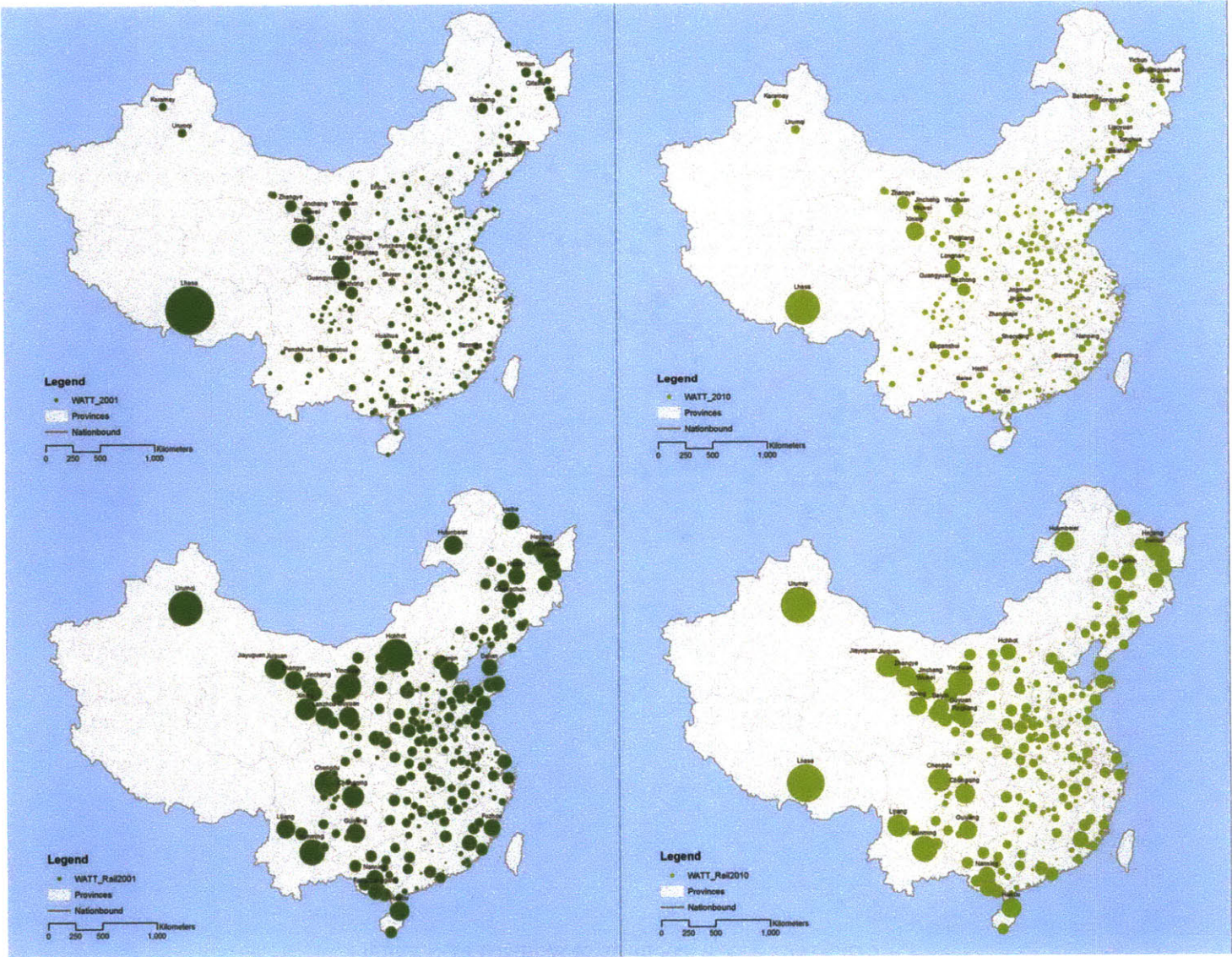
Figure A-14 Changes in all-mode WATT 2001-2010

Legend

High-speed Rail 2010

WATT_all mode_change

- 0.40 - 0.70
- 0.71 - 1.00
- 1.01 - 1.16

Provinces

Nationbound

0   250   500   1,000 Kilometers
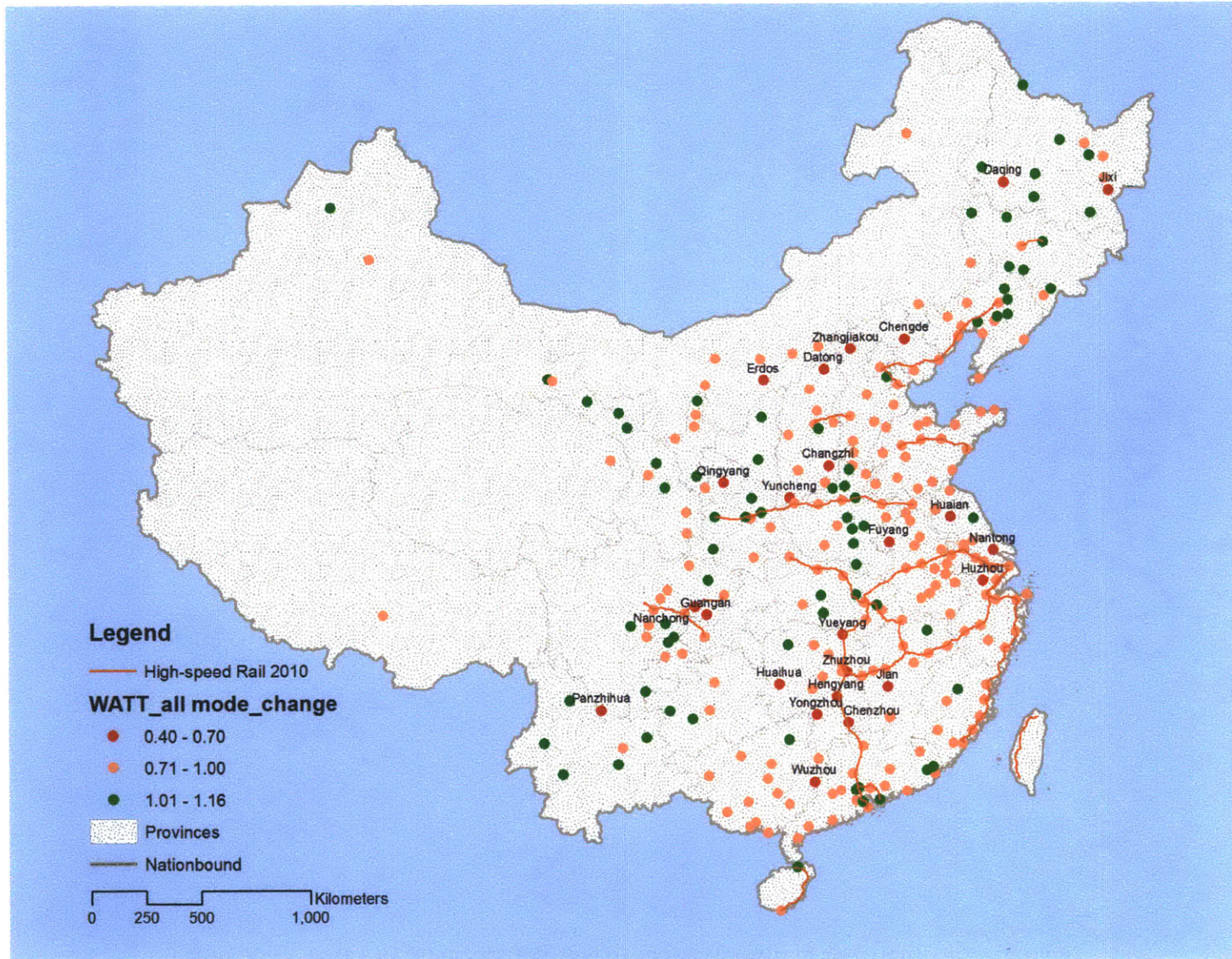
Figure A-15 Changes in railway-based WATT 2001-2010

Legend

—— High-speed Rail 2010

WATT_rail_change

- ● 0.31 - 0.60
- ● 0.61 - 1.00
- ● 1.01 - 1.45

▨ Provinces

—— Nationbound

Kilometers
0   250   500   1,000
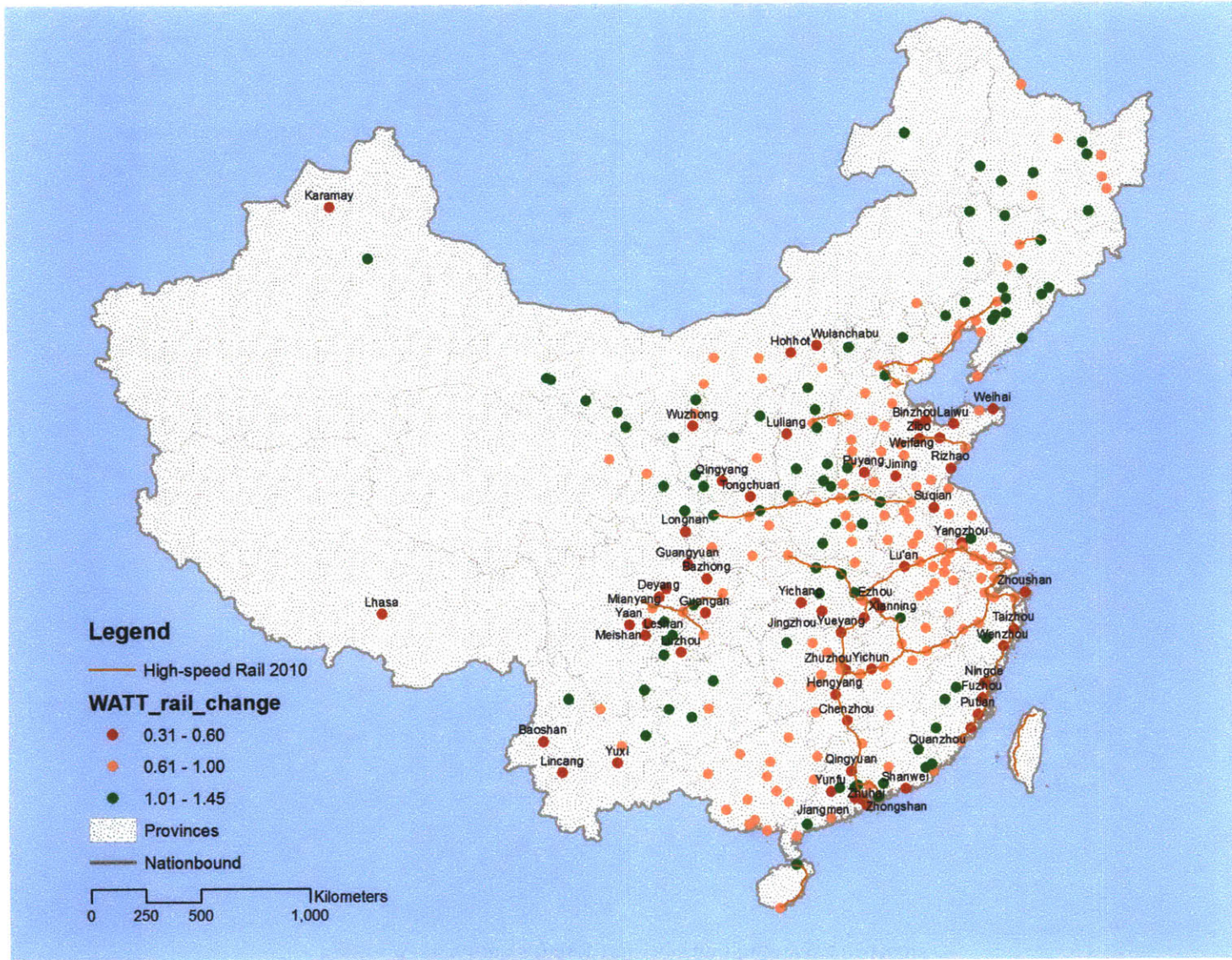
Figure A-16 China's major railways and highways in 1920s

Data source: Sun Yat-sen, 1922, The International Development of China. Author mapping

Figure A-17 Elevation of Cities in China
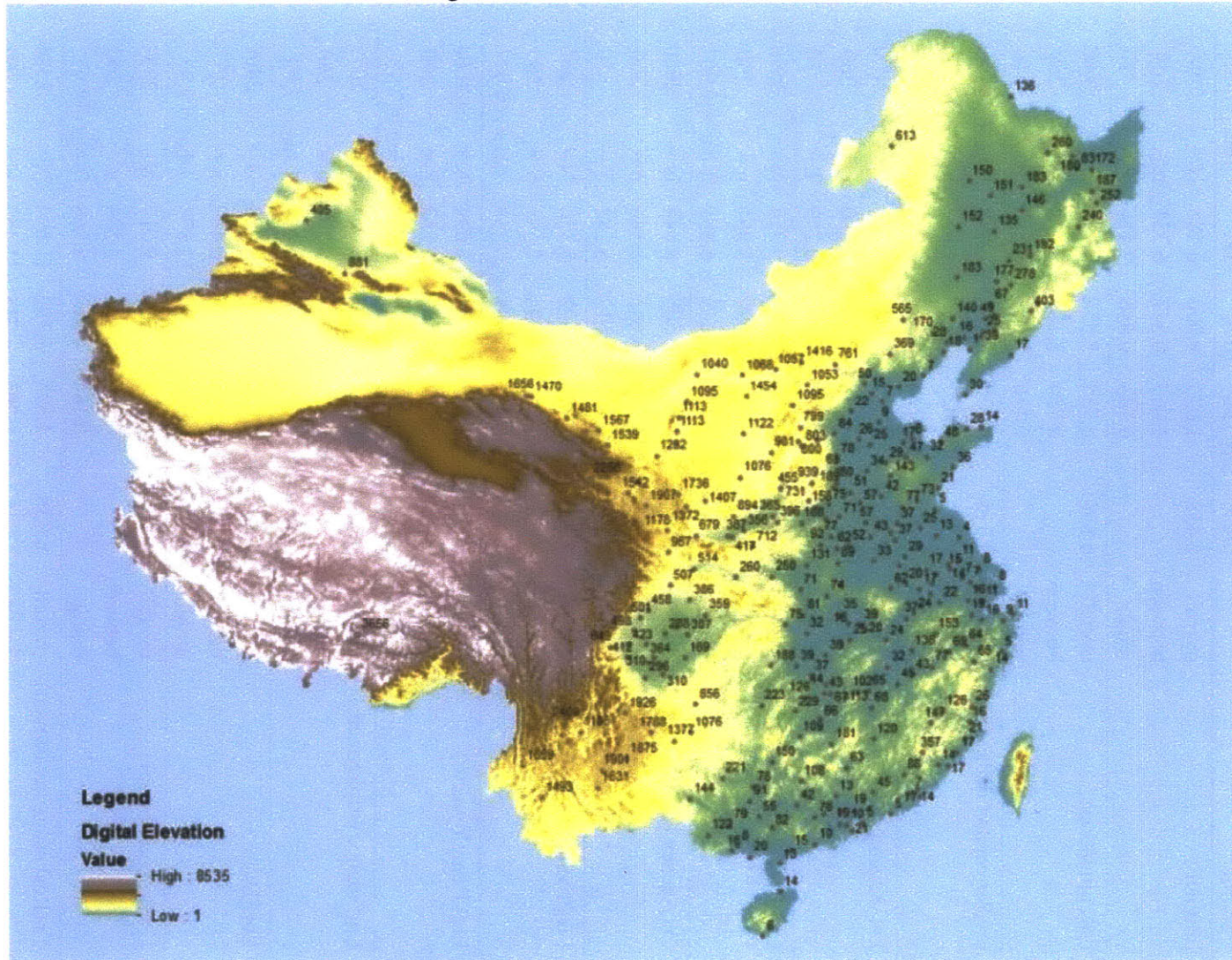
Data source: China's National Geo-information Center, author mapping

Appendix B   ESTIMATION RESULTS

Table B-1 Summary statistics of variables

Variable		Mean	Std. Dev.	Min	Max	Observations	
Ln(GDP)	overall	2.438	1.073	0.000	6.488	N =	2600
	between		1.063	0.347	6.331	n =	260
	within		0.163	0.616	3.116	T =	10
Ln(Population)	overall	6.858	0.735	5.075	9.644	N =	2600
	between		0.724	5.185	9.472	n =	260
	within		0.136	5.079	7.594	T =	10
Ln(Per capita GDP)	overall	9.395	0.638	7.681	11.898	N =	2600
	between		0.627	7.865	11.652	n =	260
	within		0.124	8.399	10.039	T =	10
Ln(Wage rate)	overall	9.221	0.277	7.224	10.235	N =	2600
	between		0.248	8.539	10.080	n =	260
	within		0.124	7.428	10.259	T =	10
Ln(Urban employment)	overall	5.455	0.952	3.219	9.254	N =	2590
	between		0.922	3.939	8.861	n =	260
	within		0.243	3.649	6.865	T-bar = 9.96	
Ln(Agency employment)	overall	4.976	0.932	2.708	8.848	N =	2600
	between		0.919	3.033	8.544	n =	260
	within		0.163	2.612	6.182	T =	10
Ln(Private employment)	overall	4.344	1.138	0.693	8.330	N =	2585
	between		1.000	2.696	7.591	n =	260
	within		0.548	0.955	6.357	T-bar = 9.94	
Ln(IT employment)	overall	0.639	1.033	-2.303	6.034	N =	2064
	between		0.988	-2.303	5.552	n =	260
	within		0.341	-2.090	2.854	T-bar = 7.93	
Ln(Finance employment)	overall	1.721	0.949	-2.303	5.606	N =	2079
	between		0.923	-2.303	5.271	n =	260
	within		0.242	-1.178	2.919	T-bar = 7.99	
Ln(FDI)	overall	8.444	2.057	1.386	13.922	N =	2409
	between		1.975	1.946	13.489	n =	257
	within		0.920	3.525	12.874	T-bar = 9.37	
Ln(Property price)	overall	6.951	0.429	4.500	9.017	N =	2333
	between		0.399	6.135	8.504	n =	260
	within		0.164	4.810	8.868	T-bar = 8.97	
Ln(Real estate investment)	overall	6.838	1.398	1.792	11.604	N =	2596
	between		1.295	3.735	11.457	n =	260
	within		0.531	3.839	9.243	T-bar = 9.98	

Ln(Tourism revenue)	overall	7.348	1.313	0.693	11.490	N =	2283
	between		1.231	3.290	11.339	n =	260
	within		0.454	1.805	10.624	T-bar = 8.78	
Ln(Number of tourists)	overall	8.538	1.126	2.996	12.277	N =	2290
	between		0.987	5.330	11.556	n =	260
	within		0.544	5.010	11.574	T-bar = 8.80	
Ln(Accessibility)	overall	5.598	0.938	2.773	8.580	N =	2595
	between		0.772	3.553	7.901	n =	260
	within		0.537	4.193	6.986	T-bar = 9.980	

Table B-2 Estimated coefficients of pooled OLS, fixed-effect and random-effect models

Dependent variables	Pooled OLS		Fixed-effect		Random-effects	
	(1)	(2)	(3)	(4)	(5)	(6)
Ln (GDP)	0.727***	0.981***	0.174***	0.013	0.180***	0.181***
	(0.054)	(0.069)	(0.011)	(0.052)	(0.012)	(0.047)
R-squared	0.405	0.512	0.326	0.341	0.405	0.406
Ln (population)	0.426***	0.981***	0.110***	-0.040	0.115***	0.097***
	(0.042)	(0.069)	(0.010)	(0.033)	(0.010)	(0.035)
R-squared	0.296	0.512	0.189	0.217	0.297	0.267
Ln (per cap GDP)	0.303***	0.412***	0.069***	0.062	0.073***	0.143***
	(0.037)	(0.053)	(0.011)	(0.053)	(0.010)	(0.042)
R-squared	0.198	0.253	0.091	0.104	0.198	0.241
Ln (wage rate)	0.099***	0.137***	0.023**	0.177***	0.030***	0.151***
	(0.016)	(0.023)	(0.010)	(0.037)	(0.009)	(0.019)
R-squared	0.112	0.151	0.096	0.173	0.112	0.151
Ln (urban employment)	0.669***	0.853***	0.260***	-0.121**	0.274***	0.249***
	(0.047)	(0.060)	(0.016)	(0.058)	(0.016)	(0.051)
R-squared	0.437	0.508	0.330	0.365	0.437	0.420
Ln (agency employment)	0.576***	0.802***	0.081***	-0.124**	0.090***	0.116***
	(0.049)	(0.062)	(0.013)	(0.048)	(0.014)	(0.043)
R-squared	0.338	0.450	0.071	0.098	0.338	0.375
Ln (private employment)	0.841***	0.928***	0.631***	-0.081	0.657***	0.625***
	(0.047)	(0.062)	(0.031)	(0.105)	(0.030)	(0.061)
R-squared	0.482	0.509	0.383	0.469	0.482	0.493
Year dummies	N	Y	N	Y	N	Y

Robust standard errors in parentheses *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table B-3 The elasticity of general economic performance to accessibility

VARIABLES	Dependent variables in logarithm form						
	GDP	Population	Per cap GDP	Wage rate	Total employment	Agency employment	Private employment
Ln(accessibility)	0.013	-0.040	0.062	0.177***	-0.121**	-0.124**	-0.081
	(0.052)	(0.033)	(0.053)	(0.037)	(0.058)	(0.048)	(0.105)
Observations	2,595	2,595	2,595	2,595	2,585	2,595	2,580
R-squared	0.341	0.217	0.104	0.173	0.365	0.098	0.469

Robust standard errors in parentheses *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table B-4 The Elasticity of sectoral economic performance to accessibility

VARIABLES	Dependent variables in logarithm form						
	IT* employment	Finance* employment	FDI	Property price	Real estate investment	Tourism revenue	Number of tourists
Ln(accessibility)	0.227**	0.180*	0.365*	-0.074	0.063	0.544***	0.180*
	(0.111)	(0.093)	(0.202)	(0.053)	(0.132)	(0.135)	(0.102)
Observations	2,059	2,074	2,405	2,328	2,591	2,278	2,285
R-squared	0.130	0.326	0.327	0.028	0.421	0.371	0.714

Robust standard errors in parentheses *** $p<0.01$, ** $p<0.05$, * $p<0.1$
*Note: Consistent statistics only available for 2003-2010 due to redefinition of industrial sectors.

Table B-5 The elasticity of general economic performance to accessibility by region

Coefficients of Accessibility by region	Dependent variables in logarithm form						
	GDP	Population	Per cap GDP	Wage rate	Total employment	Agency employment	Private employment
West	0.035	-0.027	0.070	0.136***	-0.066	-0.077	-0.027
	(0.053)	(0.032)	(0.054)	(0.036)	(0.062)	(0.051)	(0.114)
Middle	-0.029	-0.037	0.014	0.178***	-0.105	-0.114**	-0.051
	(0.051)	(0.035)	(0.048)	(0.038)	(0.068)	(0.056)	(0.120)
Eastern	-0.027	0.009	-0.029	0.061	0.075	0.037	0.153
	(0.055)	(0.038)	(0.053)	(0.043)	(0.080)	(0.063)	(0.159)
Observations	2,595	2,595	2,595	2,595	2,585	2,595	2,580
R-squared	0.349	0.223	0.131	0.182	0.394	0.143	0.477
Number of code	260	260	260	260	260	260	260

Robust standard errors in parentheses *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table B-6 The elasticity of sector-specific economic performance to accessibility by region

VARIABLES	Dependent variables in logarithm form						
	IT employment	Finance employment	FDI	Property price	Real estate investment	Tourism revenue	Number of tourists
West	0.212*	0.219**	0.074	-0.089	-0.008	0.448***	0.154
	(0.114)	(0.091)	(0.217)	(0.060)	(0.131)	(0.137)	(0.114)
Middle	0.238**	0.165	0.491**	-0.058	0.029	0.529***	0.197**
	(0.115)	(0.106)	(0.210)	(0.049)	(0.144)	(0.140)	(0.097)
Eastern	0.215*	0.249**	-0.102	-0.073	-0.226	0.212	0.150
	(0.117)	(0.100)	(0.225)	(0.059)	(0.146)	(0.140)	(0.122)
Observations	2,059	2,074	2405	2,328	2,591	2,278	2,285
R-squared	0.131	0.330	0.305	0.030	0.434	0.392	0.714
Number of code	260	260	257	260	260	260	260

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table B-7 The elasticity of general economic performance to accessibility by city size

Coefficients of Accessibility by city size	Dependent variables in logarithm form						
	GDP	Population	Per cap GDP	Wage rate	Total employment	Agency employment	Private employment
Small	0.055	-0.018	0.090	0.166***	-0.072	-0.094*	0.025
	(0.056)	(0.032)	(0.058)	(0.040)	(0.058)	(0.049)	(0.112)
Medium	-0.006	-0.043	0.042	0.180***	-0.114*	-0.120**	-0.080
	(0.047)	(0.030)	(0.048)	(0.037)	(0.058)	(0.051)	(0.104)
Large	0.034	0.011	0.042	0.170***	0.021	-0.041	0.181
	(0.054)	(0.035)	(0.053)	(0.041)	(0.064)	(0.055)	(0.126)
Observations	2,595	2,595	2,595	2,595	2,585	2,595	2,580
R-squared	0.402	0.472	0.175	0.182	0.407	0.148	0.489
Number of code	260	260	260	260	260	260	260

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table B-8 The elasticity of sectoral economic performance to accessibility by city size

Coefficients of Accessibility by city size	Dependent variables in logarithm form						
	IT employment	Finance employment	FDI	Property price	Real estate investment	Tourism revenue	Number of tourists
Small	0.236*	0.190**	0.317	-0.101*	0.092	0.558***	0.161
	(0.132)	(0.093)	(0.227)	(0.059)	(0.141)	(0.150)	(0.114)
Medium	0.221**	0.173*	0.364*	-0.049	0.044	0.473***	0.157
	(0.110)	(0.100)	(0.203)	(0.051)	(0.133)	(0.134)	(0.097)
Large	0.249**	0.191*	0.275	-0.032	0.065	0.275*	0.020
	(0.114)	(0.103)	(0.225)	(0.057)	(0.153)	(0.141)	(0.113)
Observations	2,059	2,074	2,405	2,328	2,591	2,278	2,285
R-squared	0.131	0.327	0.328	0.035	0.423	0.385	0.717
Number of code	260	260	257	260	260	260	260

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table B-9 The elasticity of general economic performance to accessibility by size and region

Coefficients of Accessibility by region and size	Dependent variables in logarithm form						
	GDP	Population	Per cap GDP	Wage rate	Total employment	Agency employment	Private employment
Western small	0.117*	0.022	0.115	0.153***	-0.037	-0.054	0.050
	(0.068)	(0.029)	(0.073)	(0.042)	(0.057)	(0.056)	(0.113)
Western medium	0.017	-0.036	0.061	0.125***	-0.053	-0.052	-0.010
	(0.045)	(0.028)	(0.046)	(0.039)	(0.060)	(0.055)	(0.121)
Western large	0.027	0.040	-0.011	0.126***	0.104*	-0.017	0.299**
	(0.053)	(0.043)	(0.054)	(0.042)	(0.061)	(0.058)	(0.125)
Middle small	0.008	0.008	0.009	0.133***	-0.000	-0.048	0.164
	(0.054)	(0.037)	(0.053)	(0.049)	(0.064)	(0.058)	(0.128)
Middle medium	-0.047	-0.037	-0.001	0.178***	-0.085	-0.117*	-0.026
	(0.046)	(0.027)	(0.045)	(0.038)	(0.065)	(0.061)	(0.115)
Middle large	-0.018	-0.014	0.003	0.221***	-0.092	-0.092	-0.011
	(0.059)	(0.039)	(0.055)	(0.046)	(0.073)	(0.064)	(0.158)
Eastern small	-0.028	-0.030	0.017	0.054	0.060	0.033	0.123
	(0.059)	(0.036)	(0.057)	(0.060)	(0.088)	(0.078)	(0.173)
Eastern medium	-0.090*	-0.045	-0.056	0.064	0.010	-0.004	0.061
	(0.053)	(0.039)	(0.052)	(0.048)	(0.080)	(0.072)	(0.166)
Eastern large	-0.032	-0.009	-0.002	0.062	0.154*	0.085	0.347**
	(0.060)	(0.043)	(0.057)	(0.045)	(0.079)	(0.070)	(0.164)
Observations	2,595	2,595	2,595	2,595	2,585	2,595	2,580
R-squared	0.434	0.529	0.216	0.205	0.451	0.196	0.507
Number of code	260	260	260	260	260	260	260

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table B-10 The elasticity of sectoral economic performance to accessibility by region and size

Coefficients of Accessibility by group	Dependent variables in logarithm form						
	IT employment	Finance employment	FDI	Property price	Real estate investment	Tourism revenue	Number of tourists
Western small	0.263	0.223**	-0.153	-0.105	0.129	0.470***	0.228
	(0.159)	(0.091)	(0.301)	(0.081)	(0.154)	(0.169)	(0.146)
Western medium	0.110	0.220**	0.203	-0.080	-0.066	0.441***	0.063
	(0.116)	(0.097)	(0.266)	(0.058)	(0.141)	(0.141)	(0.129)
Western large	0.225	0.134	0.369	-0.110*	-0.064	0.291*	-0.008
	(0.145)	(0.140)	(0.296)	(0.063)	(0.153)	(0.153)	(0.132)
Middle small	0.187	0.154	0.695**	-0.128**	-0.047	0.631***	0.124
	(0.155)	(0.097)	(0.287)	(0.060)	(0.175)	(0.171)	(0.124)
Middle medium	0.265**	0.166	0.457**	-0.016	0.027	0.438***	0.155
	(0.119)	(0.119)	(0.204)	(0.049)	(0.144)	(0.136)	(0.098)
Middle large	0.168	0.197*	0.452*	0.002	0.101	0.370**	0.077
	(0.126)	(0.108)	(0.255)	(0.065)	(0.198)	(0.146)	(0.139)
Eastern small	0.158	0.259**	-0.270	-0.101	-0.232	0.246	0.118
	(0.123)	(0.102)	(0.259)	(0.070)	(0.148)	(0.158)	(0.155)
Eastern medium	0.162	0.213**	0.097	-0.091	-0.298*	0.291*	0.209
	(0.122)	(0.100)	(0.240)	(0.064)	(0.161)	(0.148)	(0.139)
Eastern large	0.257**	0.236**	-0.144	-0.042	-0.260	0.043	-0.043
	(0.129)	(0.107)	(0.257)	(0.063)	(0.165)	(0.144)	(0.138)
Observations	2,059	2,074	2,405	2,328	2,591	2,278	2,285
R-squared	0.138	0.340	0.361	0.047	0.443	0.405	0.721
Number of code	260	260	257	260	260	260	260

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table B-11 The elasticity of general economic performance to accessibility by accessibility level

Coefficients of Accessibility by accessibility level	Dependent variables in logarithm form						
	GDP	Population	Per cap GDP	Wage rate	Total employment	Agency employment	Private employment
Low	-0.022	-0.065	0.056	0.117**	-0.052	-0.067	-0.105
	(0.068)	(0.048)	(0.069)	(0.052)	(0.086)	(0.080)	(0.159)
Medium-low	0.023	-0.040	0.075	0.143***	-0.100	-0.072	-0.173
	(0.059)	(0.034)	(0.063)	(0.037)	(0.064)	(0.054)	(0.129)
Medium	-0.011	-0.077**	0.075	0.153***	-0.174***	-0.141**	-0.200
	(0.057)	(0.037)	(0.061)	(0.042)	(0.066)	(0.057)	(0.127)
Medium-high	-0.034	-0.082*	0.059	0.167***	-0.167**	-0.140**	-0.272*
	(0.062)	(0.046)	(0.063)	(0.044)	(0.074)	(0.062)	(0.140)
High	-0.023	-0.097**	0.077	0.141***	-0.138*	-0.111*	-0.256*
	(0.065)	(0.043)	(0.067)	(0.047)	(0.080)	(0.066)	(0.155)
Observations	2,595	2,595	2,595	2,595	2,585	2,595	2,580
R-squared	0.347	0.225	0.109	0.199	0.378	0.114	0.479
Number of code	260	260	260	260	260	260	260

Robust standard errors in parentheses *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table B-12 The elasticity of sectoral economic performance to accessibility by accessibility group

Coefficients of Accessibility by accessibility level	Dependent variables in logarithm form						
	IT employment	Finance employment	FDI	Property price	Real estate investment	Tourism revenue	Number of tourists
Low	0.059	0.166	0.673**	-0.095	0.053	0.318**	0.219*
	(0.137)	(0.103)	(0.301)	(0.074)	(0.191)	(0.161)	(0.116)
Medium-low	0.191*	0.184**	0.373	-0.071	0.025	0.480***	0.221**
	(0.112)	(0.084)	(0.256)	(0.056)	(0.161)	(0.137)	(0.107)
Medium	0.103	0.167*	0.414	-0.111*	0.207	0.459***	0.151
	(0.119)	(0.094)	(0.268)	(0.067)	(0.162)	(0.155)	(0.106)
Medium-high	0.097	0.220**	0.580**	-0.082	0.090	0.458***	0.241**
	(0.125)	(0.099)	(0.274)	(0.064)	(0.174)	(0.147)	(0.113)
High	0.046	0.185*	0.514*	-0.088	0.101	0.425***	0.264**
	(0.128)	(0.104)	(0.294)	(0.066)	(0.184)	(0.152)	(0.111)
Observations	2,059	2,074	2,405	2,328	2,591	2,278	2,285
R-squared	0.137	0.331	0.332	0.035	0.430	0.377	0.717
Number of code	260	260	257	260	260	260	260

Robust standard errors in parentheses *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table B-13 The elasticity of economic performance to accessibility from pooled OLS-IV models

VARIABLES	All variables in logarithm form					
	(1)	(2)	(3)	(4)	(5)	(6)
Instrument variables	Distance to the nearest 1920 line	Sum of distance to three nearest 1920 lines	Geo-centrality	Elevation	(2) and (4) together	No IV
1st STAGE:	Dependent variable: Ln(Accessibility)					
Coefficients of IVs	-0.167*** (0.031)	-0.383*** (0.050)	0.933*** (0.165)	-0.257*** (0.030)	-0.306***| -0.218*** (0.045) | (0.027)	N/A
R-squared	0.397	0.471	0.391	0.508	0.601	N/A
2nd STAGE:	Elasticity of economic performance to accessibility					
GDP	0.983*** (0.210)	1.020*** (0.161)	0.345 (0.232)	0.897*** (0.104)	0.950*** (0.105)	0.981*** (0.022)
R-squared	0.491	0.505	0.297	0.506	0.507	0.507
Population	0.688*** (0.141)	0.736*** (0.098)	0.428*** (0.133)	0.412*** (0.081)	0.551*** (0.074)	0.569*** (0.018)
R-squared	0.332	0.338	0.347	0.341	0.369	0.369
Per cap GDP	0.296* (0.170)	0.288** (0.114)	-0.074 (0.197)	0.485*** (0.087)	0.400*** (0.085)	0.412*** (0.017)
R-squared	0.227	0.231	-	0.245	0.253	0.253
Wage rate	-0.015 (0.066)	0.034 (0.052)	-0.073 (0.078)	0.103*** (0.036)	0.073** (0.035)	0.137*** (0.008)
R-squared	-	0.068	-	0.142	0.119	0.151
Total employment	1.036*** (0.172)	0.998*** (0.125)	0.266 (0.183)	0.629*** (0.094)	0.788*** (0.087)	0.853*** (0.017)
R-squared	0.469	0.494	0.279	0.475	0.505	0.508
Agency employment	1.104*** (0.189)	1.000*** (0.133)	0.248 (0.189)	0.496*** (0.101)	0.713*** (0.092)	0.802*** (0.018)
R-squared	0.365	0.423	0.237	0.385	0.444	0.450
Private employment	0.907*** (0.172)	0.966*** (0.125)	0.235 (0.203)	0.839*** (0.102)	0.893*** (0.088)	0.928*** (0.020)
R-squared	0.498	0.508	0.285	0.505	0.508	0.509
IT employment	0.958*** (0.191)	1.005*** (0.155)	0.313 (0.240)	0.478*** (0.109)	0.710*** (0.107)	0.894*** (0.022)
R-squared	0.443	0.450	0.270	0.361	0.438	0.457
Finance employment	1.016*** (0.162)	1.036*** (0.110)	0.532*** (0.189)	0.561*** (0.098)	0.770*** (0.085)	0.840*** (0.020)
R-squared	0.448	0.458	0.421	0.432	0.480	0.483
FDI	1.881***	2.072***	2.172***	2.897***	2.558***	1.985***

	(1)	(2)	(3)	(4)	(5)	(6)
	(0.395)	(0.239)	(0.387)	(0.244)	(0.168)	(0.038)
R-squared	0.554	0.564	0.561	0.460	0.524	0.565
Property price	0.114	0.222***	-0.006	0.351***	0.295***	0.343***
	(0.097)	(0.068)	(0.086)	(0.048)	(0.039)	(0.011)
R-squared	0.207	0.335	-	0.382	0.374	0.382
Real estate investment	1.245***	1.368***	0.812***	1.136***	1.236***	1.323***
	(0.208)	(0.161)	(0.255)	(0.111)	(0.105)	(0.025)
R-squared	0.589	0.600	0.520	0.590	0.599	0.601
Tourism revenue	1.052***	1.209***	1.421***	1.143***	1.173***	1.145***
	(0.205)	(0.137)	(0.249)	(0.130)	(0.112)	(0.026)
R-squared	0.488	0.502	0.477	0.503	0.503	0.503
Number of tourists	1.088***	1.050***	1.117***	0.639***	0.824***	0.827***
	(0.177)	(0.120)	(0.193)	(0.123)	(0.104)	(0.021)
R-squared	0.456	0.481	0.466	0.488	0.504	0.504
Year dummies	Y	Y	Y	Y	Y	Y

Robust standard errors in parentheses *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table B-14 Elasticity of GDP to accessibility controlling for capital and labor inputs

	All variables in logarithm					
	Pooled OLS		Pooled OLS-IV		Fixed-effect	
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Ln(accessibility)	0.981***	0.042***	0.950***	0.211***	0.013	-0.013
	(0.022)	(0.013)	(0.105)	(0.066)	(0.052)	(0.046)
Ln(labor payment)		0.445***		0.362***		0.092***
		(0.017)		(0.043)		(0.022)
Ln(capital investment)		0.524***		0.514***		0.168***
		(0.015)		(0.031)		(0.043)
Observations	2,595	2,584	2,595	2,584	2,595	2,584
R-squared	0.512	0.921	0.511	0.914	0.341	0.393
Year dummies	Y	Y	Y	Y	Y	Y

Robust standard errors in parentheses *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table B-15 Elasticity of tourism revenue to accessibility controlling for number of hotels

VARIABLES	Dependent variable: Ln(Tourism revenue)					
	Pooled OLS		Pooled OLS-IV		Fixed-effect	
	(1)	(2)	(3)	(4)	(5)	(6)
Ln(Accessibility)	1.145***	0.446***	1.173***	0.611***	0.544***	0.498***
	(0.073)	(0.059)	(0.112)	(0.111)	(0.135)	(0.132)
Ln(Number of hotels)		0.906***		0.814***		0.290***
		(0.057)		(0.073)		(0.091)
Observations	2,278	2,175	2,278	2,175	2,278	2,175
R-squared	0.503	0.723	0.503	0.718	0.371	0.390
Year dummies	Y	Y	Y	Y	Y	Y

Robust standard errors in parentheses *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table B-16 Elasticity of number of tourists to accessibility controlling for number of hotels

VARIABLES	All variables in logarithm					
	Pooled OLS		Pooled OLS-IV		Fixed-effect	
	(1)	(2)	(3)	(4)	(5)	(6)
Accessibility	0.828***	0.265***	0.835***	0.377***	0.180*	0.162*
	(0.067)	(0.059)	(0.105)	(0.117)	(0.102)	(0.096)
Number of hotels		0.736***		0.673***		0.254***
		(0.049)		(0.070)		(0.071)
Observations	2,285	2,182	2,285	2,182	2,285	2,182
R-squared	0.496	0.693	0.496	0.690	0.714	0.727
Year dummies	Y	Y	Y	Y	Y	Y

Robust standard errors in parentheses *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table B-17 Elasticity of wage rate to accessibility controlling for industrial composition

	Dependent variable: Ln(wage)					
	Pooled OLS		Pooled OLS-IV		Fixed-effect	
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Ln(accessibility)	0.137***	0.032	0.073**	-0.033	0.177***	0.158***
	(0.023)	(0.027)	(0.035)	(0.047)	(0.037)	(0.032)
% of IT employment		0.032		0.042*		0.016
		(0.023)		(0.024)		(0.015)
% of finance employment		0.084***		0.105***		-0.006
		(0.027)		(0.031)		(0.022)
% of research employment		-0.002		0.005		-0.041**
		(0.018)		(0.018)		(0.016)
Observations	2,595	2,057	2,595	2,057	2,595	2,057
R-squared	0.151	0.204	0.119	0.189	0.043	0.056
Year dummies	Y	Y	Y	Y	Y	Y

Robust standard errors in parentheses *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table B-18 Elasticity of FDI to accessibility controlling for GDP and total employment

	Dependent variable: Ln(FDI)					
	Pooled OLS		Pooled OLS-IV		Fixed-effect	
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Ln(accessibility)	1.985***	1.028***	2.558***	2.406***	0.365*	0.351*
	(0.091)	(0.113)	(0.168)	(0.316)	(0.202)	(0.198)
Ln(GDP)		0.778***		0.253		0.626***
		(0.154)		(0.177)		(0.217)
Ln(total employment)		0.165		-0.031		-0.224*
		(0.156)		(0.190)		(0.122)
Observations	2,405	2,396	2,405	2,396	2,405	2,396
R-squared	0.565	0.671	0.524	0.556	0.327	0.334
Year dummies	Y	Y	Y	Y	Y	Y

Robust standard errors in parentheses *** $p<0.01$, ** $p<0.05$, * $p<0.1$