Impacts of French High-Speed Rail Investment on Urban Agglomeration Economies

Mengke Chen

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Impacts of French High-Speed Rail Investment on Urban Agglomeration Economies

Abstract
In order to investigate the role of high-speed rail (HSR) investment in aiding the transformation process of urban agglomeration economies, this study focuses on three fundamental questions through an observation of more than 100 French cities. First, how has HSR investment impacted the reshaping of accessibility patterns in France? Using rail travel timetables from 1982 to 2009, I adopt gravity models to identify the spatial distribution of accessibility in France. I find that although the introduction of HSR improved the level of mobility and accessibility both between Paris and other cities and among cities in general, this was unequal and depended upon the location of cities relative to the newly built HSR line. Second, does HSR investment induce agglomeration economies? If so, how? I use commune-level panel data to study the economic performance of HSR cities by using a matched-pair analysis and various regression models with instrumental variables. I find that the key determinant for boosting agglomeration economies is the level of HSR train frequencies to/from Paris, rather than travel-time savings. Moreover, panel estimation shows that the evidence for the economic impact of HSR investment is mixed and location specific. However, the impact of HSR on the knowledge-based job market is positive. Finally, what is the effect of the spatial competition of HSR investment on the location choices of French firms? I develop a survey and in-depth interview approaches to conclude that most firms in France do not believe HSR itself can influence location choice or make a significant contribution to company growth. Instead, factors related to land value appear to be the most influential determinant in the distribution and relocation of firms, particularly knowledge-based firms. In conclusion, the evidence suggests that investment in HSR needs to be considered rationally, and factors such as the optimal competitive advantage of HSR and daily HSR train frequencies should be taken into account. In addition, regardless of where an HSR station is located, a well-developed and efficient local transportation service will maximize the benefits of the HSR service itself and expand the market coverage.

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IMPACTS OF FRENCH HIGH-SPEED RAIL INVESTMENT ON URBAN AGGLOMERATION ECONOMIES

Mengke Chen

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in

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IMPACTS OF FRENCH HIGH-SPEED RAIL INVESTMENT ON URBAN AGGLOMERATION ECONOMIES

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Mengke Chen
DEDICATION

To My Parents

To Ziwen Chen

To Dr. Chengjie Zuo
ACKNOWLEDGMENTS

Conducting research on such an interesting and important topic has been a slightly long but very valuable journey. First and foremost, my deepest gratitude goes to Professor John Landis, who has been both an admirable advisor and an amiable family member. He guided me through every important phase of the PhD program and offered valuable advices when I faced challenges and difficulties. His profound knowledge, meticulous attitude, and passion for teaching have inspired and enlightened my PhD study. His supportive, truthful, and patient attitude has also influenced me personally. Here, I would like to say thank you, Professor Landis, giving me this opportunity to teach and research with you. Thank you for teaching me to think independently and critically. Thank you so much for everything.

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Thank you for taking care of me as a big brother would. To my other family members, we are a big and happy family, and I appreciate your support.

I have had an incredibly happy time with all of you.
ABSTRACT

IMPACTS OF FRENCH HIGH-SPEED RAIL INVESTMENT ON URBAN AGGLOMERATION ECONOMIES

Mengke Chen

Prof. John Landis

In order to investigate the role of high-speed rail (HSR) investment in aiding the transformation process of urban agglomeration economies, this study focuses on three fundamental questions through an observation of more than 100 French cities.

First, how has HSR investment impacted the reshaping of accessibility patterns in France? Using rail travel timetables from 1982 to 2009, I adopt gravity models to identify the spatial distribution of accessibility in France. I find that although the introduction of HSR improved the level of mobility and accessibility both between Paris and other cities and among cities in general, this was unequal and depended upon the location of cities relative to the newly built HSR line.

Second, does HSR investment induce agglomeration economies? If so, how? I use commune-level panel data to study the economic performance of HSR cities by using a matched-pair analysis and various regression models with instrumental variables. I find that the key determinant for boosting agglomeration economies is the level of HSR train frequencies to/from Paris, rather than travel-time savings. Moreover, panel estimation shows that the evidence for the economic impact of HSR investment is mixed and location specific. However, the impact of HSR on the knowledge-based job market is positive.
Finally, what is the effect of the spatial competition of HSR investment on the location choices of French firms? I develop a survey and in-depth interview approaches to conclude that most firms in France do not believe HSR itself can influence location choice or make a significant contribution to company growth. Instead, factors related to land value appear to be the most influential determinant in the distribution and relocation of firms, particularly knowledge-based firms.

In conclusion, the evidence suggests that investment in HSR needs to be considered rationally, and factors such as the optimal competitive advantage of HSR and daily HSR train frequencies should be taken into account. In addition, regardless of where an HSR station is located, a well-developed and efficient local transportation service will maximize the benefits of the HSR service itself and expand the market coverage.
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LIST OF ABBREVIATIONS AND ACRONYMS

AVE Alta Velocidad Española
BEL Belgium
CBD Central Business District
CCI Chamber of Commerce and Industry
CHE Switzerland
CON Jobs in Construction Industry
CRH China Railway High-speed
DADs Déclaration Annuelle de Données Sociales
DEU Germany
ESP Spain
GCP General Census of Population
GCP Geographical Centrality
GDP Gross Domestic Product
GIS Geographic Information System
HC Human Capital
HSR High Speed Rail
HSR1 High-speed Rail One in UK
HST High-Speed Train
ICE Inter-City Express
IGN National Institute of Geographic and Forestry Information
INSEE Institut National de la Statistique et des Études Économiques
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
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<tr>
<td>ITA</td>
<td>Italy</td>
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<tr>
<td>IV</td>
<td>Instrumental Variable</td>
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<td>KN</td>
<td>Knowledge-based Jobs</td>
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<tr>
<td>LEI</td>
<td>Leisure-based Jobs</td>
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<td>LET</td>
<td>Transport Economics Laboratory</td>
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<td>LGV</td>
<td>Ligne à Grande Vitesse à</td>
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<td>LOG</td>
<td>Jobs in Logistics</td>
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<td>LUX</td>
<td>Luxembourg</td>
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<tr>
<td>MAN</td>
<td>Jobs in Manufacturing Industry</td>
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<tr>
<td>MP</td>
<td>Matched-pair Analysis</td>
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<tr>
<td>NEG</td>
<td>New Economic Geography Theory</td>
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<tr>
<td>OLS</td>
<td>Ordinary Least Squares</td>
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<tr>
<td>PKM</td>
<td>Passenger kilometers</td>
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<td>RFF</td>
<td>Réseau Ferré de France</td>
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<td>RGI</td>
<td>Railway Gazette International</td>
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<td>SNSF</td>
<td>National Society of French Railways</td>
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<td>SOC</td>
<td>Public and Social Service Jobs</td>
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<tr>
<td>TGV</td>
<td>Train à Grande Vitesse</td>
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<tr>
<td>UIC</td>
<td>International Union of Railway</td>
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<td>UU</td>
<td>Urban Unit</td>
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CHAPTER 1 : INTRODUCTION

The development of high speed rail (HSR) can be traced back to 1964, when the first bullet train was introduced in Japan. Between 1964 and 1983, 3,300 km of HSR line were established throughout the world. Japan’s Shinkansen network dominated most of this HSR activity, accounting for more than half of the total network. Then, between 1984 and 2009, about 8,700 km of high-speed services were added, more than half of which were built during the last 6 years of that period, primarily in Spain (18%), France (17%), Germany (15%), and China (14%) (Gourvish, 2012). Over the past three years, Europe has become the leading contributor to HSR development.

The period of significant improvement of the global HSR network raises an important question as to its effects on local agglomeration economies. The existing theoretical literature suggests that the improved level of accessibility gained from HSR investment has stimulated an increase in productivity and promoted economic growth. However, in the empirical literature, after more than 40 years of exploring this relation, the matter is still under dispute. In the recent research, few studies have focused on this link or made significant contributions (Banister & Berechman, 2000; Boarnet & Haughwout, 2000; Paez, 2004; Graham, 2007; Chen, 2013). Thus, it remains unclear how HSR service influences agglomeration economies, and particularly the geographical scope at the city level.

To shed light on this, this dissertation focuses on HSR investment in France, where there is a large, comprehensive HSR network, as evidenced by its 2,037 km LGV line and its second-place ranking in Europe (close to the number one ranked Spain, which has 2,144
km). It carries far more passengers than in any other European country. According to the National Institute of Statistics and Economic Studies (INSEE), domestic passenger ridership on LGV lines has increased 100 times since the introduction of LGV service in 1981.

To achieve its aim, this study explores the economic performance of more than 600 French cities, paying special attention to 107 particular HSR cities associated with the development of the HSR service. Given the nature of agglomeration economies, which are highly concentrated in a certain narrow area (Rosenthal & Strange, 2004; Di Adario & Patacchini, 2008), this study focuses on the commune level, which is the smallest census unit in France, as the geographical scope of the investigation. In addition, this study uses the real HSR train travel time and frequencies instead of travel speed or distance. Given these highlighted features, this will be the first study to explore the linkage between local agglomeration economies and such large-scale HSR investment in France.

Most importantly, this dissertation uses a mixed-methods approach that relies on quantitative analysis, a qualitative survey, and in-depth interviews focusing on three main questions:

1) How has HSR investment reshaped the accessibility pattern in France?

2) Does HSR investment induce agglomeration economies? How? And what is the magnitude of that effect? What kinds of cities will enjoy more benefits?

3) What is the spatial competition effect of HSR investment on the location choice of French firms?
Understanding the association between agglomeration economies and the presence of HSR service is critical, and it could further help identify the key determinants in yielding the maximum benefits of HSR investment. In addition, it will help decision makers understand the likely effects of transportation and land use policy in French cities, and may offer insight into HSR investment in other countries with a similar context to that of France.

1.1. STRUCTURE OF DISSERTATION

The remainder of this dissertation is organized as follows.

Chapter 2 broadly reviews the existing theoretical and empirical research on the role of public transportation investment in boosting economic growth, focusing on HSR investment.

Chapters 3 to 7 constitute the core of the research. Each of these chapters contains its own theoretical and empirical evidence section, as well as a research methods section. Chapter 3 reviews the history and recent development of the HSR service and economic performance in France. As a background investigation, this chapter particularly focuses on the development of the French HSR system, railway stations, ridership, and, most importantly, travel time reduction and train frequencies over the past 30 years. Additionally, it discusses the economic performance in most French cities and regions. Chapter 4 provides a comprehensive picture of the evolution of intercity accessibility patterns between 1982 and 2009 in France, by analyzing two major components: (1) intercity accessibility from each selected HSR city to/from Paris, using real train time and train frequencies, and (2) intercity accessibility patterns by HSR, based on 107 selected cities using real time. Chapter 5, the descriptive analysis, explores the potential association
between HSR service and changes in the employment agglomeration of that city. By using before and after matched pair regression analysis and with/without matched pair correlation analysis, this chapter estimates a series of panel data to identify the research purposes, ranging from population and overall employment to density in a specific economic structure, such as leisure-oriented service, knowledge-based business, and social service. Most importantly, Chapter 6, as the core of this dissertation, chooses two empirical statistical methods—ordinary least squares (OLS) and a linear mixed model—to test the causality relation between the role of HSR service and local agglomeration economies, controlling for unobserved individual heterogeneity in the estimation. The purpose of Chapter 7 is to provide more descriptive evidence by designing a practical survey and developing an in-depth interview, to confirm that the availability of HSR services is not a decisive factor in the location choices of high-skills firms.

Chapter 8 synthesizes the major findings of the study and recommends three principal implications for the development of HSR investment and the likely effects of urban development policy.
CHAPTER 2 : LITERATURE REVIEW

2.1. INTRODUCTION

The arrival of high-speed rail (HSR) has caused an unprecedented shrinkage of time and space and transformed the economic geography of urban areas to varying degrees (Banister and Hall, 1993; Spiekermann and Wegener, 1994). Recently, countries like France, Spain, China, and Germany have invested widely in HSR development to reduce travel times and boost economic development. As the core of urban development, agglomeration economies (which refers to the size and density of cities) have been considered the “magic power” of urban growth and serve as important indicators for measuring levels of local productivity and economic growth.

In theory, significant investments in public transport infrastructure could lead to higher-density employment clusters, increase firm productivity and, consequently, enhance agglomeration economies. A considerable reduction in travel time as a result of HSR investment could, therefore, redistribute the locations of economic activities and increase agglomeration economies. However, this assumed link has been difficult to demonstrate, even after more than 50 years of research (Banister and Berechman, 2000). Given the lack of a comprehensive theory framework, the existing empirical findings are mixed and inconclusive.

To enhance our understanding of the findings (provided later), this chapter introduces definitions of the HSR services adopted in the study and summarizes the concept of agglomeration economies. Moreover, this study explores the most important theories supporting this linkage and briefly presents previous research findings on the economic
impacts of transport investment, especially in the context of Europe HSR investment (moreover, detailed literature on French HSR investments is provided in each of the following chapters). Finally, a conclusion is presented.

2.2. KEY BACKGROUND

- **Concept One: HSR Definition and Competitiveness of HSR**

  High-speed rail, as a type of transportation infrastructure, is a relative concept. According to the European Union definition, HSR is defined by speeds of at least 250 km/hr on separate built lines and 200 km/h on upgraded, high-speed lines. Currently, the maximum commercial speed is about 300 km/h (186 mph) for the majority of national high-speed railways (for example, in Japan, China, Taiwan, France, Germany, Spain and the United Kingdom). Moreover, in general, HSR is used for passenger transport only and doesn’t lead directly to reductions in shipping costs or the cost of goods in a narrow sense.

  However, the benefits of transport infrastructure investment on travel time reduction have spatial limits. As the literature suggests, when the travel distance is less than 150 km, the competitive advantage of HSR over conventional rail is decreased drastically by station processing time and by travel to and from stations. When the travel distance is longer than 800 km, the faster speed of air travel compensates for slow airport processing times and for access and egress time. Finally, for trips longer than 2000 km or shorter than 150 km, the competitive advantage of HSR completely vanishes (Gleave, 2004), shown in Figure 1.
As an extension of these advantages, with the shift of air travellers to HSR, short-haul flights have been discontinued, thus increasing runway capacity for longer flights, for which air travel maintains a competitive advantage over HSR. With the shift in usage from auto to HSR, highways become less congested, leading to reduced maintenance costs and, in some cases, lower numbers of traffic fatalities. Moreover, although HSR is generally used for passenger transport only, it reduces bottlenecks on conventional rail routes, improves reliability, and increases the efficiency and capacity of freight traffic on conventional lines.

Hence, along with other minor benefits of transport infrastructure investments, the immediate benefit of travel time not only influences the short-run benefits of transportation infrastructure investment, such as economic productivity, but also affects other economic components (e.g., long-run impacts or external benefits), which further promote productivity.

- **Concept Two: Types of Effects of Transport Investment**
In order to fully understand the impact of transport investment, it is worthwhile to make a distinction among various types of impacts. Table 1 shows various types of effects of transport investment (e.g., direct vs. indirect and temporary vs. permanent). The economic impacts of HSR investments are considered to be primarily drawn from three parts. One is drawn from temporary HSR capital construction effects. Investments in HSR infrastructure are generally defined as a type of capital used for the construction and maintenance of transport facilities in urban areas. This type of study focuses on the effects of HSR capital investment on new job creation and on the growth of manufacturing and HSR-facility-related industries.

Table 2-1: Types of Effects of Transport Investment

<table>
<thead>
<tr>
<th>Types of Effects of Transport Investment (source: Oosterhaven and Knaap, 2003; Chen, 2013)</th>
<th>Temporary</th>
<th>Permanent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Via markets:</td>
<td>Construction effects</td>
<td>Exploitation and time saving effects</td>
</tr>
<tr>
<td>External effects:</td>
<td>Environmental effects</td>
<td>Environmental, safety, etc. effects</td>
</tr>
<tr>
<td>Indirect</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Via demand:</td>
<td>Backward expenditure effects</td>
<td>Backward expenditure effects</td>
</tr>
<tr>
<td>Via supply:</td>
<td>Backward expenditure effects</td>
<td>Productivity and location effects</td>
</tr>
<tr>
<td>External effects:</td>
<td>Indirect emissions</td>
<td>Indirect emissions, etc.</td>
</tr>
</tbody>
</table>

The second is based on the economic impacts of the travel time time saved due to HSR investment. This permanent direct effect is the major cause of transport investment. It is expected to improve the level of accessibility for various cities and to change the entire time-space boundary in invested corridors and regions.
Most interesting is the third type of effect of transport investment, called the permanent indirect productivity and location effect. This effect has to do with the consequences of newly created or relocated people and firms, with regard to the influence of non-uniform network of urban transport system. It is a major objective of investment for cities or regions. Through the literature review and research analysis of this study, I focus only on permanent indirect time saving effects and direct permanent productivity and location effects.

- **Concept Three: Agglomeration Economies by Types and Sources**

Transport investment could generate indirect permanent effects on urban agglomeration economies, which are always central to urban economics. At a broader level, agglomeration economies occur when agents (i.e., firms or workers) benefit from being close to other agents. Marshall (1920) addressed three sources of agglomeration economies that exist regarding the concentration of these agents: 1) *labour market pooling* – larger, denser labour market pooling provides incentives for workers to exchange knowledge, ideas and information; 2) *linkages between intermediate inputs and final good suppliers* – the concentration of economic activities saves transport costs and brings benefits to firms located near their suppliers and customers; and 3) *technological spillover* – a clustering of firms in specific fields leads to quicker diffusion or adoption of ideas.

Recently, an alternative taxonomy provided by Duranton and Puga (2004) described these three sources of agglomeration in depth. They name the sources *sharing*, *matching* and *learning*. Sharing mechanisms refer to the sharing of indivisible facilities, diverse pools of input suppliers (to reduce costs) and narrower specification and spread
risks. Matching refers to the benefits of having a dense pool of labour close to a larger pool of firms, including saving time on matching skills and tasks, on filling new positions (for the firms) and on searching and finding jobs (for the workers). Earlier matching between labour and firms can also reduce risk and increase competitiveness. Learning refers to the generation, diffusion and accumulation of knowledge. Even with fast communication technologies, highly concentrated workers and firms provide opportunities for face-to-face contact and create further chances for transferring knowledge and skills.

2.3. **THEORETICAL FOUNDATION: NEG THEORY AND BID-RENT THEORY**

Two fundamental theories support the existing empirical findings related to transport investment and economic performance. These are Krugman’s New Economic Geography (NEG) theory and classic bid-rent theory. The NEG theory emphasizes inter-city economic geography patterns and suggests that the emergence of large agglomerations relies on increasing transport costs and increasing returns to scale, while classic bid-rent theory explains economic distribution at the intra-city level. A detailed interpretation of each theory in relation to the HSR case follows.

As mentioned before, the NEG theory sheds light on the geographical concentration of economic activity, suggesting that a combination of market access and labour mobility results in an agglomeration effect under scale economies (Puga, 2008; Krugman, 1991). As the foundation theory in this study, NEG theory not only provides an explanation of the importance of agglomeration economies (i.e., sharing, matching and learning), but also
links transport costs with agglomeration economies at an inter-city level. Although this theory was built and based on the manufacturing industry, its essence can be applied to other industrial groups because it highlights transport costs as internal factors in determining the location of economic activity and emphasizes the linkage between firms and suppliers, as well as those between firms and consumers. For example, on the basis of this theory, Glaeser and Kohlhase (2003) argued that, if there were no transport costs, agglomeration economies could not exist, but that in today’s service-based economy, the mobility cost of people over space remains high. They argued that the advantages of proximity to a client/other people seem to stem from “saving the costs of providing and acquiring services and from improving the flow of knowledge”. This argument indicates that the value of travel time is still important in today’s distribution pattern of agglomeration economies.

At the intra-city level, classic bid-rent economic theory notes how urban patterns change with the distance to the Center Business District (CBD) in a monocentric city (e.g., Alonso, 1964; Muth, 1969). It indicates that the trade-off between commuting costs and land prices leads to residential and commerce locations. In this theory, jobs are assumed to be concentrated in a single CBD, while households live in residential communities that surround the CBD. The bid rent decreases with the distance from the CBD, reflecting the increased cost of commuting from distant locations to jobs in the CBD. For households, the decision of where to live will depend on relative preferences regarding housing and transportation costs. Similarly, firms generally choose the locations where they can pursue maximum profits by balancing their preferences against the costs of transporting inputs from suppliers and outputs to markets. Overall, businesses are more sensitive to
transportation costs than households. They are more willing than households to pay the higher land values of the CBD.

Hoyt, Harris and Ullman applied this logic to a non-monocentric model and discussed the role of transportation in shaping land use patterns from the perspective of transport networks, axes and nodes. In the special case of HSR, stations located either in the CBD or at the edge of the city provide higher access to other cities and increase the occurrence of high-density clusters around stations. This high-speed, rail-station oriented development pattern distorts the smooth downward sloping shape of the traditional bid-rent curve. However, the theory does not explain whether these newly clustered economic activities are newly created or simply relocated from other places or cities.

2.4. RELATED EMPIRICAL EVIDENCES

Under the framework of existing theories, many empirical studies have explored the linkage between HSR investment and urban economic development. Simply and relatively, the literatures are summarized and organized into three main categories: benefits to accessibility, benefits to urban agglomeration economies, and benefits to the spatial competition of firms. The first category refers to the short-term and direct benefits of HSR investment. The second and third categories refer to the long-terms and indirect benefits of travel time reduction on urban agglomeration economies and spatial economies. The number of empirical studies existing in the second category is quite low. Therefore, this study includes some general studies from transport investment and economic development, as well.
2.4.1. Benefits on Accessibility

According to existing evidence in the literature, there is no doubt that HSR has had significant impacts on travel time savings in major cities. Most of literature in this category is descriptive and suggests that high-speed rail investment is associated with lower travel times, higher comfort and travel reliability, reductions in the probability of accidents and, in some cases, the release of extra capacity, which helps to alleviate congestion in other modes of transport (Chen, 2013; Graham, 2007).

Generally, with a new HSR line open, user time for a round trip includes access time, egress time, waiting time and in-vehicle time. Evidence regarding travel time savings in the literature could be summarized by saying that, with the introduction of an HSR line, there are travel time savings of 45 to 50 minutes for distances in the range of 350 to 400 km. Access, egress and waiting time are practically the same.

In the case of the French TGV Atlantique, for example, Tours, at 240 km from Paris, showed a reduction in travel time from 130 minutes to 72 minutes, as well as a significant reduction in business traffic of 24% (INSEE). Nantes, 380 km from Paris, saw a reduction in travel time of 74 minutes (from 220 minutes to 136 minutes) after the introduction of the HSR service. In the case of Toulouse, 700 km from Paris, the average travel time to Paris was reduced by about 50 minutes. Overall, most French TGV cities have saved more than 40% of their travel times from/to Paris over the past thirty years (INSEE).

In the case of evaluating the overall accessibility pattern, many scholars from European countries have approved the improved accessibility patterns resulting from the availability of HSR services. For instance, Gutierrez (2001) evaluates the accessibility
pattern of the future Madria-Barcelona-French border HSR line using three types of accessibility indicators: weighted average travel times, economic potential and day accessibility. As a result, he finds that the effects of new-built accessibility depend on the geographic scale. Specifically, he concludes that there is a balancing effect that exists at the corridor and the European level because smaller cities obtain relatively more benefit than large cities, which were already highly accessible before the introduction of HSR lines (Gutiérrez J., 2001). Another study from Thompson (1995) focuses on the accessibility pattern of a major transport hub: Lyon, France. With the services of a high-speed railway, a motorway and an airport, Lyon not only has greatly integrated accessibility from Western Europe, but also maintains its gateway function to the region of Mediterranean. Thus, the impacts of HSR investments on travel time savings and on accessibility are conclusive.

2.4.2. Benefits to Agglomeration Economies

According to the theoretical framework of new economic geography, the existing studies in this field emphasize three major stands. The first focuses on the locations of production and exports, which, according to Krugman (1991) and essential to agglomeration theory, should concentrate close to large markets (David and Weinstein, 2008; Hanson and Chong, 2004). The second, which is similar to the first, focuses on technology diffusion and the impact of trade and industry location (Eaton and Kortum, 1999). These two stands have been well explored, both theoretically and empirically, and well explained in terms of why economic activity tends to concentrate in regional agglomerations. Lastly and importantly, the role of access to regional markets as a major force for economic growth has recently received increasing attention (Redding and
Venables, 2004; Head and Mayer, 2004 and Hanson, 1996, 1997, 2005). Similar to the major research question of this dissertation, this literature focuses more on the last stand, which involves improving economic growth by improving access to regional market.

So far, the evidence found in the last category, concerning the impacts of HSR investment on agglomeration economies, is mixed. On one hand, several recent studies suggest that HSR investments increase agglomeration economies. For instance, Graham (2007) studies the level of agglomeration based on impacts in the context of HSR in Britain. He finds that the magnitudes of agglomeration benefits corresponding to 5% and 50% increases in travel time are small. Graham’s other studies (2007) model firm-level productivity as a function of agglomeration, which is defined as employment accessibility. With transportation investment, he finds positive agglomeration elasticity for some industries, such as publishing and food manufacturing. The average elasticity is 0.129 with respect to employment accessibility. This indicates that, for every additional increase in accessibility, the productivity increases by 0.129 per cent.

Another good study was conducted by Chen and Peter (2011). They examined the spatial-economic impacts of high-speed trains (HSTs) in the United Kingdom and found that HSTs could generate renewed economic growth. Their studies demonstrated faster growth rates for populations and city economies on HST lines than for those that were bypassed, based on time series for before and after HST services. More importantly, these effects were largely concentrated in tourism-related activities.

On the other hand, several HSR scholars, including Vickerman (2007) and Chen (2013), emphasize that HSR services are more about maintaining current geography than changing it. They consider that HSR services alone are not sufficient to achieve an increase
in agglomeration economies. For instance, Burmeister and Colletis-Wahl (1996) suggested that about one-third of all business travel was changed due to the introduction of the TGV service in Lille. However, nearly 90% of firms indicated no impact of the TGV on their overall activity. Similarly, a recent study from France looked at 493 urban units (UUs) at INSEE between 1982 and 2006 (Koning, 2013). It found that there were significant differences between UUs served by high-speed rail lines (HSLs) and those served simply by high-speed trains (HSTs). The UU areas served by HSTs experienced better average performances, but the effect due directly to transport investment was negative. Meanwhile, the UUs served by the HSLs had lower rates of job growth, but the benefits obtained from the introduction of the HSR service was about 1.3%. Thus, this study suggests that the impacts of HSR services on job growth are mixed. They could be positive or negative. The findings of this study indicate that the effects are dependent on the type of HSR service.

Moreover, a comprehensive study comparing the effects of HSR services in the UK and France concludes that the wider effects of HSR services positively benefited passengers due to travel time reduction (Chen, 2013). However, HSR services alone are not sufficient to promote economic growth. Chen’s study emphasizes that many other factors and conditions are needed, too. For instance, this study performed a qualitative analysis on the role of public intervention in expanding the effects of HSR services. Its findings show that public intervention and strategic planning is critical – even more important than the factor attached to the transport system. In other words, good and efficient public intervention and strategic planning could lead the HSR city achieve maximum benefits from the introduction of an HSR system. Similar evidences could be found in Murakami and Cervero’ study (2010) as well.
2.4.3. Benefits to Spatial Competition

The literature on the benefits to spatial competition compares the impacts of a given change in transport provision on two or more different regions, especially in cases where there exist different conditions for transport infrastructure supply. This literature is still in dispute, and its possible comparative impacts, including spatial concentration and the specialization of firms, labour markets and property land values, are considered to be the most important impacts related to the spatial competition effect.

Major theories on the specialization and concentration of firms have contributed by some economists (e.g., Krugman, Hallet and Fujita) and further improved by others, such as Rossi-Hansberg (2005). Essentially, the effects of the decline of transport costs on specialization or concentration are not simple; rather, they can be presented as an inverted U-curve, as shown in the following figure (Krugman, 1991; Fujita, 2011). As mentioned before, the reduction of transport costs leads to a high cluster of industries and helps to form agglomeration economies. However, all related impact factors are non-linear and non-monotonic. The increasing concentration of industries may lead to diseconomies, not just by increasing the marginal costs of providing additional services, but also by bringing other detriments that arise with larger urban areas, such as crime, environmental issues, and congestion. As Figure 2 shows, in places where scale economies dominate, any reduction in transport costs may lead to a concentration of economic activity in larger core regions. Similarly, in places with a lack of scale economies and lower costs of inputs, such as wage and rent, decentration may occur instead of concentration. Whether there are too few or too many agglomeration economies is not clear. This leads to ambiguities in the impact of
transport investment on the relative performance of different regions (Venables and Gasiorek, 1999).

![Diagram of transport costs and agglomeration](image)

Figure 2-2: Transport Costs and Agglomeration (Source: Fujita (2011))

In empirical studies, the impact of HSR on French firms’ location decisions seems negligible. The initial study was done by Bonnafous (1987), who designed a survey to predict firm relocations before and after the inauguration of the Paris–Lyon HSR line. Bonnafous paid special attention to ten cities in Burgundy and the Rhone-Alps Region. He concluded that, during a period of economic recession, government intervention or economic recovery policies seem to play a more important role in location decisions than the availability of HSR services. However, Bonnafour noted that it is a challenge to isolate the effects of a new HSR service when tracking firm movements for just two or three years after the inauguration of the service. Two or three years might be too short a time to observe relocation patterns. Later on, Nyfer (1999) used Lyon as an example to show how regionally competing cities entice many firms to relocate near HSR stations. He mentioned that the Part Dieu station, a TGV station in Lyon, attracts a significant number of firms. For instance, the occupancy rates of office buildings in the area increased about 40%
between 1983 and 1990. Nyfer explained that this attraction is a result of improved accessibility. Eventually, he concluded that HSR services contribute to attracting firms, but that they are not a main factor.

### 2.5. CONCLUSION

In summary, this chapter begins with the definition of HSR services and their competitive advantages. The concept and types of agglomeration economies are introduced here as well. In order to facilitate a better understanding of the concept framework of economic impacts of HSR investment, this chapter summarized two major theories that support our findings (which are provided later). In addition, through a critical review of the existing literature on the spatial economies of HSR investment, it is clear that the introduction of HSR service can certainly improve mobility and accessibility among cities, especially in the case of major cities. However, improved accessibility alone is not sufficient to promote agglomeration economies. Many other factors and conditions should be considered, such as the role of public intervention, local strategic planning, types of HSR infrastructure and so on. In addition, the impacts of improved transport services are not powerful enough to stimulate firm relocation. The empirical evidence summarized in this chapter shows that the relocation effects of HSR are much weaker than theories suggest.
CHAPTER 3 : OVERVIEW ON FRENCH HSR SYSTEM
AND ECONOMY DEVELOPMENT

3.1. INTRODUCTION

The development of high-speed rail can be traced back to 1964, when the first “bullet train” was introduced in Japan. From 1964 to 1983, 3,300 km of HSR (High-Speed Rail) line were established all over the world. Most activities were dominated by Japan’s Shinkansen network and accounted for more than half of the total. From 1984 to 2009, about 8,700 km of high-speed services were provided. It is worth noting that more than half of them were built all over the world during the last six years of that period, with Spain (18%), France (17%), Germany (15%), and China (14%) leading the way (Gourvish, 2012). Over the past three years, Europe has become the leading contributor of HSR development.

France is an interesting case among European countries. Today, HSR is a national priority in France, as evidenced by its 2,037 km of the LGV line and its second-place ranking in Europe (close to number-one ranked Spain, which has 2,144 km). The HSR lines currently under construction will bring this total to 2,600 km by 2017. It carries far more passengers than any other European country. INSEE indicates that domestic passenger ridership on LGV lines has increased 100 times since the introduction of LGV service in 1981.

This study is going to focus French high-speed rail service and explore the role of time-saving travel in shaping urban agglomeration economies. As a background investigation on this relationship, this chapter will provide a broader view of the
The development of the HSR system and economic growth, thereby helping to understand the key research of this dissertation. To accomplish this, this chapter will particularly focus on the development of the French high-speed rail system, railway stations, passenger ridership, and, most importantly, travel time reduction and train frequencies over the past 30 years. Additionally, the economic performance in most French cities and regions is discussed.

The structure of the paper is as follows. First, the main phases and principal performance characteristics of LGV and TGV networks in France as well as HST are introduced and summarized. Second, from section 3.3 to 3.5, the evolution of travel time changes and train frequencies as a result of improved rail service are provided, as well as travel costs and passenger ridership. Third, this chapter will show the trend of population, employment, and economic structure changes associated with the development of French HST service. The final section will draw conclusions based on the information provided.

3.2. THE DEVELOPMENT AND CHARACTERISTICS OF FRENCH HSR NETWORK

Uniquely, the French HST network has mixed infrastructure systems. One type is called the Ligne à Grande Vitesse (LGV), a new, separate HSR network along congested links for accessing big cities. However, in order to avoid exorbitant construction and expropriation costs, the French government upgraded some segments of the conventional service and named it the Train à Grande Vitesse (TGV). The TGV network is located in less crowded and less demanding corridors as a supplement service of LGV. However, on average, both LGV and TGV provide rail service with an operating speed of above 250km/h, satisfying HST requirements.
3.2.1. French LGV (Ligne à Grande Vitesse) Network

The introduction of HSR service in France with a new, separate operational track, named LGV Sud-Est, was designed to mitigate traffic congestion on the rail link connecting Paris to Lyon. This LGV line was a milestone in the history of railways, with importance comparable to the Japanese Shinkansen of 1964. It was not only the first high-speed rail line in France, but it has also become a symbol of modern society.

After its establishment in 1981, the LGV Sub-Est line operated at 270 km/hr to produce a travel time of nearly two hours on the 450 km journey, with 20 return journeys per weekday (Bonnafous, 1987). The significant time saved traveling attracted a large number of passengers from more traditional travel modes. The total number of rail passengers, according to Vickerman (1997), increased from 12.5 million in 1980 to 22.9 million in 1992. About 18.9 million of them were HST passengers, and this number gradually increased to more than 25 million in 2008. According to a statistical survey in 1985, air traffic fell from 31% to 7% while rail traffic rose from 40% to 72% (Bonnafous, 1987). By 1993, this link had already been amortized, only 12 years after it began. Now, it carries more than 150 trains a day at an operational speed of 320 km/h.

The success of the LGV Sud-Est line led to the French government investing more funds to extend the line to other places, but always originating in Paris (summarized in Table 1). Over the past 30 years, many new LGV lines have been made to connect major French cities with Paris, namely the LGV-Atlantique (to Le Mans and Tours in 1989–90), the LGV-Rhône-Alpes (to Valence in 1992–94), the LGV-Nord (to Calais in 1993), the Paris interconnections (1994–96), the LGV-Méditerranée (to Marseille in 2001), the LGV-
Est (to Metz and Nancy in 2007), the LGV-Perpignan-Figueres (to Spain in 2010), and LGV-Rhin-Rhône (to Mulhouse, with the first phase opened in 2011).

Table 3-1: LGV Lines in France

<table>
<thead>
<tr>
<th>Operator</th>
<th>Primary HSR Lines</th>
<th>Open Year</th>
<th>Track Length(km)</th>
<th>Average Operational Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>SNCF</td>
<td>LGV Sud-Est</td>
<td>1981-1983</td>
<td>417</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LGV-Atlantique</td>
<td>1989-1990</td>
<td>281</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LGV-Rhône-Alpes</td>
<td>1992</td>
<td>121</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LGV-Nord</td>
<td>1993</td>
<td>333</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LGV-Méditerranée</td>
<td>2001</td>
<td>251</td>
<td>320km/h</td>
</tr>
<tr>
<td></td>
<td>LGV-Est</td>
<td>2007</td>
<td>300</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LGV-Perpignan-Figueres</td>
<td>2010</td>
<td>44</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LGV-Rhin-Rhône</td>
<td>2011</td>
<td>140</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lines Under Construction</th>
<th>Proposed Year</th>
<th>Track Length(km)</th>
<th>Planned Operational Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>LGV Est, second phase</td>
<td>2016</td>
<td>106</td>
<td></td>
</tr>
<tr>
<td>LGV Sud Europe Atlantique (Tours–Bordeaux)</td>
<td>2017</td>
<td>302</td>
<td></td>
</tr>
<tr>
<td>LGV Bretagne-Pays de la Loire (Le Mans–Rennes), Nîmes-Montpellier, bypass toward the border of Spain</td>
<td>2017</td>
<td>182</td>
<td>320km/h</td>
</tr>
</tbody>
</table>

Data Source: Summarized from *Railway Gazette International*.

Additionally, another four HSR lines (about 650 km total) are now under construction and will be in service by 2017 (shown in Table 1 and Figure 1). Most of them are extensions of existing HSR lines and expand HSR service to Eastern, Western, and Southern France. For example, LGV Sud Europe Atlantique (also known as LGV Sud-Ouest) is running between Tours and Bordeaux as an extension of the LGV Atlantique line.
It will improve the accessibility of southwestern France and provide a better connection to diverse parts of the country and the rest of Europe.

However, the French high-speed rail development plan does not end there. The massive expansion of HSR lines in France, an additional 11 lines, has been planned, totaling around 2,000 km of additional HSR by 2020\(^1\). These new planned HSR lines will not only keep improving HSR networks to primary French cities, but also keep expanding the service area of HSR to second-tier or even smaller cities by providing them a better link to major French cities. For example, the LGV Provence-Alpes-Côte d'Azur is planned to extend the LGV Méditerranée line towards the city of Nice, which is the fifth-most-populous city in France and is located on its southeast coast. It will shrink the travel time from Paris to Nice from 5hr 25 min to 3 hr 50 min, which is very competitive with air travel times. Another example is the second Paris-Lyon LGV line via the city of Orléans, which is located in central France. This LGV line will fill the gaps in central France where there is currently no LGV service or very little TGV service.

\(^{1}\) Railway Gazette International
3.2.2. French TGV (Train à Grande Vitesse) Network

The Train à Grande Vitesse (TGV) represents French high-speed train service with an average cruising speed of 250 km/h. The TGV does not aim to reduce travel time for short- and middle-distance travelers. Rather, it aims to improve long-distance interurban mobility. In particular, it focuses on business and leisure passengers (Crozet, 2013). Running on both LGV and existing conventional rail networks, TGV trains can reach a much wider network.

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which is four times longer than the dedicated LGV lines. In total, over 200 stations in France are now served by TGVs, shown in Figure 2. Due to its interoperability, investment in the LGV lines will also expand these benefits to TGVs and regenerate TGV cities, as evidenced by renovation of TGV stations in Rennes, Nantes, etc. (Crozet, 2013). Moreover, the moderate traffic on these TGV links helps to make TGV service more popular and accessible for customers.

Generally speaking, TGV service in many French journals represents both the LGV and TGV system. In this study, it is worth distinguishing these two types of infrastructure in order to examine their various impacts on economic growth. In the following chapters, HSR or HST denotes both LGV and TGV service.

As shown in Figure 2, the blue rail line represents LGV network while black lines show the network pattern of the TGV system. Most of the TGV stations (red circles) are located in less crowded and less demanding corridors as a supplement service of the LGV system. From the first TGV stations built in France, there have been 114 stations under the service, including both TGV and LGV stations. The mixed infrastructure of high-speed train service remains a model for the rest of the world. National Society of French Railways (SNCF) has successfully demonstrated how to extend fast, safe, and environmentally friendly high-speed train service to most of the country.
Figure 3-2: French TGV Networks

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3 Source: http://commons.wikimedia.org/wiki/File:Carte_TGV-fr.svg
3.2.3. Location of HSR Stations

France’s national railway network shows that 159 cities have TGV service (including LGV service). Based on data availability and population size, 107 cities are part of this study. Table 2 reflects the expanded coverage of high-speed train service from both LGV and TGV lines (only stations selected in this study) over the past 30 years. Both LGV and TGV stations have doubled in the first two time frames. But only about 20 HST stations have been built in the last time frame.

<table>
<thead>
<tr>
<th>Type of Service</th>
<th># of HST Stations opened</th>
<th># of HST Stations in Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>LGV</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>TGV</td>
<td>38</td>
<td>40</td>
</tr>
<tr>
<td>Total</td>
<td>42</td>
<td>44</td>
</tr>
</tbody>
</table>

Moreover, a significant number of TGV stations are concentrated and distributed based on high travel demand in regions of southeast France, including Rhône-Alpes, Provence-Alpes-Côte d'Azur, and Languedoc-Roussillon. The first two regions are respectively ranked as the second- and the third-strongest economies, followed closely by the top region called Île-de-France. The rest of them are dispersed on the west, southwest, and east regions of France.

The location characteristics of HSR cities are generally divided into three categories: central station, periphery station, and “beetroot” station. A central station is located in the center of the city, while a peripheral station is located in the outskirts of the city or urban area. Central and peripheral stations are typical in many countries. The last type of
“beetroot” station—is unique to France and is located in the open countryside, several kilometers from cities.

A good example of a central station is Paris. It has four major TGV stations in the city center, each serving different regions of France and Europe, namely Paris-Gare de l’Est, Paris-Gare de Lyon, Paris-Montparnasse, and Paris-Gare du Nord shown on the map below.

![Figure 3-3: TGV Stations in Paris (left) and Lyon (right)](image)

Lyon is another city that has both central and peripheral stations. It has two TGV stations in the city center. One is called Gare de la Part-Dieu, the primary TGV station in Lyon, situated in the Paris-Lyon-Marseille LGV line and serving as a significant hub. It is not only connected to SNCF but also international rail networks. Another station is Gare de Lyon-Perrache, as the terminus of the LGV-Sub-Est line from Paris. It is also served by conventional trains from other regions of France. In addition to these two TGV stations, it is worth noting that the third TGV station, a periphery station, is located about 20km east.

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of Lyon city center. It is called Gare de Lyon Saint-Exupéry and is directly attached to Lyon Saint-Exupéry Airport. This station is serving TGV trains on the LGV-Rhône-Alpes line, which is part of the primary line running from Paris to Marseille.

Few HSR stations and LGV stations are built in suburban areas or in the open countryside away from cities. This type of station has a nickname called la gare des betteraves, which means “beetroot station.” For example, LGV Haute Picardie station (shown below\(^5\)) is located halfway between the towns of Amiens and Saint-Quentin. When it was built, the press and local authorities criticized it for being too far away from any towns. Only two high-speed trains from Paris were scheduled to stop in this small station, so it did not attract passengers from either Amiens station or Saint-Quentin. In the same way, French transport politics brought about more beetroot stations in France. Another example is Gare de Lorraine LGV station (shown below\(^6\)) as an intermediate station between cities of Metz and Nancy. This station was located in a place with population of only about 800\(^7\). It is too far to attract travelers. Because of the small population size, this type of station is excluded from this study.

\(^5\) Source: modified based on figure from http://www.geopolymer.org/about/access-map
\(^6\) Source: http://commons.wikimedia.org/wiki/File:CarteLorraineTGV.svg
\(^7\) Source: INSEE, 2013
3.3. **IMPACT OF HSR INVESTMENT ON TRAVEL TIME REDUCTION**

Accompanied by the development of HST service in France, travel time among French cities by rail has been significantly reduced. To show this significance, this study collects travel time data among each agglomeration from the Thomas Cook European Railway timetable for the years of 1982, 1990, 1999, and 2009. In this background study chapter, the regional pattern of travel time to and from Paris are only provided here. The detailed evolution of travel time among 107 agglomerations will be discussed in next chapter.

In general, after the introduction of first LGV Sub-Est from Paris to Lyon and some parts of upgrading to TGV service, the reduction of travel time by rail is evident. Between 1982 and 1990, the average travel times to and from Paris were reduced about 18%. On the LGV service lines, high-speed trains brought travel time savings of 43 min (about 30%) from Paris to Lyon, 50 min (48%) from Paris to Le Mans, 36 min (29%) from Paris to Le Creusot, and 27 min (20%) from Paris to Macon. Similarly, on the TGV service lines, the
time to Aix-les-Bains was reduced from more than 5 hr to 3 hr, to Annecy to 3.5 hours, and to Avignon from 7 hr to within 4 hr. Similarly, from 1990–1999 and 1999–2009, cities either with high-speed train service or located on HST lines saved significant travel time to Paris, while cities without them did not.

Averaging travel time of these HST cities by regions can emerge spatial regional distribution of evolution of travel time changes to and from Paris over the last 30 years, shown in Figure 5 with highlighted regions receiving the most benefits from travel time saving, and Figure 6 with the spatial distribution of these prompted regions for each time period.

There is no doubt that the regional patterns of train time saving are highly associated with the introduction of HSR service in those regions. In addition, there are also two interesting points that can be summarized from the evolution pattern of train time reduction.

First, every newly opened HST station can cause a ripple effect. It not only directly influences regional patterns of train time saving in which new HST station are located, but also influences can be incrementally felt in nearby regions located on shared rail lines. For example, from 1982 to 1990, the introduction of the LGV line from Paris to Lyon improved the region of Bourgogne and Rhône-Alpes, where 30% of train time was saved to and from Paris. The regions of Languedoc-Roussillon and Provence-Alpes-Côte d'Azur, located in southeastern France, did not have any improved rail service during that time period; however, they got about 29% of travel time reductions to and from Paris, simply because they shared the same LGV line to Paris. Similarly, this ripple effect of new HST service can be easier found for 1990–1999 and 1999–2009.
Second, if we trace changes of train time saving over the past 30 years, 5 regions out of 21 are the biggest winners under the improved rail service. In order, they are Languedoc-Roussillon, Provence-Alpes-Côte d'Azur, Champagne-Ardenne, Lorraine and Alsace, and Nord-Pas de Calais. The marked improvement in accessibility of this region will be analyzed along with their economic growth in a later chapter.

Figure 3-5: Changes of Travel Time to/from Paris by Regions 1982–2009
Figure 3-6: Regional Pattern of Travel Time Changes to/from Paris
3.4. IMPACT OF HSR INVESTMENT ON TRAIN FREQUENCIES

On the TGV network, average changes of daily direct train frequencies is grouped and presented in Figure 7, reflecting average service changes from Paris on the daily direct train from 1982 to 2009. The total frequency of HSR services generally increased by 788 over time. According to the changes in magnitude over that period, train frequency changes can be grouped into five categories: 1) *above 10*, where cities increased about 11–20 train frequencies from Paris; 3) *1–10*, where cities improved train service by adding about 1–10 trains on daily service from Paris; 4) *0*, where cities retained the same number of train services; 5) *below 0*, where cities lost frequencies on daily train from Paris.

The changes of patterns are explicit. On one hand, about 56 cities gain the overall train frequencies and 72 cities gain specially in HSR train frequencies in the range of 1 to 10, and the other 5 HSR cities have even more train service that increase more than 10 frequencies. More significantly, HSR train service changes from Paris in some HSR cities increase more than 18. For example, Rennes, a city located in western France and on the extension service of the LGV line from Paris to Le Mans, has increased about 29 daily train frequencies from Paris in 1982–2009, with an increase of 18 overall rail frequencies.

On the other hand, daily overall train service in 24 French cities has remained the same as that of 1982. Most of these cities are located either in less dense areas or relatively small cities where having low travel demand means that service has remained largely unchanged. For example, city of Chateauroux, located in central France, has experience a gradual loss in population over that 30-year period. Meanwhile, a considerable number of HST cities, about 23 total, have lost daily train frequencies from Paris from 1982 to 2009.
One main reason for this phenomenon is the priority of TGV service in French cities that has focused on improving rail service from Paris to highly dense, rail-traffic-congested major cities while ignoring small French cities. For example an HST city named Arras, a commune with about 43,000 people and located northern of France, has reduced train frequencies from 22 to 13 on direct daily rail service to and from Paris. In addition, when SNCF provides HSR service for a city, HSR service will partially or completely replace the conventional rail service, but with the less frequencies.

![Pattern of Train Frequency Changes: 1982-2009](image)

**Figure 3-7: Pattern of Train Frequency Changes in 1982–2009**

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8 Data source: Thomas Cook European Railway Timetable, France. Train Frequencies are counted with the following criteria: 1) from Paris, 2) daily trains, 3) direct TGV train, if no TGV service in that city, the direct express train services are counted. If cities have neither direct TGV train nor direct express trains, train frequencies are counted from these cities via nearest TGV service shared on the same rail line to Paris with less than half hour of train transfer waiting time.
3.5. AFFORDABLE TRAVEL COST AND PASSENGER RIDERSHIP

Comparing French TGV train fares to those of high-speed rail systems in operation today demonstrates that French transportation systems are typically more economically affordable than America’s Acela Express, UK’s HSR1, and Germany’s ICE, as shown in Figure 8. Peer experience on specific high-speed routes shows that French-TGV rides cost about $0.26 a kilometer, similar to $0.25 for Madrid-Barcelona in Spain, but much less than $0.66 for Köln-Frankfurt on Germany ICE and $0.55 for London-Stratford International on UK’s HSR1 line. However, none of them can compete with rider cost for China’s CRH, which is only $0.07 a kilometer for Beijing-Shanghai in China. If we apply Chinese rider cost rate to the Acela Express service, it means that train fares from New York to Washington, D.C., costs only $25 for a one-way trip.

![Bar Chart: Passenger Rider Cost per Kilometer of Travel (US$)](image)

Figure 3-8: Passenger Rider Cost per km of Travel

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9 Data Source: Rail Europe, Amtrak, and trains.ctrip.com. All ticket price is the regular price and booked one week before the trip in the year 2013. Specific HSR routes are listed and attached in the APPENDIX.
The relatively affordable nature of travel by French TGV train makes passenger ridership, including international trips, increase since the first TGV station opened in 1981. As Figure 9 below shows, passenger ridership increased from 1.26 million in 1982 to 114.5 million in 2010, and the networks of TGV service expanded from 408 km to 2037 km. Meanwhile, it also clearly shows that there are two big leaping points when ridership dramatically increased. One is in the year of 1991, one year after the LGV-Atlantique line was opened. The TGV system carried about 37 million passengers in 1991, an increase of 17.84 million (93%) on the previous year that the LGV-Atlantique line was opened. The other jumping point is 2008, which is one year before the LGV-Est was opened. The passenger ridership reached 114 million during 2008, an increase of 17 million (18%) for the year of 2006.

![French TGV Passenger Ridership](image)

**Figure 3-9: TGV Passenger Ridership[^10]**

The TGV service with relatively affordable train fares has not only increased passenger ridership, but also has led to people traveling more frequency and farther in France. The following chart of passenger-kilometers traveled on TGV system demonstrates this. Passenger kilometers (pkm) is the unit of transport measurement used to measure the distance in kilometers traveled by passengers on the mode of transport. In other words, it is the distance traveled times the number of passengers traveling that distance. As the figure 10 shows, from 1994 to 2012, passenger kilometers traveled on domestic high-speed rail service presented a strong growth rate over the past 20 years, with slightly seasonally changes. Largely due to tourism, people traveled more during summers and less in winters in France. Overall, there were about 4.8 billion passenger-kilometers traveled on entire TGV network for July 2012, at a rate that has doubled since 1994.

Figure 3-10: Domestic Rail Passenger Transport by HST

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11 Data Source: INSEE.
3.6. POPULATION, EMPLOYMENT ECONOMIC STRUCTURE

As of 2010, France has the world’s fifth-largest economy and the second-largest national economy by nominal Gross Domestic Product (GDP). The total population in France increased from 54 million in 1982 to 62 million in 2009. With having a large and diversified industrial base, France is also the most popular tourist destination all over the world, hosting more than 80 million foreign tourists per year. That makes the service sector contribute the largest share about 79% of total output. Historical GDP growth rate reported by INSEE from 1982 to 2009 averaged around 0.5%, with two strong economic slowdown periods: 1) 1990–1994: GDP growth rate fell from + 0.7% to -0.7% in 1994. 2) 2008–2009: economy dramatically declined and reached a record low of -1.58% within 15 months. Understanding these two great recessions will help this study explain the evolution pattern of urban employment density and economic structure in France in later analysis.

3.6.1. Population and Employment in HST Cities

Table 3 shows the changes of population and employment in 1982–1990, 1990–1999, and 1999–2009 at city level. Using the city of Paris as a reference, an increase in population and employment occurred in HST cities on average. Even during the economic recession period of 1990–1999, population increased about 1.9% in HST cities, while Paris lost about 1%. Employment increased about 2.9%, while Paris lost about 12% of in-city jobs. Within these HSR cities, surprisingly, TGV cities have a stronger performance than LGV cities in terms of relative population growth and job density. LGV cities, like in the

12 Unit of analysis: commune in INSEE
city of Paris, experienced population decrease during 1982–1990. Employment density declined during economic slowdown and later gained about 10% employment density in latest 10 years. Meanwhile, TGV cities kept around 2% of population growth in the most recent 10-year time periods. Employment increased about 12.2% within the time period of 1999–2009.

Table 3-3: Changes in Population and Employment

<table>
<thead>
<tr>
<th>Categories</th>
<th>% of Changes in Population and Employment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>City of Paris</td>
</tr>
<tr>
<td>Population Change 1982-1990</td>
<td>-1%</td>
</tr>
<tr>
<td>Population Change 1990-1999</td>
<td>-1%</td>
</tr>
<tr>
<td>Population Change 1999-2009</td>
<td>5%</td>
</tr>
<tr>
<td>Employment Density Change 1982-1990</td>
<td>0%</td>
</tr>
<tr>
<td>Employment Density Change 1990-1999</td>
<td>-12%</td>
</tr>
<tr>
<td>Employment Density Change 1999-2009</td>
<td>12%</td>
</tr>
</tbody>
</table>

Data Source: INSEE, Census.

3.6.2. Economic Structure in HST Cities

Job and labor market data in France can be disaggregated into the 14 major industrial categories on the small district scale (commune) by INSEE, shown in Table 4. In order to explicitly display the economic structure in France, these 14 major categories were aggregated correspondently into six core business categories: 1) manufacturing, 2) social service, 3) leisure service, 4) knowledge business, 5) logistics, and 6) construction industry.
Table 3-4: Categories of Economic Structure

<table>
<thead>
<tr>
<th>Job Functions</th>
<th>Common Business Categories</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Manufacturing</td>
<td>1. Manufacturing</td>
</tr>
<tr>
<td>• Health</td>
<td>2. Social Service</td>
</tr>
<tr>
<td>• Education</td>
<td></td>
</tr>
<tr>
<td>• Culture, Leisure</td>
<td>3. Leisure Service</td>
</tr>
<tr>
<td>• Local service</td>
<td></td>
</tr>
<tr>
<td>• Public administration</td>
<td>4. Knowledge Business</td>
</tr>
<tr>
<td>• Intellectual service</td>
<td></td>
</tr>
<tr>
<td>• Management</td>
<td></td>
</tr>
<tr>
<td>• Design/research</td>
<td></td>
</tr>
<tr>
<td>• Transportation and logistics</td>
<td>5. Logistics</td>
</tr>
<tr>
<td>• Business to business</td>
<td></td>
</tr>
<tr>
<td>• Distributions</td>
<td></td>
</tr>
<tr>
<td>• Building public work</td>
<td>6. Construction Industry</td>
</tr>
<tr>
<td>• Maintenance</td>
<td></td>
</tr>
</tbody>
</table>

Table 5 shows the changes of economic structure in 1982–2009 on both LGV and TGV cities, using Paris as a reference. At the commune level, the smallest geography unit in France, the averaged HST cities have a stronger growth in type of economic activities for knowledge business, leisure service, and social service on average than the highly concentrated economic activity center—Paris.

The hypothesis underlying this study poses that the introduction of the high-speed train could boost economic restructuring toward knowledge-based economic activities and tourism. Cities that provide both LGV and TGV service have seen evidence of this shifting of economic structure. If compared TGV with LGV, the results show that TGV cities have a slightly stronger relative increase than LGV cities. For example, percentage of changes in knowledge business in TGV cities have increased about 12%, 7%, and 18% in three 10-year periods of 1982–2009m while LGV has grown less, about 7%, 3%, and 15%, respectively.
Table 3-5: Changes in Economic Structure

<table>
<thead>
<tr>
<th>Categories</th>
<th>% of Changes in Employment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Paris</td>
</tr>
<tr>
<td><strong>Total 1982-1990</strong></td>
<td></td>
</tr>
<tr>
<td>Knowledge Business</td>
<td>0%</td>
</tr>
<tr>
<td>Construction Industry</td>
<td>-2%</td>
</tr>
<tr>
<td>Logistics</td>
<td>-2%</td>
</tr>
<tr>
<td>Leisure</td>
<td>17%</td>
</tr>
<tr>
<td>Social Service</td>
<td>17%</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>-27%</td>
</tr>
<tr>
<td><strong>Total 1990-1999</strong></td>
<td></td>
</tr>
<tr>
<td>Knowledge Business</td>
<td>-12%</td>
</tr>
<tr>
<td>Construction Industry</td>
<td>-24%</td>
</tr>
<tr>
<td>Logistics</td>
<td>-19%</td>
</tr>
<tr>
<td>Leisure</td>
<td>4%</td>
</tr>
<tr>
<td>Social Service</td>
<td>9%</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>-37%</td>
</tr>
<tr>
<td><strong>Total 1999-2009</strong></td>
<td></td>
</tr>
<tr>
<td>Knowledge Business</td>
<td>12%</td>
</tr>
<tr>
<td>Construction Industry</td>
<td>11%</td>
</tr>
<tr>
<td>Logistics</td>
<td>3%</td>
</tr>
<tr>
<td>Leisure</td>
<td>17%</td>
</tr>
<tr>
<td>Social Service</td>
<td>18%</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>8%</td>
</tr>
</tbody>
</table>

**Data Source: INSEE**

3.6.3. Trend on Economic Distribution by Region

Along with massive infrastructure investment, travel time is not only a changed element. Moreover, the distribution of new population, employment, and economic activities have been changed and shifted at the regional level in 1982–2009. Table 6 displays the trend of changes in population, employment, and economic structure by seven region areas, including Ile de France, North, West, Central France, East, Southwest, and Southeast, associated with the number of LGVs and TGVs in that region.

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13 The map of region areas are shown in Appendix
This table explicitly displays three main trends. Firstly, during the time period of 1982–1999, new economic activities are heavily distributed and concentrated around Paris metropolitan areas (Ile de France). Particularly, after the arrival of the HSR from Paris to Lyon in 1981, while population in this region increased the same rate as that in the southeast region, total employment gained about 41%. More impressively, jobs in knowledge business and leisure have relatively increased about 129% and 166%, respectively. In the following 10 years, although tourism-based activities have increased more in the east region, where the second HSR line just started to operate there, overall employment and knowledge-based business retained a higher performance than other regions.

Secondly, the cluster of new knowledge businesses have been moved from Paris’s metropolitan area to the southeast region, where 46 cities are served by HST, much more than any other region. In 1999–2000, the southeast region has obtained more new knowledge-based economic activities, as shown by the 46% increase in 1999–2009. It is much higher than the increase of 6% in the region of Ile de France and the 13%-24% increase in other regions.

Thirdly, relocation effects of HST service in a region need not be a simple “zero-sum” game. All regions in France have shown a positive and strong advance in knowledge-intensive businesses and tourist-oriented leisure service. These time-sensitive business industries relocating from somewhere to a more accessible regional capital or regional business center could generate net increases in economic development that could have wider economic impact benefits on the entire regions (Cervero & Aschauer, 1998; Weisbrod, 2009). However, this impact of the study area will be examined in a later study.
Table 3-6: Trend of Economic Structure by Region

<table>
<thead>
<tr>
<th>Region</th>
<th>Ile de France</th>
<th>North</th>
<th>West</th>
<th>Central France</th>
<th>East</th>
<th>South West</th>
<th>South East</th>
</tr>
</thead>
<tbody>
<tr>
<td>LGV</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>4</td>
<td>5</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>TGV</td>
<td>3</td>
<td>14</td>
<td>30</td>
<td>12</td>
<td>15</td>
<td>23</td>
<td>40</td>
</tr>
<tr>
<td>TOTAL Fast Train Cities (159 stations)</td>
<td>6</td>
<td>17</td>
<td>31</td>
<td>16</td>
<td>20</td>
<td>23</td>
<td>46</td>
</tr>
<tr>
<td>PopChange_99-09</td>
<td>6%</td>
<td>-1%</td>
<td>1%</td>
<td>-3%</td>
<td>0%</td>
<td>5%</td>
<td>7%</td>
</tr>
<tr>
<td>PopChange_90-99</td>
<td>-2%</td>
<td>3%</td>
<td>4%</td>
<td>-3%</td>
<td>2%</td>
<td>3%</td>
<td>2%</td>
</tr>
<tr>
<td>PopChange_82-90</td>
<td>-1%</td>
<td>-3%</td>
<td>1%</td>
<td>-2%</td>
<td>2%</td>
<td>0%</td>
<td>5%</td>
</tr>
<tr>
<td>Employment Change 82-90</td>
<td>41%</td>
<td>2%</td>
<td>3%</td>
<td>0%</td>
<td>7%</td>
<td>6%</td>
<td>10%</td>
</tr>
<tr>
<td>KN_82-90</td>
<td>129%</td>
<td>12%</td>
<td>11%</td>
<td>7%</td>
<td>22%</td>
<td>16%</td>
<td>25%</td>
</tr>
<tr>
<td>CON_82-90</td>
<td>20%</td>
<td>-2%</td>
<td>-5%</td>
<td>-1%</td>
<td>14%</td>
<td>0%</td>
<td>5%</td>
</tr>
<tr>
<td>LOG_82-90</td>
<td>33%</td>
<td>0%</td>
<td>4%</td>
<td>2%</td>
<td>18%</td>
<td>9%</td>
<td>12%</td>
</tr>
<tr>
<td>LEI_82-90</td>
<td>166%</td>
<td>15%</td>
<td>17%</td>
<td>13%</td>
<td>6%</td>
<td>20%</td>
<td>37%</td>
</tr>
<tr>
<td>SOC_82-90</td>
<td>37%</td>
<td>20%</td>
<td>22%</td>
<td>22%</td>
<td>24%</td>
<td>34%</td>
<td>17%</td>
</tr>
<tr>
<td>MAN_82-90</td>
<td>0%</td>
<td>-23%</td>
<td>-17%</td>
<td>-21%</td>
<td>-16%</td>
<td>-15%</td>
<td>-15%</td>
</tr>
<tr>
<td>Employment Change 90-99</td>
<td>11%</td>
<td>1%</td>
<td>9%</td>
<td>-1%</td>
<td>8%</td>
<td>7%</td>
<td>2%</td>
</tr>
<tr>
<td>KN_90-99</td>
<td>26%</td>
<td>8%</td>
<td>14%</td>
<td>4%</td>
<td>13%</td>
<td>16%</td>
<td>8%</td>
</tr>
<tr>
<td>CON_90-99</td>
<td>-12%</td>
<td>-11%</td>
<td>-2%</td>
<td>-11%</td>
<td>-7%</td>
<td>-1%</td>
<td>-12%</td>
</tr>
<tr>
<td>LOG_90-99</td>
<td>0%</td>
<td>-4%</td>
<td>3%</td>
<td>-3%</td>
<td>14%</td>
<td>2%</td>
<td>-1%</td>
</tr>
<tr>
<td>LEI_90-99</td>
<td>13%</td>
<td>24%</td>
<td>29%</td>
<td>24%</td>
<td>95%</td>
<td>24%</td>
<td>23%</td>
</tr>
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3.7. CHAPTER CONCLUSIONS

The basic background study on the French HSR system suggests a large integrated high-speed rail network has been developed in the past 30 years. It has not only led to
significant time-space convergence but also has attracted a considerable number of passengers due to affordable ticket prices and reasonable daily train frequencies. However, the changes in travel time savings and the level of train frequencies in each agglomeration is not uniform. The priority of high-speed rail investment is still dense urban areas.

On the other hand, the spatial economic geography pattern in France has changed gradually over time. The economic structure has been shifted from a manufacturing structure to a service-orient structure like knowledge-based service and tourism-oriented service. The new cluster of knowledge-based economic activities has been moved from Paris to parts of southeastern France like Marseille and Nice.

Nevertheless, the key question—how greater convergence generated by HSR service may change the agglomeration economies of cities—still cannot be determined from this chapter. Whether the improved accessibility could enhance agglomeration at the city level or whether this time-space convergence could re-order the hierarchy of urban system or power enough to redistribute economic activity, will be discussed in the next three chapters.
CHAPTER 4 : EVOLUTION OF INTERCITY ACCESSIBILITY

4.1 INTRODUCTION

High-speed rail (HSR) networks have the potential to change time-space geography and make cities seem closer to each other by improving accessibility. In the French context, one such network connecting Paris to other major cities is considered the strategic backbone of the French transport system. Since the introduction of the first French HSR line in 1981, several studies have analyzed the changes in accessibility along the HSR corridor or have focused on major cities, such as Lyon, Marseille, or Toulouse (Vickerman, Spiekermann, & Wegener, 1999). However, few studies have considered or observed the evolution of the intercity accessibility patterns associated with the wider development of France’s HSR network. More importantly, existing large-scale studies are based on predicted travel time rather than real train time (Gutiérrez, González, & Gómez, 1996).

To fill this gap, the current chapter provides a comprehensive picture of the evolution of inter-city accessibility patterns between 1982 and 2009 in France. This study presents the impact of accumulated HSR investment on intercity accessibility, paying special attention to two major components: 1) intercity accessibility from each selected HSR city to/from Paris using real train time and train frequencies, and 2) intercity accessibility patterns by HSR based on 107 selected cities using real time. To measure accessibility, a gravity-type model—economic potential—was selected and is used to identify the spatial distribution of accessibility in France, emphasizing the effects of HSR,
and locating intercity accessibility changes. Eventually, accessibility maps from a Geographic Information System (GIS) will indicate that greater gains in intercity accessibility are made by mega-cities (e.g., Marseille and Lyon) and regional capital cities (e.g., Rennes), than by other western coastal cities and hinterland cities, regardless of absolute increases or relative changes in accessibility. Overall, the most improved accessibility to Paris or other cities is associated with the development of the Ligne à Grande Vitesse (LGV) network. In short, the cities located on the LGV network enjoy more accessibility benefits, especially the cities on the southern border of the southeastern region of France, which have experienced considerable changes—both relative and absolute.

This paper is divided into seven main parts. Section 2 reviews the recent studies on French intercity HSR accessibility. Section 3 discusses methods for measuring accessibility indicators. Section 4 describes the travel times and populations that are used in this study as well as the measures of accessibility indicators. In Section 5, the accessibility impact of high speed rail development on each agglomeration to/from Paris according to the indicators selected is discussed. Section 6 extends the study to focus on the changes in accessibility patterns among the 107 agglomerations, and explores the evolution of accessibility patterns associated with the introduction of HSR service. The chapter’s findings are summarized in section 7.

4.2 STUDIES ON FRENCH HSR INTERCITY ACCESSIBILITY

Studies on French intercity high-speed rail accessibility can be grouped in two major categories: 1) accessibility studies on European transportation network that partially
includes French rail network, 2) studies on changes of accessibility due to a new built French transport line or a transport hub.

Accessibility studies on European transport network: a series of empirical evidences from this group demonstrated that there is no doubt that rail investment has had significant impacts on changing the time-space map of Europe (Spiekermann & Wegener, 1994; Gutiérrez & Urbano, 1996; Vickerman R., 1995; Martin & Reggiani, 2007). For example, Gutierrez et al., (1996) illustrate the absolute and relative changes in accessibility as a results of European high-speed rail network development. They use a weighted average distance indicator to measure accessibility. Comparing 1993 high-speed rail network with the predicted 2010 network, the study suggests that the improved accessibility pattern is distorted by the presence of railway lines, especially those which offer the possibility of traveling at higher speeds. This distorted pattern are highly associated with the location of high-speed rail stations or along high-speed rail corridors. It also means that HSR network will increase the imbalances between major cities and their hinterlands.

Another a great piece of work on European high-speed rail network came from Vickerman et al., (1997). This comprehensive study examined the changes of accessibility from trans-European Networks by adopting two approach: economic potential and daily accessibility as a way to quantify the level of accessibility. Albeit based on a different indicator, this study also made a similar conclusion as Gutierrez et al., (1996) did. They found that the effect of TENs may reinforce the absolute dominance of the major economic centers, but may also increase difference between central and peripheral regions.
Meanwhile, another interesting work from Vickerman and Ulied (2009) argues that medium or small cities in the center of Europe will receive more relatively increases in accessibility than large metropolitan areas, especially the cities located far away from economic center of Europe. However, overall, relative accessibility across various cities may not change significantly (Vickerman & Ulied, 2009).

Accessibility studies on specify transport line or transport hub: empirical evidences from this group provide similar conclusion as that in the previous group. There is no doubt that high-speed rail investment would significantly reduce travel time among major cities as well as increase level of accessibility of medium or small cities. For example, Gutierrez (2001) evaluates the accessibility pattern of the future Madria-Barcelona-French border HSR line by using three types of accessibility indicators: weighted average travel times, economic potential and day accessibility. As a result, he finds the effects of new built accessibility depend on the geographic scale. Specifically, he concludes that there is a balancing effects exist at the corridor and European level. Because smaller cities obtain relative more than large cities where already highly accessible even before the introduction of HSR line. (Gutiérrez J., 2001)

Another study from Thompson (1995) focuses on the accessibility pattern of major transport hub: the case of Lyon, France. With the service of high-speed rail, motorway and airport, Lyon not only has greater integrated accessibility from Western Europe, but also will keep maintain its gateway function to the region of Mediterranean. Later, (Chen & Hall, 2011) studies travel time saving brought by high-speed rail investment in the Nord-Pas de Calais region of France. Although she doesn’t develop an accessibility indicator, Chen discusses the impact of TGV-Nord line on travel time reduction by looking at both
intra-regional, inter-regional and international level. She concludes that newly built high-speed rail service enables Lille to become an important transport hub. In addition to reinforce its accessibility to Paris, Lille also gains accessibility to London, Brussels and other major French capital cities, such as Marseille and Lyon.

Overall, studies on French intercity high-speed rail accessibility provide the vision on accessibility pattern of high-speed rail network at the border view. However, either analysis on absolute change or relative change can not provide detailed information on accessibility of French high-speed rail development. Moreover, most studies in this group adopt predicted access time rather than real train time. Only few studies, such as Chen & Hall (2011) use the real high-speed rail train time table. To improve this type of study, this chapter is going to use real high-speed rail travel time to conduct accessibility pattern in 1982, 1990, 1999 and 2009, and further to compare their absolute and relative changes of accessibility in 107 French HSR cities, provided in later.

4.3 ACCESSIBILITY INDICATORS

Accessibility, as fundamental topic, has been widely studied in urban and transportation planning (Hansen, 1959; Grengs, Levine, J, & etc, 2010; Litman, 2011). Accessibility refers to the ease of reaching goods, services, activities and destinations, which all together are called opportunities (Handy, 2002). It emphasizes particularly “the potential interaction and exchange” during travel and gives prominence to travel choice (Hansen, 1959). Thus, improving accessibility is a key element in the goals section in almost all transportation plans in the US (Handy, 2002).
However, accessibility is not easy to define in quantifiable terms. Many various types of indicator measures are used in empirical studies (Morris, Dumble, & Wigan, 1978; Gutiérrez & Urbano, 1996; Handy & Niemeier, 1997). To carry out this study, this study focuses only on one of gravity-type accessibility measures, called economic potential model. This model captured the key elements in quantifying accessibility: 1) an attractiveness factor or location characteristics, which indicates the qualities of the suitable destinations, 2) an impedance factor, which refers the characteristics of transport linkage/network, usually measured by travel time and travel cost (Vickerman R. , 1974; Handy S. , 2002)

The standard approach of economic potential model is followed by Clark & Wilson (1969) and Keeblea, Owensb, & Thompsona (1982). The basic logic of this approach is that the spatial interaction can be measured as a function of distance or travel time cost. It focuses to quantify the accumulated opportunities of interaction for one location with others. This indicators are also used widely used in many empirical studies (Keeblea, Owensb, & Thompsona , 1982; Linneker & Spence, 1991; Smith & Gibb, 1993). For example, study from Linnerker and Spence (1991) adopts a gravity-type measure to evaluate the impact of a new invested federal highway around London and display how accessibility pattern changes associated with new added transport linkage. The classical mathematical expression is as follows:

\[
A_i = \sum_{j=1}^{n} \frac{M_j}{T_{ij}}
\]
Where $A_i$ is the economic potential of place $i$, $M_j$ is the mass of the destination urban agglomeration of place $j$, $T_{ij}$ is the transport cost between place $i$ and place $j$, $\alpha$ is a distance-decay parameter. In most studies, it is often set as 1 in empirical studies.

In the context of high-speed rail, this economic potential indicator could represent the strength of economic linkage of a place with other city agglomerations. The higher the value attained, the more accessible this location is.

4.4 DATA AND METHODS

In order to calculate accessibility changes associated with the development of HSR networks in France in the 1982–1990, 1990–1999, and 1999–2009 time periods, 107 city agglomerations with populations over 10,000 inhabitants and served by HSR networks were chosen as centers of economic activity. The population data for these agglomerations were obtained from French National Institute of Statistics and Economic Studies (INSEE) census data at the city (called commune in French) level.

Meanwhile, real scheduled travel time by HSR is considered an impedance factor in calculating accessibility indicators. Travel time from these 107 agglomerations to/from Paris, and the travel times between each agglomeration were individually calculated by Thomas Cook Rail Timetables in 1982, 1990, 1999, and 2009. The calculation of train time from a comprehensive and complex train timetable is intricate. To enable calculations and make them more realistic, the following criteria are considered in this study:
- Train times are based on timetables for the month of April for each year in order to avoid the peak summer season and the winter off-season, and are averaged according to daily time schedules to/from Paris and other cities.
- Average train time includes regular SNCF (French National Railway Company) conventional train services (including rapid, express train, and inter-city regional trains) and HSR service. However, in the present study, only direct trains from one agglomeration to another, including both domestic and international trains, are considered.
- Some cities have more than one train station. When assessing train frequency, all stations in the same city were counted together if the same train stopped at both stations. Otherwise, they were considered separately.
- When assessing daily rail service, only trains that run at least four days per week were considered; trains that operate only on weekends were excluded.
- Trains that are scheduled temporarily, such as only for short periods during the year or only on certain holidays, were also excluded.

In this study, average train times for both conventional rail services and HSR service were considered, rather than the shortest travel time only from the latter service for two reasons. First, using average train times more closely reflects reality, thereby providing greater accuracy in establishing an accessibility index. Typically, HSR services provide the shortest travel times between cities, but it doesn’t mean that the introduction of HSR service could replace all types of train service and immediately promote the overall accessibility. Second, train frequency is an important factor in determining the level of a
rail service. Calculating average train time provides an opportunity to account for total train frequencies to/from Paris. For example, Cannes has only five trains to/from Paris, with an average travel time of 573 minutes. Among these five train frequencies, only one of them is a TGV service with the shortest travel time of 390 minutes. It cuts the train time from 618 minutes to 573 minutes, which is almost the same as the average scheduled train time in 1982. Thus, HSR service provide an option for traveler to save travel time, but whether HSR service can generally reshape the time space linkage to/from Paris that depends on the quality of HSR service.

In this chapter, the study focuses on evolution of two accessibility patterns: 1) accessibility of 107 agglomerations to/from Paris, 2) accessibility pattern among 107 agglomerations.

To measure the accessibility of each agglomeration to/from Paris, this study adopted a modified economic potential model in which travel time is main indicators. However, the attractiveness of Paris to other cities is constant. Thus, this study set $M_j$ in equation 1 as 1. The indicator can be expressed as follows.

$$A_i = \sum_{j=1}^{n} \frac{1}{T_{ij}}$$

Similarly, where $A_i$ is the economic potential of place $i$, $T_{ij}$ is the transport cost between place $i$ and place $j$, $c$ is a distance-decay parameter, assumed to equal 1.

In order to add frequencies as another impedance factor, a method from Bruinsma and Rietveld (1995) are adopted here. This study mentions that the total travel $T$ is consist of three basic elements:

$$T = V + RT + I$$
Where V is penalty because one can not depart at the desired moment in rail service. RT is real travel time, and I is time for checking in and checking out. However, the checking in and checking out doesn’t fit rail service. This study assumes I as 0.

The penalty V is estimated as follows.

\[ V = \frac{4E}{F} \]

Where E is the effective travel period. In this study, the effective travel period covers 24 hours a day. Thus, E is equal to 24 hours in this study. F indicates the train frequencies of that effective travel period.

To combine these equations together, the accessibility indicator can be calculated by using the following expression;

**Equation 2: Accessibility to/from Paris**

\[
A = \sum_{i,j} \frac{1}{T_{ij}} = \sum \frac{1}{tt_{ij} + \frac{4E}{F}}
\]

To calculate accessibility pattern on the national level, this study conduct a 107*107 time matrix among each agglomerations in the year of 1982, 1990, 1999 and 2009. The standard economic potential model are used in this part, shown as follows.

**Equation 3: Accessibility among 107 agglomerations**

\[
A_i = \sum_{j=1}^{n} \frac{M_j}{\frac{M_j}{T_{ij}}} = \sum_{j=1}^{n} \frac{M_j}{T_{ij}}
\]

Where \( A_i \) is the economic potential of place \( i \), \( M_j \) is represented by the size of population of place \( j \), \( T_{ij} \) is the rail travel time between place \( i \) and place \( j \), \( \alpha \) is a distance-decay parameter, as assuming equal to 1.
To display the evolution of accessibility pattern over time, this study uses Geographical Information System (GIS) to visualize the spatial and temporal pattern of accessibility. In the recent existing studies, three approaches are used. One is using a time-space map to visualize the impact of transport infrastructure on spatial structure (e.g., Vickerman, Spiekermann, & Wegener, 1999). The basic elements of this approach is using travel time instead of physical distance to proportion their relative geographical location. In other words, agglomeration centers are separated by travel time. The short travel time between two agglomerations results in their presentation close together on the map. It is straightforward to indicate that areas where rail service is performing well and other areas where it is inefficient. However, this method is good at displaying the changes at the boarder scale of view. The detailed of changes, especially changes in small agglomeration may be fade out in this type of approach.

The second type of approach is to spread accessibility based from limited accessible rail stations to the whole region (e.g., Gutiérrez & Urbano, 1996). This method interpolates the isoaccessibility regions from accessible regions. However, given the context of France, the whole region is not flat. If using this method, it may mislead and deviate enormously from reality.

The last approach is building nodal accessibility (e.g., Bruinsma & Rietveld, 1998). The size of points is proportional to their accessibility of that economic node. This study is going to adopt this method. It is not only keeping this study rigorous, but also clearly and directly ahead to appear the changes of accessibility for each agglomeration that associated with the construction of transport infrastructure.
4.5 EVOLUTION OF ACCESSIBILITY PATTERNS TO/FROM PARIS

Using statistical equation 1, this study established an index of accessibility to/from Paris based on daily train travel time and total daily train frequencies. Figure 1 shows the evolution of accessibility to/from Paris from 1982–2009 with absolute and relative changes displayed in the left and right images, respectively. Each node in the map represents each agglomeration in the study. The legends in both maps indicate the various sizes of the nodes, symbolizing the hierarchy of the urban systems, grouped into four categories: 1) major cities, 2) big-medium cities, 3) small-medium cities, and 4) small cities. The colors of the nodes signify the absolute values or relative changes in the level of economic potential. It is worth noting that relative changes can be expressed as either percentage share or ratio. In the present study, relative changes are expressed in the accessibility index as ratios for the period from 1982 to 2009.

In the absolute values (the left-hand figure), the average variation in the economic potential of the cities that are located along the LGV line or on extensions of the LGV lines are much greater than those located elsewhere. Cities, such as Le Mans and Tours (shown in dark blue), located on the LGV line have enjoyed more economic potential than cities located on extensions of the LGV network, such as Rennes and Nantes (shown in light blue). However, both of these groups have greater accessibility than cities (shown in light green) located farther from the LGV network or farther from the city of Paris, such as cities located on the southern border of France. This is due to the fact the potential indicators in this sector are based on travel time and train frequencies to Paris only, so that most French cities located far from the LGV lines undergo very little variation in their potential values.
In other words, the absolute values of the differences are due to distance-decay from the city of Paris.

In relative values, although the general pattern remains the same, it is clear that major cities, no matter where they are located relative to Paris, with highly reduced travel time and improved daily train frequencies, have higher values on the accessibility index.
Figure 4-1: Absolute Changes (left) and Relative Changes (right) in Accessibility to/from Paris: 1982-2009
The absolute changes and relative changes, organized by hierarchy of urban systems, are shown in Table 1. In order to highlight the role of LGV service in the overall rail system, it is listed separately in the table and the accessibility of cities that receive LGV service are indicated.

Table 1 presents the evolution of accessibility between each agglomeration and Paris. Overall, the development of HSR service brought about an improvement in accessibility of 61% between each agglomeration and Paris (see Table 1). However, LGV cities, such as Lyon, Marseille, and Lille, have experienced more than 90% improvement in accessibility to/from Paris.

Three interesting patterns are evident in Table 1. First, there is no doubt that the development of HSR service significantly promotes the level of accessibility to a national economic center—Paris. The magnitude of the changes in accessibility for each size of city can be reflected by this point. For example, small-medium cities, such as Sete, Macon, and Tarbes, enjoy easier access to/from Paris, with accessibility levels increasing from 44.89 in 1982 to 77.63 in 2009. Meanwhile small-medium cities with LGV service reached 101.01 in 2009 from their initial accessibility levels of 44.91. Similar patterns can be found in major cities, big-medium cities, and small cities.

Second, the absolute values and relative changes for each category of LGV cities indicate that major LGV cities and big-medium LGV cities, such as Lyon, Nice, Calais, and Cannes, experienced relatively smooth improvement in terms of accessibility to Paris in three time periods: 1982–1990, 1990–1999, and 1999–2009. For example, although all major cities experienced lower accessibility increases for the 1990–1999 time period, some major cities with LGV service experienced increases of 25% (13.81), 29% (19.86), and 27%
(23.98), respectively, within each time period. Nevertheless, small-medium and small LGV cities were more highly concentrated in the first two time periods in order to be more connected to Paris. For instance, cities such as Orange, Menton, and Macon, were connected by LGV rail service in the first two time periods and accessibility improved in those periods with rates of 41% and 61%, respectively. However, in the last ten years, the accessibility of those cities has remained the same, or has regressed by 1%. These patterns are highly associated with the introduction of HSR service in those cities.

Third, in the 1982–2009 period, the relative changes of accessibility also indicate that more relative benefits were experienced by big-medium cities and small-medium cities. Both of these groups experienced improvements of about 128% and 125% in accessibility to/from Paris, which is slightly higher than major metropolitan cities with 106% increases from 1982 to 2009. This is identical to the evidence reported by Vickerman and Ulied (2009). Compared with major cities, such as Lyon, Tours, and Toulon, which are highly accessible, big-medium cities or small-medium cities, especially those located long distances from Paris, receive more relative increases in accessibility.
Table 4-1: Evolution of Accessibility to/from Paris

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</tr>
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<td>LGV</td>
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<td>41.13</td>
<td>47.21</td>
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63
4.6 EVOLUTION OF HSR INTERCITY ACCESSIBILITY PATTERNS


In this section, an economic potential model is generated to display the changes in accessibility due to HSR among the 107 agglomerations from 1982 to 2009. In this study, according to economic potential measures, population is used as a proxy for economic potential. Meanwhile, a travel time matrix (107 * 107) among 107 agglomerations in the Thomas Cook European Rail timetable was generated and is used in this section.

Figure 2 presents the most recent (2009) economic potential accessibility. First, it is clear that the three largest French cities—Paris, Marseille, and Lyon—had the highest economic potential in 2009 (shown in dark blue). For instance, there is no doubt that Paris, with an accessibility index of more than 2400, not only has the largest economic potential in France, but also far surpasses the other cities.

Second, there are distinct and pronounced differences between regional capital cities and other similar-sized cities. Although most capital cities (excluding Paris, Marseille, and Lyon) are not directly located on the LGV network, they have considerably higher economic potential than elsewhere, as shown in light blue in Figure 2. For example, the capital city of Rennes, located in western France with a population of more than 200,000, has a more than 100-unit higher economic potential than the city of Reims, which is located east of Paris with more than 181,000 inhabitants.
Figure 4-2: Accessibility in 2009: Economic Potential Indicator
Third, considerable disparities in the accessibilities of capital cities are clear. For instance, the city of Orleans, located in central France has a better geographical location than Rennes. However, the accessibility of Orleans is much less than that of Rennes. This is due to the priorities of transport infrastructure investment. Orleans has good access to Paris but not to all other cities. To access most French cities, Orleans has to first access Paris and make linkages to other locations.

Fourth, as small-medium or small cities, most coastal cities in the western region of France, as well as hinterland cities located in eastern and southeastern France, have lower economic potential due to their cumulative longer travel times from other cities.

An economic potential map for the year 1982 was also generated. It shows that although the overall level of accessibility increased, the general pattern of accessibility remained the same. Thus, in the present study, economic potential for 2009 only is shown.

4.6.2. Initial and Normalized Changes in Economic Potential

In order to more closely examine the changes in accessibility induced by HSR networks, the changes in economic potential in France during the 1982–2009 period were mapped. However, given the large variation in the economic potential index in general, the accessibility index was normalized to enable clear visualization of these changes in each city.

Figure 3 presents the initial absolute difference and relative changes in economic potential in France between 1982 and 2009. The absolute change is the difference between the economic potential from 1982 to 2009. The relative change is a ratio of initial accessibility. Both of these two maps present three clear patterns. First, it is clear that cities
located in the southeastern region of France have much larger economic potential increases than other cities, reflecting from both high absolute changes and relative values. For instance, Lyon, the third largest city in France, continued to indicate increased accessibility although it was very easily accessible in 1982. Second, Paris, not surprisingly, had the largest absolute change in economic potential since 1982 but its relative value indicates that it was not the city that experienced the greatest relative increase due to its high level of economic potential in 1982. Third, both absolute values and relative changes suggest that much greater gains were made by either regional capital cities or cities located along the LGV Rhône-Alpes and the LGV Méditerranée lines.

Figure 4 displays the normalized changes in accessibility with absolute values (left) and relative changes (right). This figure seems to provide a contradictory picture. According to the absolute changes, there is no doubt that the most change in economic potential occurred in Paris, associated with the development of the HSR network, followed by Marseille and Lyon. More surprising, most cities in the western, central, and southwestern regions of France experienced reduced or slightly increased economic potential since 1982. This is due to the normalized accessibility index. Although the initial economic potential value for these cities has positively increased over time, the normalized value has declined marginally.
Figure 4-3: Changes in Intercity Accessibility: Initial Index
Figure 4-4: Changes in Accessibility by HSR: Absolute Changes (left) and Relative Changes (right) _Normalized Value
In the relative changes (Figure 4, right), as a ratio of initial accessibility, the relative value presents a similar picture. The greatest gains were made by major cities along the LGV network. Moreover, both absolute values and relative changes indicate that most cities in southeastern France were winners, especially cities along the HSR line from Paris to Marseille and cities located on the boarder of southern France. For instance, Montpellier showed more than 71 units of absolute change and had a more than 50% relative increase in economic potential with the development of the HSR network.

A slight difference between two changes appears in cities located in eastern France, such as Metz and Strasbourg. These cities have smaller absolute changes but higher relative gains because of low initial values in 1982. For instance, the city of Metz, as the capital and prefecture of both the Lorraine region and the Moselle department, gained about 8 units in economic potential but has had about an 11% increase over the past 30 years.

Indeed, greater gains were made by major cities, especially cities along the LGV network or cities on the southern border of the southeastern region. Meanwhile, the previous chapter shows that most new economic activities took place there. It seems there is a spatial correlation between increased economic potential and new increased economic activities. However, whether or not this is caused by improved accessibility will be discussed in the next chapter.

4.7 CHAPTER DISCUSSION

In summary, there is no doubt that the introduction of HSR service improved the level of mobility and accessibility from cities to Paris or among cities, albeit unequally, according to the location of cities relative to the newly built HSR line. Two types of gravity
models were adopted to measure accessibility to/from Paris and intercity accessibility among 107 selected agglomerations.

As expected, the accessibility pattern from cities to/from Paris indicates the spatial extent of the LGV network in improving the linkages of major cities to Paris. The absolute changes and relative increases in economic potential show that cities located on the LGV network or on the extension of LGV network experienced greater gains than other cities. Moreover, the big-medium or small-medium cities had relatively larger changes in accessibility due to the development of the HSR network. The changes in intercity accessibility among the 107 agglomerations presents similar pictures.

The development of both LGV and TGV network draws similar patterns of intercity accessibility. In this study, normalized accessibility values with weighted indexes for each agglomeration in the total group of cities in France were used. These values indicate the rank or percentage shares over the whole group. Surprisingly, it was discovered that although greater gains were made by most regional capital cities, the rank of their positions on accessibility pattern remained the same, reflecting the lower normalized changes in the intercity pattern. Only cities located in the southeast region along the LGV network had more absolute and relative improvements in accessibility.

Thus, the development of an HSR network has improved the overall level of accessibility over the past thirty years; however, the economic potential pattern remains the same. Only a few cities, such as Montpellier, Metz, and Nancy, had significant improvements in their accessibility advantage. Moreover, the HSR network has not reduced accessibility inequalities between the cities in France.
CHAPTER 5: MATCHED PAIR DESCRIPTIVE ANALYSIS

5.1. INTRODUCTION

In this chapter, the study explores whether having high-speed rail (HSR) service may be associated with changes in the employment agglomeration of a specific city. As a descriptive analysis, the purpose of this chapter is to add knowledge to the current existing literature and provide insight into the decision-making process of transport investments, through observing how French cities have grown in the past 30 years, and examining whether the changes that have occurred in employment agglomeration were associated with the availability of HSR service. Moreover, given the special hierarchy of urban systems in France, where the economy is oriented around Paris, as well the huge heterogeneity among cities, this study extends the analyses to show the variation in employment agglomeration across various industrial groups or by city sizes.

To do so, using before and after regression analysis and with/without matched pair correlation analysis, this study assesses a series of panel data to identity the research purpose, ranging from population and overall employment, to density in specific economic structure, such as leisure-oriented services, knowledge-based businesses, and social services, etc. The analysis covers 108 HSR communes\(^{14}\) (including Paris) and 519 non-HSR communes. As a result, the regression analysis and matched pair correlation analysis in this chapter reveal that HSR cities experienced varying effects from having HSR service. If compared with matched non-HSR cities, the latter, especially medium or small non-HSR

\(^{14}\) In France, according to INSEE definition, commune refers to city.
cities, have experienced relative growth during the time period of 1982–2009, which is a clear reflection that the impacts of HSR service on employment agglomeration do not constitute a “zero-sum” game. Overall, this part of the analysis suggests that HSR service by itself is not a sufficient factor in boosting increases in employment agglomeration, but the lack of significant transport infrastructure can become a severe constraint to its labor market development.

This chapter is organized as follows. Section 2 reviews the unit of analysis and data variables. Section 3 describes the research methods this study uses for the descriptive analysis. In Section 4 and 5, an interpretation is given of the findings from the estimation results. In order to give a detailed explanation of these findings, Section 6 offers some samples of matched pairs from both HSR and non-HSR cities by looking further into their geographic location, economic performance, and major economic sources. Finally, Section 7 discusses the overall results and gives a conclusion.

5.2. UNIT OF ANALYSIS, VARIABLES, AND DATA COLLECTION

The French traditional statistical areas unit called a “commune” have been selected from many statistical areas developed by INSEE\(^ {15}\) and are used in this study as a spatial unit for the city level. As the smallest and oldest administrative geographical unit in France, census data are consistent at the commune level during our observation time period of 1982 to 2009. Each commune unit indicates the boundary of that city. For example, the commune of Lyon includes the city of Lyon, and encompasses the nine arrondissements of that city.

\(^{15}\) INSEE: Institut National de la Statistique et des Études Économiques, is the acronym of the National Institute of Statistics and Economic Studies in France.
As a subdivision unit of a commune, an arrondissement is usually used in the three largest cities: Paris, Lyon, and Marseille. Each functions similarly to that of a district in the United States. However, this designation is not available for the rest of French cities. Therefore, this study uses the unit of the commune as the study unit for the whole research.

In total, France has 36568\textsuperscript{16} communes, including metropolitan France and overseas. However, most communes have only several thousands of population. Therefore, for this study, the researchers decided to select communes that have at least 10,000 population. For those HSR cities, the time table of its HSR stations is available for at least two years of 1982, 1990, 1999, and 2009. As a result, 627 commune were finally selected as the study area of this research, including 108 HSR communes and 519 non-HSR communes (shown in Figure 1).

\textsuperscript{16} Source: INSEE
The variables used in this matched pair analysis are listed in Table 1. Population and employment data are drawn from the General Census of Population (GCP) and Déclaration Annuelle de Données Sociales/DADs\(^{17}\) separately. They were conducted in 1982, 1990, 1999, and 2009 by the INSEE. The dummy variables on TGV and LGV stations are also included in this study in order to distinguish the impacts generated by these two different types of rail infrastructure.

\(^{17}\) DADs stands for Annual declaration of social data
Table 5-1: Variables and Data Source

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>INDICATORS</th>
<th>DATA SOURCE</th>
<th>TIME PERIOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban Size</td>
<td>Population Density</td>
<td>GCP</td>
<td></td>
</tr>
<tr>
<td>Economic Indicator</td>
<td>Employment Density</td>
<td>DADs</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Category B: Tourism-oriented Job Density</td>
<td>DADs</td>
<td>• 1990–1999</td>
</tr>
<tr>
<td></td>
<td>Category C: Social and Public service Job Density</td>
<td>DADs</td>
<td>• 1999–2009</td>
</tr>
<tr>
<td>HSR Service</td>
<td>Dummy variable for TGV station</td>
<td>Thomas Cook</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dummy variable for LGV station</td>
<td>Thomas Cook</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Year of HSR station's inauguration</td>
<td>Systra</td>
<td></td>
</tr>
<tr>
<td>Location Characteristics</td>
<td>Region (Île-de-France, Central France, West, East, North, South East, and South West)</td>
<td>INSEE</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Distance to Paris in Km</td>
<td>Calculated based on data from IGN</td>
<td></td>
</tr>
</tbody>
</table>

Note:
1: GCP: General Census of Population from INSEE
3. DADs: Annual declaration of social data
4. IGN France: National Institute of Geographic and Forestry Information
5. Systra: transportation consulting firms

5.3. RESEARCH DESIGN AND RESEARCH METHODS

In order to observe the differential effects generated from HSR investment on urban agglomeration economies, various methods have been used in the existing literature (see Chapter 2). This paper firstly uses the OLS regression model and secondly offers an alternative methodology—matched pair (MP) analysis—to estimate these economic impacts. As a statistical technique, matching has been used to evaluate the effect of a treatment by comparing the treated and the non-treated (or control) groups in the quasi-
experiment. The intention of this MP analysis is to find one or more non-treated unit(s) with similar characteristics to those of every treated unit, and use these as the basis of assessing the effect of treatment.

In this study, I first use before-and-after regression analysis, which focuses only on cities that are served by HSR service, and compare economic phenomenon before HSR service comes with that after having HSR service. Matching of the same city before and after being served by HSR, for example, can eliminate the need to reduce differences as a source of variation so that the impact of HSR service can be isolated and estimated with greater accuracy.

Secondly, I use a type of MP analysis called with-and-without matched pair analysis, which consists of matching cities served by HSR service with cities that don’t have HSR stops under certain criteria, and then assessing the differences. This matching of twin cities is used to observe changes of economic growth patterns and economic structure over the observational period and test whether these changes are correlated with HSR service during the time period of 1982 to 2009.

It is worth noting that while these methods are not panaceas to cure all observational study problems, they can help to eliminate many of the differences in natural endowments, as well as long-run whole economic environment differences and then to observe the correlation between the phenomenon of urban economic impacts and the introduction of HSR service.
5.3.1. Research Methods 1: Before-and-after Regression Analysis

Matching HSR cities with the subject of this study is intended to take into account all (or as many as possible) of the influences, from geographical characteristics to the combined historical, cultural, and economic environments, rather than the primary treatment effect—that is, HSR service. In this study, a simple OLS regression model is used and is considered sufficient to estimate the effect of HSR service.

**OLS Regression Model**

To determine the OLS regression, we applied the following formula:

\[
Y_{HSR_{after}} = \alpha + X_{HSR_{before}}\beta + Z_{2009}\gamma + D + e_{ij},
\]

where \(Y\) represents the level of various economic indicators after HSR service, while \(X\) denotes the level of the same economic indicator before HSR service. \(Z\) is the level of the economic indicator at the metropolitan level. \(D\) is a dummy variable representing the size of the city.

In this study, all economic indicators of HSR cities in the year of 1982 are considered as a control group, called \(HSR_{before}\), and all of those in 2009 are considered as our treatment group, called \(HSR_{after}\). Although the first TGV service in France started to operate in September, 1981 from Paris to Lyon, and the inauguration of a few other TGV stations occurred in 1982, this study treats them all as \(HSR_{before}\) in the year of 1982. The main reason for this is that 1) French census data and economic indicators at the commune level are only available for 1982, 1990, 1999, and 2009; and 2) changes of employment and economic structure pattern—for example, job density in knowledge-based firms—are
the outcomes of long-term influences. These patterns will not change significantly in several months or within a year. Bonnafous’s study (1987) also mentioned that there were no spectacular changes within the jobs' patterns and firms' relocation within one year after the introduction of the Paris–Lyon HSR line. These effects have to be studied over a period of time. It is challenging to isolate them within two or three years after the introduction of TGV service. Therefore, this study uses the year of 1982 as a control group. The potential errors are accepted here.

5.3.2. Research Methods 2: With-and-without Matched Pair Correlation Analysis

The matching approach in this study looks for other cities that have similar urban or economic characteristics but have not been served by TGV service. Of the TGV cities, 108 cities are considered as the treatment group while the matched cities selected from 519 non-TGV cities are also twin cities as the control group. The logic of this matched pair correlation analysis is shown in the following Figure 2.
In the matching process, each treated city could match one or many cities from the control group based on the same matching criteria. The different match pair samples for 108 TGV cities are computed based on one or more of the following criteria: 1) within 10% of difference of population density in the year of 1982; 2) within 10% or 20% of difference of employment density in the year of 1982; 3) located in the same big region, assuming various regions have different economic cultures (North, South, East, West, South West, South East, and Central France); and 4) within 10% of difference of the distance to Paris.

Given a selected matched pair sample, this study uses correlation analysis to determine if having a TGV will result in a change in economic performance, such as overall job density and knowledge-based business. The correlation coefficient ranges between ±1.0 (plus or minus one). A coefficient of +1.0 indicates there is perfect positive correlation,
which means that changes in providing HSR service will result in an identical growth in the urban economy. Oppositely, a coefficient of -1.0 represents the introduction of HSR service, which will result in an identical change in the employment market but the change will be in the opposite direction. A coefficient of 0 means there is no relationship between these two variables. It is worth noting that these matched pair correlation analyses cannot be interpreted as establishing cause-and-effect relationships. They can only help to indicate how or to what extent these two variables are associated with each other.

The selection of the twin city is a key challenge in this part of the analysis. The reason is that this comparison should specify the changes of economic performance that arise subsequent to the introduction of TGV service. Thus, the selected match pair samples will directly influence the final outcome of this analysis. Given the context of France, the hierarchy of its cities are unique in the world. As mentioned in the previous chapter of this study, Paris is the engine of the whole French economy. While its population accounted for 19% of the total population of metropolitan France, its GDP accounted for 31% of the total. As is shown in Figure 3, the curve of population for TGV cities and non-TGV cities declines steeply even from the second and third largest French cities, Marseille and Lyon. Similarly, after the top 20 of non-TGV cities, population curve tends to flatten. Therefore, the population of TGV cities (14 TGV cities), shown as a black dashed line in Figure 3, cannot find a perfect matched twin city from the control group. In this part of the analysis, this study lists and treats these major or big cities separately. In short, one aim of this study is to identify suitable pairs of twin cities. Although some matched pair samples do not

\[\text{Data are based on 2011 and from INSEE.}\]
appear to be as perfectly matched as required, a better choice cannot be made given the structure of French cities. Consequently, as Gmbh's (2013) study suggests, in this type of analysis, the potential for errors must be accepted.

![Figure 5-3: Population Distribution by City Size](image)

5.4. RESULTS OF ANALYSIS: BEFORE AND AFTER TGV SERVICE

5.4.1. Overall Changes in Population and Economic Structure

Examining the experience of 107 stations, this study compares the local population growth and economic structure of cities of various sizes with itself after the arrival of TGV service with that before the TGV service. The results are summarized and organized in Table 2. In brief, over the period from 1982 to 2009, all economic indicators after HSR service, including population density, employment density, and various economic structure indicators (knowledge-based job density, leisure-oriented job density, social services job density, construction, logistics job density, and manufacturing job density) have a significantly positive relation with the level of economic performance before HSR service.
In addition, the city size dummy variable in each economic indicator shows the city size is highly relative with the level of economic performance. The bigger the city, the higher the level of economic performance.

Among these six main economic structures, it is interesting to observe that only knowledge-based businesses and leisure-oriented services at the city level are significantly negative with the performance of those services at the geographical core of the metropolitan area. It suggests that only these two economic structures have a high level of sensitivity to the geographical location and highly concentrated at the center rather than spreading into regional areas.

Table 5-2: Before and after TGV Service Regression Analysis

<table>
<thead>
<tr>
<th>Dependent Variables</th>
<th>Independent Variables</th>
<th>Coefficient</th>
<th>Adjusted R-squared</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population Density 2009</td>
<td>Population Density 1982</td>
<td>0.981***</td>
<td>0.986</td>
</tr>
<tr>
<td></td>
<td>Metropolitan Population Density 2009</td>
<td>0.000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>City Size</td>
<td>-0.024*</td>
<td></td>
</tr>
<tr>
<td>Employment Density 2009</td>
<td>Employment Density 1982</td>
<td>1.004***</td>
<td>0.988</td>
</tr>
<tr>
<td></td>
<td>Metropolitan Employment Density 2009</td>
<td>0.026</td>
<td></td>
</tr>
<tr>
<td></td>
<td>City Size</td>
<td>-0.03**</td>
<td></td>
</tr>
<tr>
<td>Knowledge-Jobs Density 2009</td>
<td>Knowledge-based Job Density 1982</td>
<td>1.162***</td>
<td>0.990</td>
</tr>
<tr>
<td></td>
<td>Metropolitan Knowledge Jobs Density 2009</td>
<td>-0.202***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>City Size</td>
<td>-0.031***</td>
<td></td>
</tr>
<tr>
<td>Leisure-Jobs Density 2009</td>
<td>Leisure Jobs Density 1982</td>
<td>1.039***</td>
<td>0.994</td>
</tr>
<tr>
<td></td>
<td>Metropolitan Leisure Jobs Density 2009</td>
<td>-0.052**</td>
<td></td>
</tr>
<tr>
<td></td>
<td>City Size</td>
<td>-0.016*</td>
<td></td>
</tr>
<tr>
<td>Social Service Jobs Density</td>
<td>Social Service Jobs Density 1982</td>
<td>0.988***</td>
<td>0.987</td>
</tr>
<tr>
<td></td>
<td>Metropolitan Social Service Jobs Density 2009</td>
<td>-0.009</td>
<td></td>
</tr>
<tr>
<td></td>
<td>City Size</td>
<td>-0.024*</td>
<td></td>
</tr>
<tr>
<td>Construction Jobs Density 2009</td>
<td>Construction Jobs Density 1982</td>
<td>0.924***</td>
<td>0.974</td>
</tr>
<tr>
<td></td>
<td>Metropolitan Construction Jobs Density 2009</td>
<td>0.06**</td>
<td></td>
</tr>
<tr>
<td></td>
<td>City Size</td>
<td>-0.042**</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Logistics Jobs Density 1982</td>
<td>0.952***</td>
<td>0.973</td>
</tr>
<tr>
<td>Logistics Jobs Density 2009</td>
<td>Metropolitan Logistics Jobs Density 2009</td>
<td>0.033</td>
<td></td>
</tr>
<tr>
<td>----------------------------</td>
<td>----------------------------------------</td>
<td>-------</td>
<td></td>
</tr>
<tr>
<td>City Size</td>
<td></td>
<td>-0.018</td>
<td></td>
</tr>
<tr>
<td>Manufacturing Jobs Density 2009</td>
<td>Manufacturing Jobs Density 1982</td>
<td><strong>0.804</strong>*</td>
<td>0.854</td>
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<tr>
<td>Metropolitan Manufacturing Jobs Density 2009</td>
<td>Metropolitan Manufacturing Jobs Density 2009</td>
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<td></td>
</tr>
<tr>
<td>City Size</td>
<td></td>
<td>-0.047</td>
<td></td>
</tr>
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</table>

### 5.4.2. Changes of Local Population and Economic Structure by City Size

To examine the various economic effects of TGV service on cities of different sizes, this study divides the initial HSR cities into four groups on the level of the 2009 commune population: above 100,000 population (“major city”), in the range of 50,000–10,000 inhabitants (“big–medium city”), in the range of 25,000–49,999 inhabitants (“small–medium city”), and less than 25,000 population (“small city”). These four groups are equally distributed: the major city group has 29 samples, big–medium city group has 26 HSR cities; similarly, the small-medium group has 28 samples, and the small city group has slightly fewer samples but still has 24 HSR cities. Meanwhile, this study also includes the capital city of regions that are also served by TGV stations, but lists them separately as a reference to other groups. The capital city group has above 80,000 population. It also means that this group overlaps with the major city and big–medium city group of the sample.
Figure 4\(^{19}\) shows the change of industrial groups over the past 30 years by various city sizes. Knowledge-based businesses are still a major economic base across various sizes of cities. Social services and leisure businesses enjoy a positive increase in job density. In particular, all major cities served by TGV (excluding Paris) have stronger economic performance across economic structures, with an increase of 207 jobs per km\(^2\) in the knowledge industry group, 102 and 159 jobs per km\(^2\) in the leisure businesses and social services separately at the significance level of 0.00. Overall, an increased magnitude of job density across industrial groups is much greater in the major cities, such as Lille, Lyon, and Le Mans, than the rest of French cities.

This chart also shows an interesting pattern, which is that small–medium TGV cities (25k–49k inhabitants) have enjoyed a larger amount of growth in overall job density and each economic structure group, than have big–medium cities in the range of 10k–50k inhabitants. Two possible explanations are provided here. For one, under the process of decentralization, big–medium cities have become more decentralized than small cities, with the result that they experience lower increases of job density within the geographic boundaries of the city. Other small–medium HSR cities, which are located near to economic centers or other countries (e.g., the city of Annemasse lies on the border of Switzerland) or on the seaside, are able to attract large numbers of tourists. Thus, the job density of the leisure service is greater in small–medium cities than big–medium cities.

\(^{19}\) **Note:** Average changes of population density in small cities, small–medium, and big-medium cities are not statistically significant at the 0.01 level. The rest of the analyses are all significant at the level of 0.00.
Figure 5-4: Changes of Population and Economic structure by City Size

Again, this before and after regression analysis is built up more as a descriptive analysis on evaluating the performance of the economic structure of these 108 TGV cities over the past 30 years. These results cannot lead to results that tell us whether these denser industrial groups in the commune level are relevant or caused by providing TGV service. Therefore, in the next part of the analysis, this study includes both TGV cities and non-TGV cities to examine whether these impacts are only particular in these TGV cities.
5.5. RESULTS OF ANALYSIS: WITH/WITHOUT MATCHED PAIR CORRELATION ANALYSIS

5.5.1. Descriptive Analysis on Treatment Group and Control Group

Due to the unique hierarchy of cities, this study selected out a group of major cities, for example, the cities of Lyon, Marseille, Toulouse, Strasbourg, etc. However, for about 14 cities in total, we could not find suitable matching twin cities. This study contains them in this part of the descriptive analysis but excludes them in the following correlation analysis.

Figure 5 presents the overall change pattern of population density and the employment market on HSR cities and non-HSR cities during the time period of 1982 to 2009. Again, the rest of the HSR cities (93 cities) are considered as the “Treatment Group,” while all non-TGV cities (519) are our “Control Group.” Two major patterns are presented in this figure.
Figure 5-5: Descriptive Analysis of Treatment Group and Control Group
First, the magnitude of population size and employment performance varies across different study groups. In general, unselected big TGV cities (gray line) have a much larger size of population and employment market than the treatment group (orange line) and control group (blue line). Then, these indicators in the treatment group are slightly larger than the control group. For example, in terms of population density, unselected big cities have above 4000 population per km$^2$, the treatment group has around 2000 inhabits/km$^2$, while the control group has an average population density between 1000 and 1500 person/km$^2$.

Second, the variations of change in population density, employment density, knowledge-based business, and leisure-oriented service are similar between the control group and treatment group, but bigger in the unselected big TGV cities over the observational time period. It is true that unselected big TGV cities have had a sharp growth in population and employment market over the past 30 years. However, surprisingly, the average range of variation in these four indicators is observed similarly between the treatment group and control group. Only in the knowledge-based businesses and leisure-orient services does the treatment group have a slightly better growth than the control group.

This descriptive analysis only provides an overall picture of what our study samples look like but cannot provide the detailed information on the difference of performance in population and the employment market between the treatment group and control group. Thus, this study moves further, to select matched twin cities and test whether having a HSR station could promote employment agglomeration.
5.5.2. Correlation Analysis 1: HSR, Population, and Geographic Location

Typically, when presenting data comparing two or more groups, either absolute or relative differences will be used to express the variance. An absolute change is a subtraction while a relative difference is a ratio. Both of them may influence how big a difference “feels” and therefore neither provides extra meanings. This study uses both ways to measure the changes in population and employment agglomeration and test the correlation between these changes and whether it is the consequence of having a TGV service. However, the correlation coefficient on absolute changes with HSR service varies; moreover, the majority of them are not statistically significant. Therefore, this study uses relative value (percentage change) to measure the growth of population density and employment agglomeration; the summarized results are presented in Table 3.

In the overall correlation analysis, which includes a complete sample from both the control group and treatment group, the relative percentage changes in all of the employment performance indicators have a significantly weak and negative correlation with having HSR service, with correlation coefficients ranging from -.151 to -.232. In brief, this suggests that the control group, non-HSR cities, have enjoyed relatively greater growth than the treatment group.

Matching HSR cities with non-HSR cities, this study designs three scenarios by using three different matching criteria. In scenario 1, we match an HSR city with one or more non-HSR cities if they demonstrate a difference in population density of 5% and moreover are located in the same region. The correlation coefficient still suggests the
relative changes in employment agglomeration have a statistically weak and negative relationship with having an HSR service, with coefficients ranging from -0.232 to -0.324.

Table 5-3: Matched Pair Correlation Analysis

<table>
<thead>
<tr>
<th>Overall Correlation</th>
<th>Pearson Correlation</th>
<th>P_EmpD82_09</th>
<th>P_KND82_09</th>
<th>P_LeiD82_09</th>
<th>P_SocD82_09</th>
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</thead>
<tbody>
<tr>
<td>HSR</td>
<td>-.156**</td>
<td>-.187**</td>
<td>-.232**</td>
<td>-.151**</td>
<td></td>
</tr>
</tbody>
</table>

Scenario 1: Pairs = 278

Matching Criteria
1. Within 5% difference of Population Density
2. Located in the same region

<table>
<thead>
<tr>
<th>Pearson Correlation</th>
<th>P_EmpD82_09</th>
<th>P_KnD82_09</th>
<th>P_LeiD82_09</th>
<th>P_SocD82_09</th>
</tr>
</thead>
<tbody>
<tr>
<td>HSR</td>
<td>-.242**</td>
<td>-.273**</td>
<td>-.324**</td>
<td>-.283**</td>
</tr>
</tbody>
</table>

Scenario 2: Pairs = 62

Matching Criteria
1. With 10% difference of Population Density
2. Located in the same region
3. Within 20% difference of Population

<table>
<thead>
<tr>
<th>Pearson Correlation</th>
<th>P_EmpD82_09</th>
<th>P_KnD82_09</th>
<th>P_LeiD82_09</th>
<th>P_SocD82_09</th>
</tr>
</thead>
<tbody>
<tr>
<td>HSR</td>
<td>-.164</td>
<td>-.273**</td>
<td>-.273**</td>
<td>-.162</td>
</tr>
</tbody>
</table>

Scenario 3: Pairs = 84

Matching Criteria
1. With 10% difference of Population Density
2. Within 20% difference of distance to Paris
3. Within 20% difference of Population

<table>
<thead>
<tr>
<th>Pearson Correlation</th>
<th>P_EmpD82_09</th>
<th>P_KnD82_09</th>
<th>P_LeiD82_09</th>
<th>P_SocD82_09</th>
</tr>
</thead>
<tbody>
<tr>
<td>HSR</td>
<td>-.149*</td>
<td>-.182**</td>
<td>-.299**</td>
<td>-.151*</td>
</tr>
</tbody>
</table>

Note:

- P_EmpD82_09: percentage changes of employment density between 1982 to 2009
- P_KnD82_09: percentage changes of knowledge-based job density between 1982 to 2009
- P_LeiD82_09: percentage changes of leisure-oriented business density between 1982 to 2009
- P_SocD82_09: percentage changes of job density in social services between 1982 to 2009

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
Scenario 2 and scenario 3 are very similar in terms of matching criteria and outcome of analysis. The only difference is that the constraint for matching the criteria on location slightly different. In scenario 2, a constraint of this study is that the matched twin cities have to be located in the same region and have experienced economic development under the same economic culture. Meanwhile, scenario 3 stipulated that each of the twin cities has to be located in a site that is a similar distance from Paris but does not have to be located in the same region. According to these matching criteria, this study finds about 62 pairs and 84 pairs have been successfully matched separately. The correlation results, which are similar to those of scenario 1, also suggest that non-HSR cities have positive relatively greater growth on employment agglomeration. In other words, having an HSR station in a city is not a promising condition for an improving employment market.

5.5.3. Correlation Analysis 2: HSR, Employment Structure by City Size

Table 4 summarizes the correlation analysis between the presence of an HSR station and economic structure grouped by city size. In terms of the definition for big–medium city, small–medium city, and small city, this study continues to use the same categories as that in the sector of regression analysis. As the results present, the study was still unable to find suitable matched twin cities for major cities and thus such are not listed in this table.

Not surprisingly, through the observation of 17 matched twin cities, small–medium HSR cities were found to have a significantly moderate negative correlation with the relative changes in employment agglomeration. Two possible interpretations is that with the limitation of technical and financial impediments, some new stations, built more or less
on the urban periphery, may not connect well with the local and regional transport network, and thus the service from the HSR cannot distribute significantly into the urban center. For example, within the city of Macon, a brand new HSR station was built and located within 15 minutes driving time from the city center. This phenomenon is also described by Facchinetti-Mannone (1999), who points out that most small and medium French cities are connected to the HSR service through either the conventional lines in the city center or through newly built HSR stations near the city's edge. Consequently, he argues that the economic development potential of these small- or medium-size cities is not sufficient for developing a new high-density cluster around these newly built stations.

The other explanation concerns the level of HSR service. Although having an HSR located in or nearby a city reduces travel time and broadens the catchment area of the station, the train frequencies on TGV service may replace all frequencies from the conventional rails. To some degree, the level of service experiences a decline although the average time a passenger spends on the train is reduced. Relatively, some non-HSR stations have been located near small–medium cities with good access to a major regional center or major transport hub and have thereby enjoyed greater growth in job density, comparative to HSR stations.

Table 5-4: HSR and Employment Structure by City Size

| Correlation Analysis |
|----------------------|-----------------|----------------|-----------------|-----------------|-----------------|
| Big–medium City N = 10 | **Pearson Correlation** | Employment Density 82_09 | Knowledge-based Density | Leisure Density | Social Service Density |
| HSR | 0.241 | 0.368 | -0.256 | -0.037 |
| Small-medium City N = 34 | **HSR** | **-0.445** | **-0.504** | **-0.582** | **-0.325** |
Big–medium cities have been matched with 10 pairs from non-HSR cities. The coefficient of correlation analysis indicates that having an HSR station is weakly positively correlated with relative changes in overall employment density and knowledge-based businesses, but weakly negatively correlated with leisure-oriented services and social services. However, these phenomenon are not consistent across all big–medium cities, therefore, not all coefficients are statistically significant.

5.6. EXPLANATIONS BY USING SAMPLES OF MATCHED TWIN CITIES

In this section, this study uses samples of matched twin cities to add a detailed interpretation to the above descriptive analysis through simply focusing on two major fundamental questions: Is having HSR service promising for job growth? Does saving significant travel time matter?

5.6.1. Explanation 1: Is Having HSR Service Promising for Job Growth?

The existing literature (Venables, 2007; Graham, 2007) provides empirical evidence from the model to suggest that improved accessibility will increase the effective labor market density for firms, but differentially in different sectors. However, given the context of French cites, the picture of the relation between HSR service and labor agglomeration is mixed. This study uses one representative matched pair to display and interpret this correlation.
The matched twin cities (city of Menton and city of Vallauris) are selected from a group of matched small–medium cities, with the matching criteria of within 10% difference of population density, within 20% difference of distance to Paris, and within 20% difference of population. The geographical location information is shown in Figure 6 and the comparative indicators in population and employment agglomeration are summarized in Table 5.

![Figure 5-6: Geographical Location of Matched Sample Cities](image)

Table 5 suggests that the HSR city of Menton and non-HSR city of Vallauris have similar location and transportation characteristics but various performance in employment agglomeration across different sectors. As an ocean city, each of them is located in the Provence-Alpes-Côte d'Azur region in southeastern France, having a similar distance to...
Paris and the regional capital city—Marseille. Both of them have about 28,000 inhabitants within the city. However, despite the absolute increases or percentage changes in employment agglomerations, non-HSR city Vallauris experienced substantial increases in job agglomerations. For example, knowledge-based businesses (e.g., consulting, accounting, investment banking, and so on) have increased about 84% in total, with a comparative increase of only 15% in the HSR city of Menton. What is the potential economic driving force backing up the city of Vallauris? Although Vallauris does not yet have HSR service, it is today effectively an extension of the city of Antibes, which is an HSR city. With good support of local public transport connection from Vallauris to Antibes, the city of Vallauris was still able to enjoy the improved accessibility that was brought by HSR service in Antibes. That is why the average travel time saved during trips to Paris over the past 30 years in the city of Vallauris is 240 minutes, as compared to the more than 156 minutes of travel time saved in Menton. Therefore, the availability of HSR service cannot be used to promise the prospects of transformation in employment agglomeration. Similar evidence could be found in many of the other matched twin cities in this study.

All in all, it seems that while having HSR service could lead to greater or lesser increases in job agglomeration, such a functionality does ensure the HSR city will have better economic performance than other non-HSR cities. The prospects for the economic transformation of non-HSR cities could be for improved economic performance as well, as long as some strategic interventions take place, for instance, such as being well connected to other primary transport hubs.
Table 5-5: Matched Pair Sample Cities: Small–Medium Cities

<table>
<thead>
<tr>
<th>CATEGORIES</th>
<th>HSR CITY</th>
<th>NON-HSR CITY</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LOCATION CHARACTERISTICS</strong></td>
<td>Menton</td>
<td>Vallauris</td>
</tr>
<tr>
<td>Region</td>
<td>Provence-Alpes-Côte d'Azur region in southeastern France.</td>
<td></td>
</tr>
<tr>
<td>Ocean City</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>TRANSPORT CHARACTERISTICS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance to Paris</td>
<td>961km</td>
<td>914km</td>
</tr>
<tr>
<td>Distance to Region Capital City: Marseille</td>
<td>236km</td>
<td>189km</td>
</tr>
<tr>
<td>HSR station open year</td>
<td>1987</td>
<td>n/a</td>
</tr>
<tr>
<td>Changes of travel time saving to Paris</td>
<td>156 mins</td>
<td>240 mins</td>
</tr>
<tr>
<td>Changes of travel time saving to Marseille</td>
<td>-13 mins</td>
<td>-11 mins</td>
</tr>
<tr>
<td><strong>ABSOLUTE CHANGES IN POPULATION AND EMPLOYMENT DENSITY</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PD99_09</td>
<td>3.945</td>
<td>167.085</td>
</tr>
<tr>
<td>PD90_99</td>
<td>-24.586</td>
<td>108.087</td>
</tr>
<tr>
<td>PD82_90</td>
<td>285.666</td>
<td>234.189</td>
</tr>
<tr>
<td>ED99_09</td>
<td>48.813</td>
<td>172.018</td>
</tr>
<tr>
<td>ED90_99</td>
<td>-16.133</td>
<td>50.741</td>
</tr>
<tr>
<td>ED82_90</td>
<td>62.558</td>
<td>74.760</td>
</tr>
<tr>
<td><strong>PERCENTAGE CHANGES OF EMPLOYMENT AGGLOMERATION ACROSS BY DIFFERENT SECTORS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P_ED99_09</td>
<td>8%</td>
<td>33%</td>
</tr>
<tr>
<td>P_ED90_99</td>
<td>-3%</td>
<td>11%</td>
</tr>
<tr>
<td>P_ED82_90</td>
<td>11%</td>
<td>19%</td>
</tr>
<tr>
<td>P_KD99_09</td>
<td>15%</td>
<td>84%</td>
</tr>
<tr>
<td>P_KD90_99</td>
<td>-3%</td>
<td>38%</td>
</tr>
<tr>
<td>P_KD82_90</td>
<td>11%</td>
<td>52%</td>
</tr>
<tr>
<td>P_LD99_09</td>
<td>1%</td>
<td>38%</td>
</tr>
<tr>
<td>P_LD90_99</td>
<td>13%</td>
<td>39%</td>
</tr>
<tr>
<td>P_LD82_90</td>
<td>10%</td>
<td>12%</td>
</tr>
<tr>
<td>P_SD99_09</td>
<td>0%</td>
<td>38%</td>
</tr>
<tr>
<td>P_SD90_99</td>
<td>25%</td>
<td>26%</td>
</tr>
<tr>
<td>P_SD82_90</td>
<td>24%</td>
<td>19%</td>
</tr>
</tbody>
</table>

**NOTE:**

PD: Population density
ED: Employment density
KN: Knowledge-based businesses
LD: Leisure-oriented services
SD: Social services
5.6.2. Explanation 2: Does Saving Significant Travel Time Matter?

In the sector of matched pair analysis, this study chose HSR cities that have enjoyed average travel time savings greater than 50% between 1982 and 2009. By the matching of non-HSR cities that have similar sizes of population, population density, and similar geographical location, this study finds that HSR cities with significantly improved travel time will have greater increases in employment agglomeration. But, compared with the matched twin cities, the difference in changes of employment agglomeration is found across a wide divergence.

Two matched samples (city of Agen and city of Allauch, city of Agen and city of Apt) are selected from a group of matched twin cities, under the matching criteria of being within 10% difference of population density, within 20% difference of distance to Paris, and within 20% difference of population. The geographical locations of HSR cities (in red) and non-HSR cities (in blue) are shown in Figure 7.
Figure 5-7: Matched Pairs: Agen, Apt, and Allauch

The HSR city of Agen is located in the southwestern region of France. Beginning in 1990, Gare Agen Station in the city has provided HSR service, linking the city to Paris with a train travel time of about 253 minutes to/from, around 57 minutes of train travel time to the regional capital city, Toulouse, and around an hour from another regional capital city, Bordeaux. Over the past 30 years, the population of Agen has increased from 13,107 to 24,031 residents. Similarly, the matched non-HSR cities of Allauch and Apt, located in the southeastern region of France, have similar distances to/from Paris, and are both near to the second-largest metropolitan area of Marseille. The population of Apt has remained
the same, about 11,400 residents, while the population in Allauch has enlarged from 13,519 to 18,645 residents within the city from 1982 to 2009.

Based on the inauguration of HSR service to the city of Agen starting from 1990, this study did not observe any clearly and significantly greater increases in employment agglomeration than that of non-HSR cities. The changes in agglomeration by various industrial groups are mixed, as is shown in Table 6. If we use the HSR city of Agen as the reference, the changes of overall employment density in the city of Allauch have been slightly better over the past 30 years, especially within the knowledge-based services. After the introduction of HSR service in Agen in 1990, the agglomeration has increased 50% and 11% separately during 1990–1999 and 1999–2009. This is slightly less than the increases of 50% and 21% in the city of Allauch. However, the HSR city Agen experienced better performance in social services during 1990–2009 with a percentage increase of 42% compared to that of 25% in Allauch.

Correspondingly, if we are still using the HSR city of Agen as the reference, the city of Apt's overall performance in employment agglomeration cannot compete with that of Agen, no matter which industrial sectors and no matter which time period are being compared, except for increases in knowledge agglomeration during 1982–1990.
Table 5-6: Employment Agglomeration by Sector, Agen, Apt and Allauch

<table>
<thead>
<tr>
<th>Employment Agglomeration by Sector</th>
<th>Agen</th>
<th>Apt</th>
<th>Allauch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Employment density 99_09</td>
<td>21%</td>
<td>14%</td>
<td>15%</td>
</tr>
<tr>
<td>Employment density 90_99</td>
<td>14%</td>
<td>1%</td>
<td>35%</td>
</tr>
<tr>
<td>Employment density 82_90</td>
<td>29%</td>
<td>18%</td>
<td>22%</td>
</tr>
<tr>
<td>Knowledge-based job density 99_09</td>
<td>11%</td>
<td>-12%</td>
<td>21%</td>
</tr>
<tr>
<td>Knowledge-based job density 90_99</td>
<td>50%</td>
<td>-5%</td>
<td>57%</td>
</tr>
<tr>
<td>Knowledge-based job density 82_90</td>
<td>31%</td>
<td>38%</td>
<td>28%</td>
</tr>
<tr>
<td>Leisure-based job density 99_09</td>
<td>36%</td>
<td>51%</td>
<td>37%</td>
</tr>
<tr>
<td>Leisure-based job density 90_99</td>
<td>13%</td>
<td>11%</td>
<td>124%</td>
</tr>
<tr>
<td>Leisure-based job density 82_90</td>
<td>76%</td>
<td>48%</td>
<td>56%</td>
</tr>
<tr>
<td>Social services job density 99_09</td>
<td>42%</td>
<td>27%</td>
<td>25%</td>
</tr>
<tr>
<td>Social services job density 90_99</td>
<td>19%</td>
<td>18%</td>
<td>97%</td>
</tr>
<tr>
<td>Social services job density 82_90</td>
<td>65%</td>
<td>38%</td>
<td>25%</td>
</tr>
</tbody>
</table>

Hence, with significant improved train travel time, the HSR city of Agen has experienced considerable increases in employment agglomeration. However, even with travel time savings greater than 50%, it is hard to reach a common conclusion that HSR cities have greater performance than non-HSR cities in terms of rising employment agglomeration. In brief, HSR cities, such as Agen, are highly competitive with some non-HSR cities, for instance, the city of Apt, but not all of them, such as Allauch, which is a city that does not have HSR service but does feature good access to major economic centers.

5.7. CHAPTER DISCUSSION

Bringing these discussion points together, we conclude that HSR service by itself is not a sufficient factor in boosting the increases in employment agglomeration, but the lack of significant transport infrastructure can become a severe constraint to a city's labor
market development. The detailed conclusions are organized and provided in the following paragraphs.

First, over the past 30 years, HSR cities have experienced varying effects. Overall, HSR shows clear positive results in terms of retaining the existing spatial economic geography, not changing it. The first part of the analysis on matching cities before and after they receive HSR service suggests that regional capital cities and major French cities have received the greatest increases in employment agglomeration at the city level. If we are observing labor density across various sizes of cities, it is evident that small–medium cities have more moderate changes than big–medium French cities, many of which may be under the process of decentralization. Following from that observation, the changes of job agglomeration in small French cities are limited, even negative. Therefore, overall, in association with the introduction of HSR service, the hierarchy of the urban system did not greatly change or experience reordering.

Second, HSR is more about improving the connectivity between cities than promoting employment agglomeration, especially for medium- or small-size cities. The second part of the analysis in this chapter provides an analysis of the matched pair correlation for HSR cities and non-HSR cities. Given the unique hierarchy of the urban system in France, it is difficult to find suitably matched non-HSR cities for major or capital cities. However, this study finds appropriate matched twin cities for medium or small HSR cities. The results from matched pair analysis demonstrate that HSR cities, even with considerably improved accessibility by rail, do not necessarily have a better performance in employment agglomeration than non-HSR cities. Therefore, having HSR service is not promising in terms of promoting economic growth. Even with significant travel time saving,
for example, of about more than 50%, HSR cities could have positive correlation with
changes in employment agglomeration, and are highly competitive with some non-HSR
cities, but not all.

Third, the influence of HSR service on agglomeration economies are not a “zero-
sum” game. While HSR cities enjoy travel time savings through the introduction of HSR
service, some cities, which are located nearby major cities or have good access to major
transport hubs, have received benefits from travel time saving as well. These benefits
further influence their employment agglomeration. The matched pair correlation analysis
also finds that non-HSR cities did not lose out, but even have more relative growth.

Fourth, the employment of knowledge-based businesses, leisure-oriented services,
and social services shows a positive correlation with HSR service, but such correlation is
not consistent among all HSR cities, varying across city size. Major cities and big–medium
both have absolute increases in the job density of these three types of industries, while
small–medium and small cities have less relative growth.

The chapter is more about descriptive analysis, but still is affected by some
limitations. The study in this chapter did not take into account the specific year when HSR
service started in a specific city, but only observed the changes of a city’s performance in
employment agglomeration during a wide time period. Although the time period covers the
situation of that city before and after HSR service, it cannot help to understand how HSR
service was experienced by the effected city over various short or long-term time periods.
Moreover, matched pair correlation analysis in this chapter focuses more on medium and
small cities due to matching issues for the major cities. However, these limitations will be
further considered and fixed in a later analysis.
CHAPTER 6: DOES HIGH-SPEED RAIL INVESTMENT INDUCE AGGLOMERATION ECONOMIES EFFECTS?

6.1. INTRODUCTION

This chapter uses commune-level\(^{20}\) longitudinal and panel data to study economic performance of HSR cities from 1982 to 2009. This is a period of significant improvement of the HSR network in France and raises important questions as to its impact on urban agglomeration economies. To the best of the author’s knowledge, the work presented in this chapter is the first to explore the linkage between agglomeration economies and such large-scale HSR investment by using real HSR train time and train frequencies of 107 French cities.

The key justification behind the common theory is that significant transport infrastructure could boost agglomeration economies through reducing transport cost and thereby inducing more spatial economic activities. To test this causality relationship, this study defines the measures of agglomeration economies and carefully selects the key features of HSR service, then uses two powerful empirical methods—OLS and the linear mixed model—to provide evidence on this relationship, using unobserved individual heterogeneity in estimation as the control.

Results show that knowledge-based jobs are concentrated at the local level due to the introduction of HSR service. It is also clear that the daily frequency of HSR to/from

\(^{20}\) Commune in French INSEE indicates the level of city.
Paris determines the changes in agglomeration economies. However, whether HSR service drives the city to be more disperse or concentrated are not evident.

This paper is organized as follows: The next section describes the theoretical background on the linkage between HSR and agglomeration economies. Section 3 presents the units of analysis and data sources. Sections 4 and 5 discuss the empirical methods and measures on variables. The results and discussion for agglomeration economies are presented in Section 6. Finally, Section 7 concludes.

6.2. THEORETICAL BACKGROUND ON THE LINKAGE BETWEEN HSR AND AGGLOMERATION ECONOMIES

In theory, urban agglomeration economies occur from improved opportunities for the labor market pool, specialization in input and output markets and enhanced efficiency in knowledge spillovers from locating firms near to others in the same industry (Marshall, 1890). These “sharing,” “matching” and “learning” mechanisms 21 propose that agglomeration economies result in a combination of benefits, such as lower travel costs for firms and higher productivity.

Several theoretical models have been developed to link agglomeration economies and transport investment. The most recent well-developed model, the New Economic Geography (NEG) theory, was derived by Krugman in 1991. As mentioned in an earlier chapter, this theory addresses the geographical concentration of economic activity and

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21 Three types of mechanisms in agglomeration economies are summarized by Duranton and Puga (2004).
suggests that the combination of market access and labor mobility results in an agglomeration effect under scale economies (Puga, 2009; Krugman, 1991).

As the foundation theory in this study, NEG theory not only provides an explanation on the importance of agglomeration economies (sharing, matching and learning) but also links the transport cost with agglomeration economies. Although this theory was built and based on the manufacturing industry, the essence of the theory can be applied to other industrial groups because transport costs are highlighted as an internal factor in determining the location of economic activity and because the linkages between firms and suppliers as well as firms and consumers are emphasized. For example, using this theory, Glaeser and Kohlhase (2003) argued that if there were no transport costs, agglomeration economies could not exist; however, in today’s service-based economy, the mobility cost of people over space remains high. They argued that the advantage of proximity to clients/other people seems to come from “saving the costs of providing and acquiring services and from improving the flow of knowledge.” The above discussion indicates that the value of travel time is still important in today’s distribution pattern of agglomeration economies.

To quantify this linkage, information in the literature remains equivocal. In the case of HSR investment, endogeneity between HSR service and agglomeration economies has received major attention (e.g., Ciccone and Hall, 1996; Duranton and Puga, 2004; Graham, 2009). HSR lines are generally endogenous to economic geography. The strongest economic agglomeration generated with the highest travel demand is the first to be connected by HSR. For example, Paris, Lyon and Marseille, major capital cities in France, always have the highest priority for HSR service. Other regional capital cities follow in
HSR investment. It is impossible to establish what would happen in the absence of HSR service and to separate its effects from a city’s natural growth. This is a challenge existing in this study.

6.3. UNIT OF ANALYSIS AND DATA

The French traditional statistical area unit, the “Commune,” as developed by INSEE\textsuperscript{22}, is used in this study as the spatial unit for the city level. As the smallest and oldest administrative geographical unit in France, the census data are consistent at the commune level during our observation period from 1982 to 2009. Each commune unit indicates the boundary of that city. For example, the commune of Lyon shows the city of Lyon.

France has 36,568\textsuperscript{23} communes, including metropolitan France and overseas territories. However, most communes only have a population of several thousand. Therefore, in this study communes having a population of at least 10,000 were selected. For those HSR cities, the timetables of their HSR stations were available for at least two years during the study period. As mentioned previously, this study excludes Paris in the analysis. In total, 107 cities as individual observational subjects within three ten-year periods of time were selected and included in the models. Table 1 provides the data sources of the dependent variables and explanatory indicators.

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\textsuperscript{22} INSEE: \textit{Institut National de la Statistique et des Études Économiques}, is the acronym of the National Institute of Statistics and Economic Studies in France.

\textsuperscript{23} Source: INSEE
Table 6-1: Data Sources

<table>
<thead>
<tr>
<th>Group</th>
<th>Category</th>
<th>Data Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dependent Variables</td>
<td>Employment Density</td>
<td>INSEE</td>
</tr>
<tr>
<td></td>
<td>Agglomeration Economies</td>
<td>job and labor market data from INSEE</td>
</tr>
<tr>
<td>Independent Variable</td>
<td>HSR Features</td>
<td>Thomas Cook European Rail Timetable, SNCF and French Systra Consulting</td>
</tr>
<tr>
<td>EconControl</td>
<td>Human Capital</td>
<td>job and labor market data and population census from INSEE</td>
</tr>
<tr>
<td></td>
<td>Population Density</td>
<td>INSEE, census of population</td>
</tr>
<tr>
<td></td>
<td>Vacant Housing Rate</td>
<td>INSEE, census of population</td>
</tr>
<tr>
<td>CityControl</td>
<td></td>
<td>Data from INSEE and conducted in ArcGIS</td>
</tr>
<tr>
<td>GeoControl</td>
<td></td>
<td>Data from IGN and conducted in ArcGIS</td>
</tr>
</tbody>
</table>

As mentioned in earlier chapters, job and labor market data in France can be disaggregated into the 14 major industrial categories on the commune scale by INSEE. This study aggregates these categories into six major industrial categories: 1) manufacturing, 2) social service, 3) leisure service, 4) knowledge business, 5) logistics and 6) construction. All data on the economic structure have been used to calculate human capital and agglomeration economies. Population and demographic data come from the French census covering the intercensal periods 1982–1990, 1990–1999 and 1999–2009 and are provided in INSEE. Education and housing information come from the French census as well.

HSR travel time is the most important contribution in this study. The travel time matrix from/to Paris and the frequency of train service were developed by the author from the Thomas Cook European Rail timetable of 1982, 1990, 1999 and 2009. The year of inauguration of each HSR city was obtained from French Systra consulting firms.
The location of HSR stations was identified by using Google map and was categorized as: 1) located in the center of the city, 2) located at the edge of the city, 3) periphery station far from a city. For example, the city of Le Creusot opened a TGV station in 1981, which is located about 10 km from the city. This type of station is considered to be a periphery station.

In order to control for the natural advantage of geographic location of HSR cities, this study has multiple dummy variables to identify 1) the proximity of these cities to other neighboring countries, such as Italy and Belgium; 2) whether these cities are seaside cities. This study assumes that cities located on the border of France and near other countries receive more economic benefits from other counties while seaside cities may have more growth in tourism-oriented services.

6.4. MEASURING VARIABLES: AGGLOMERATION ECONOMIES, HUMAN CAPITAL AND INSTRUMENTAL VARIABLES

6.4.1. Agglomeration Economies

To build measures of agglomeration economies, this study adopts a concept from Melo and Graham (2010) on identifying agglomeration economies. Melo and Graham (2010) indicated that “agglomeration economies are a function of the centration of a diversity of job activities, closely correlated with the size of a given areas.” It is the combination of localization economies and urbanization economies. When localization economies stem from the clustering of firms in the same sector, urbanization externalities derive from easy access to specialized inputs among various industrial sectors, such as
knowledge-based job activities, access to public service and so on. Based on this concept, this study develops two measures to identify urban agglomeration economies.

First, this study uses a common measure of employment density of a given city as a proxy for agglomeration economies. In other words, the number of jobs per square kilometer within a city represents the level of agglomeration externalities. These density-based measures have been widely used in the literature as a means of identifying agglomeration economies (e.g., Ciccone and Hall, 1996; Ciccone, 2002; Combes et al., 2007, 2008a, 2008b; Mion and Naticchioni, 2005). Employment density can be expressed as follows:

\[
Employment\ Density = \frac{Total\ number\ of\ jobs}{Land\ area}
\]

Second, this study adds the feature of urbanization externalities into the identity of agglomeration economies. To measure the extent of urbanization externalities, this study uses the Hirschmann indicator:

\[
H_t = \sum_j \left(\frac{emp_t}{emp}\right)^2
\]

where \( emp \) indicates number of jobs, \( j \) represents the sector of economic structure of a given city and \( t \) is the time period. An increase in \( H_t \) indicates a concentration in a few sectors and less diversity of the local economy.

As discussed above, agglomeration economies can be expressed as follows:

\[
AggEco = EmpDensity * \frac{1}{H_t} = \frac{Total\ number\ of\ Jobs}{Land\ area} * \frac{1}{\sum_j \left(\frac{emp_t}{emp}\right)^2}.
\]
Employment density and $\frac{1}{H_t}$ are positively correlated with the level of agglomeration economies. The increase in either could reflect a more concentrated or more diverse local economy.

6.4.2. Human Capital

In standard studies on evaluating the agglomeration effect, property value and income as variables of labor capital are incorporated into the studies. However, neither of these are available at the commune level in France for the observational time period. In order to measure the extent of labor capital, this study uses the following measure to identity the level of human capital (HC) within a given city:

$$HC = \frac{\text{Population with university education or above}}{\text{Population with age above 24}}.$$

When the percentage of higher education in that city is high, there is a higher level of human capital, which is further reflected in the higher level of the local economy.

6.4.3. Instrumental Variables

Instrumental variables (IVs) have been widely used in similar econometric analysis to control the endogeneity issues existing in the relationship between economic performance with respect to improved accessibility. It is clear that HSR infrastructure is not randomly located. In addition to HSR investment changes in the level of agglomeration economies, changes in agglomeration could increase the likelihood that national or local transport policies develop an HSR service. To control a mutual-causal relationship, the literature offers some examples of identification strategies to address causality issues. The
popular strategy is to conduct with and without or before and after regression using IV. For example, Duranton and Turner (2012) evaluated the impact of the highway network in the U.S. on the employment market. They adopted an instrumental strategy based on the 1947 plan of the interstate highway network and also on the 1898 railroad network to address the endogeneity of the highway system location. Similar strategies on IVs can be found in many empirical studies (Brandt et al., 2011; Chatman, 2011; Koning et al., 2013).

This study selects three major IVs and adds them to both the OLS model and the linear mixed model. These selected IVs might be correlated with the current level of HSR service but not directly influence the recent levels of agglomeration economies. The first IV is using historical track mileage within each metropolitan area in 1853. Information on the 1853 plan of the French rail network comes from the book “Chemins de fer français” by Victor Bois. This study digitizes the railways based on multiple maps included in the book and calculates the rail track mileage within each employment area\(^{24}\) in ArcGIS. The assumption is that the more rail track mileage there is in a city, the more likely it is to have a higher level of HSR service.

The second IV selected in this study is the geographical centrality (GC) index, which was introduced by Head and Mayer (2004) and is a good candidate in terms of controlling exogeneity issues because the index only depends on the physical location of a country relative to the rest of the cities within that country. Given the context of France, economic activities are highly concentrated around Paris, which is located in central France. Therefore, the GC index can define the advantage of geographic locations of cities in

\(^{24}\) Employment area is an official unit of geography from INSEE. It is similar to the metropolitan boundary in the U.S.
France. A higher GC index of a city indicates a higher level of city accessibility. Moreover, the GC index is not related to economic performance because the closest TGV cities to the Paris metropolitan area are still in a one-hour travel time threshold.

The GC index can be express as follows:

\[
GC_i = \sum_{i\neq j}^{107} d_{ij}^{-1},
\]

where \(d_{ij}\) is the Euclidian distance to other cities. The GC index may be positively correlated with the level of accessibility. To calculate this index, this study created a 107×107 point-to-point matrix of a coordinate system and used ArcGIS to calculate the Euclidian distance among cities.

The last IV adopted in this study is altitude. Altitude as a weak IV is used to cover a topographic range from seaside cities to mountain cities. There might be a weak relationship between altitude and economic performance; however, altitude cannot directly influence recent urban agglomeration economies. Information on altitude from the European Environment Agency were obtained and extracted by using ArcGIS.

6.5. EMPIRICAL METHODOLOGY

To quantify the agglomeration benefits of transport investment, Venables (2007) suggested that researchers should consider two major factors: 1) the change in access to economic benefits that will result from improved transport service through transport investment; 2) the change in productivity as a way of reflecting an increase in agglomeration. Consequently, this study incorporates these two factors into two selected empirical methods to estimate the casual effects of HSR investment and agglomeration economies.
Method 1: Multivariate OLS Regression Model

\[ Y_{ij} = \alpha + X_{ij}\beta + e_{ij}, \]

where \( Y_{ij} \) is the change in the agglomeration economies indicator. Let \( X \) denote a vector of explanatory variables, including the change in access to economic benefits as a result of introducing HSR service; \( e_{ij} \) is the error term and subscripts \( i, j \) are index city and time period between 1982 and 2009, respectively.

In this case, the OLS model can be written as follows:

\[
\Delta \Delta_{t-1}^{t} AggEco = \alpha + \sum_i \beta_i (HSR Feature)_{t,t-1}^i + \\
\sum_j y_j (\Delta \Delta_{t-1}^{t} EconControl)^j + \sum_k \delta_k (CityControl)^k + \\
\sum_m \theta_m (GeoControl)^m + \epsilon,
\]

where \( \Delta \Delta_{t-1}^{t} AggEco \) is the growth of agglomeration economies in commune \( i \) between the time periods \( t \) and \( t-1 \). The explanatory variables are as follows:

- **HSR Feature:**
  - Train frequencies of HSR service to/from Paris
  - Travel time savings to/from Paris
  - Train frequencies of all rail services to/from Paris
  - Level of overall accessibility (calculated in an earlier chapter)
  - Location of the HSR station

- **EconControl** (Economic performance indicators):
  - Human capital
  - Vacant housing rate
o Population density

- **CityControl** (City size and city type indicators):
  - Categories of city size, including major, big-medium, small-medium and small city
  - Seaside city
  - Regional capital city

- **GeoControl**:
  - Proximity to neighboring countries, including Belgium (BEL), Italy (ITA), Switzerland (CHE), Germany (DEU), Luxembourg (LUX), and Spain (ESP)

The major caution in using the OLS model is that the model neglects the cross-sectional and time series nature of the data. In this case, each city as the study subject is observed for three time periods between 1982 and 2009. The economic performance of each city is highly correlated among the three time periods. However, the OLS model treats these three observations independently. Moreover, for most economic datasets, the error terms are not randomly distributed. Unobserved individual heterogeneity may also be correlated with listed independent variables. Eventually, these existing unobserved correlations will lead to omitted variable bias. To consider this major limitation of the OLS model, this study adopts the linear mixed effects model.

- **Method 2: Linear Mixed Effects Model**

With the panel data, the linear mixed effects model, and including both fixed and random effects, it is possible to estimate the parameters that describe how the mean responses changes over time as well as predict how individual response trajectories change
in the future. Moreover, it allows the analysis of between-subject and within-subject sources of variation in the longitudinal responses. In this case, the linear mixed model provides good control of the variation between French HSR cities and the variation of each city among different time periods.

The linear mixed effects model can be expressed as

\[ Y_i = X_i \beta + Z_i b_i + e_i, \]

where \( X_i \) is a matrix of covariates by using the same variables listed in the OLS model, \( Z_i \) is an \( n_i \times q \) matrix of covariates with \( q \leq p \), \( \beta \) is a \( p \times 1 \) vector of fixed effects, \( b_i \) is a \( q \times 1 \) vector of random effects and \( b_i \sim N(0, D) \) and \( e_i \) is an \( n_i \times 1 \) vector of errors and \( e_i \sim N(0, R_i) \) \( i = 1, \ldots, n \).

- **Model Hypothesis**

Table 2 lists the hypothesis of each variable in the methods. The analysis assumes each variable in the category of the HSR feature is positively related to the increase of agglomeration economies, with the exception of the train frequencies because train frequencies to/from Paris not only include HSR frequencies but also all other types of rail services, such as overnight train services. Thus, with the control of HSR train frequencies, more overnight train services indicate a lower level of accessibility and further indicate a lower increase in agglomeration.

As the economic control variables, human capital, occupied housing rate and population density are assumed to have a positive relationship with an increase of agglomeration economies. In addition, a city located in close proximity to the ocean and regional capital cities, which have a large economic potential, will have a greater increase
in job density. Similarly, a city proximal to nearby countries is assumed to obtain more economic benefits from HSR investment.

Table 6-2: Model Hypothesis

<table>
<thead>
<tr>
<th>HSR Feature:</th>
<th>Hypothesis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Train frequencies of HSR service to/from Paris</td>
<td>+</td>
</tr>
<tr>
<td>Travel time savings to/from Paris</td>
<td>+</td>
</tr>
<tr>
<td>Train frequencies of all rail services to/from Paris</td>
<td>-</td>
</tr>
<tr>
<td>Level of overall accessibility</td>
<td>+</td>
</tr>
<tr>
<td>Location of HSR station from edge to center</td>
<td>+</td>
</tr>
</tbody>
</table>

**EconControl**
- Human capital          +
- Occupied housing rate  +
- Population density     +

**CityControl**
- Seaside city           +
- Regional capital city   +

**GeoControl:**
- Proximity to Belgium (BEL)  +
- Proximity to Italy (ITA)   +
- Proximity to Switzerland (CHE)  +
- Proximity to Germany (DEU)   +
- Proximity to Spain (ESP)     +

### 6.6. RESULTS AND DISCUSSION

#### 6.6.1. Aggregate Estimate of Panel Data from the Change Value

Table 3 presents the results of both the OLS regression and linear mixed model for estimating the HSR impact on agglomeration economies based on panel data\(^{25}\). In columns

\(^{25}\) Note: This study also explores the relation between employment density and HSR service. Estimates are similar to those using second measures on agglomeration economies. Therefore, only results from the latter measures are provided in this study.
1, 2 and 3, changes in the agglomeration economies are regressed on multiple features of introducing HSR service, such as travel time savings and train frequencies, with gradual consideration of the control of economic performance, city characteristics, and geographic location variables by using OLS. In column 4, the same regression is performed as in column 3 but using the feature of HSR service with the GC index, track mileage amount in 1853 and elevation. Compared to the corresponding OLS coefficients, this study finds that the estimated coefficient of the pooled OLS-IVs model is slightly less than previous simple pooled OLS models. Most of these coefficients are significant at the same level, indicating that the mutual relationship between HSR investment and agglomeration economies is not a major source of estimation bias.

In columns 1, 2, 3 and 4, surprisingly, the measured travel time savings to/from Paris elasticity of mean agglomeration economic growth in all models ranges from 4% to 8%. Although estimates are lower than theory suggests, this phenomenon is not statistically significant among all cities. The coefficient of the level of HSR service (i.e., train frequencies of HSR service) to/from Paris is 0.44 at a significance level of 1%. This suggests that although almost all studies on this topic indicate that the travel time savings is the key factor, the level of HSR train frequencies to/from Paris is actually the most important and reasonable predictor for growth of agglomeration economies. This is close to previous suggestions by Crozet (2013) that frequency is a decisive factor in favor of TGV travel. Daily travel between Paris to Lyon, to Nantes, Rennes and Lille are often more than 20 journeys. Given the same amount of travel time savings, more HSR train frequencies indicate that there is more likely to be more interaction in economic activities between cities and Paris.
To compare the impact of HSR train frequencies with all other rail mode, this study also incorporates the level of all rail frequencies to/from Paris as an explanatory variable into the models. All rail frequencies to/from Paris includes not only HSR frequencies but also other regular rail, such as express trains and overnight trains. The coefficient of this variable in all models ranges between –0.34 and –0.23 at a significance level of above 5%, indicating a significantly negative relationship with urban agglomerating economies growth. The reason for this is that overall train frequencies have generally been reduced over the past three decades, and the conventional rail service has been gradually replaced by HSR service. However, due to the operational costs of HSR service, complete replacement of other rail services by HSR is not possible. For example, the city of Dijon had 13 daily trains to/from Paris and 22 in total rail services from 1990 to 1999. Ten years later, HSR train frequencies rose to 16 per day while the overall rail service dropped to 18 daily. The negative estimates reflect the very important role of HSR train frequencies in boosting agglomeration economies.

In columns 5 to 8, results are shown for the number of linear mixed models that use the same variables as the OLS models. After controlling for the correlation between cities and also within a city of different periods, the coefficient on the level of HSR train frequencies is positive and highly significant in all cases. However, the level of all rail train frequencies is not statistically significant in the mixed model+IVs model, possibly because the mixed model examines the correlation between variables of the level of all train frequencies and HSR train frequencies and then reduces the influence of this variable.

Of note is that the coefficient of market access is nearly zero and not significant. From 1982 to 2009, the French HSR network was developed into a large and
comprehensive rail network that now covers most of the populated urban areas. Most French cities have had improved accessibility not just to Paris but also to other cities. Because of the equal improvement of overall market access, this cannot be used to predict changes in agglomeration economies.

Most importantly, the significant positive estimate of the LGV dummy variable suggests LGV cities have increased agglomeration economies, which is the reverse of what the OLS-IVs model suggests. To further explore this relationship, this study carefully observed agglomeration growth within 13 LGV cities, including Marseille, Lyon and Tours. Nearly all LGV cities dispersed local agglomeration for 1982–1990 and 1990–1999; however, all showed a strong increase for 1999–2009. Lyon and Tours, in particular, increased their agglomeration economies by more than 11% over the previous time period. This significant increase during the last period may overestimate the role of an LGV service.

This is consistent with the findings of Koning et al. (2013) who found that the two different models gave opposing results for the relationship between LGV and changes in employment density; they gave no reasonable explanation for the findings.
Table 6-3: Results of Aggregate Estimates

<table>
<thead>
<tr>
<th>Variables</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
<th>(7)</th>
<th>(8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel Time Savings to/from Paris</td>
<td>0.08</td>
<td>0.04</td>
<td>0.05</td>
<td>0.06</td>
<td>0.12</td>
<td>0.02</td>
<td>0.14</td>
<td>0.18</td>
</tr>
<tr>
<td>Level of HSR Train Frequencies</td>
<td>0.44***</td>
<td>0.28***</td>
<td>0.30***</td>
<td>0.29***</td>
<td>32.26***</td>
<td>27.07***</td>
<td>29.13***</td>
<td>28.01***</td>
</tr>
<tr>
<td>Level of All Rail Train Frequencies</td>
<td>-0.34***</td>
<td>-0.23**</td>
<td>-0.24**</td>
<td>-0.23**</td>
<td>-18.38**</td>
<td>-14.95*</td>
<td>-15.96*</td>
<td>-14.87</td>
</tr>
<tr>
<td>Market Access Index</td>
<td>0.18***</td>
<td>0.10</td>
<td>0.10</td>
<td>0.10</td>
<td>0.01**</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>HST</td>
<td>0.03</td>
<td>-0.05</td>
<td>-0.03</td>
<td>-0.03</td>
<td>-111.43</td>
<td>-143.03*</td>
<td>-124.61</td>
<td>-119.53</td>
</tr>
<tr>
<td>LGV</td>
<td>-0.21***</td>
<td>-0.15**</td>
<td>-0.17**</td>
<td>-0.15**</td>
<td>289.21**</td>
<td>226.61**</td>
<td>234.77**</td>
<td>212.64*</td>
</tr>
<tr>
<td>Center Station</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-131.26</td>
<td>-230.88*</td>
<td>-294.73**</td>
<td>-260.15*</td>
</tr>
<tr>
<td>Edge Station</td>
<td>0.05</td>
<td>0.02</td>
<td>-0.05</td>
<td>0.05</td>
<td>50.01</td>
<td>168.28</td>
<td>202.23</td>
<td>150.89</td>
</tr>
<tr>
<td>Periphery Station</td>
<td>0.07</td>
<td>0.1*</td>
<td>0.11</td>
<td>0.12**</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>EconControl</td>
<td>-</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>-</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>CityControl</td>
<td>-</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>-</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>GeoControl</td>
<td>-</td>
<td>-</td>
<td>Y</td>
<td>Y</td>
<td>-</td>
<td>-</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Instrumental Variables</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Y</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Y</td>
</tr>
<tr>
<td>Adjusted R-Squared</td>
<td>0.150</td>
<td>0.257</td>
<td>0.272</td>
<td>0.276</td>
<td>0.150</td>
<td>0.257</td>
<td>0.272</td>
<td>0.276</td>
</tr>
<tr>
<td>Observations (N)</td>
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<td>321</td>
<td>321</td>
<td>321</td>
<td>321</td>
<td>321</td>
<td>321</td>
<td>321</td>
</tr>
</tbody>
</table>

Note: Coefficients are indicated by *, **, *** for significance at the 10%, 5% and 1% levels, respectively.
6.6.2. Aggregate Estimate of Panel Data from the Base Value

This part of the analysis uses the present value of agglomeration as the dependent variable in the OLS model with the IVs model. The control variables are the same as those of the previous model but include a new variable, which is the initial agglomeration economies, as a way to control the initial base of economic potential. Thus, in the regression model, the present agglomeration economies are regressed on the initial agglomeration economies and multiple features of introducing the HSR service, with the gradually consideration of the control of economic performance and geographic location.

The results are shown in Table 4. The coefficient of initial agglomeration economies is about +0.9, which suggests that 90% of changes in agglomeration economies could be explained by the level of initial agglomeration economies. In other words, the initial agglomeration economies determine the magnitude of changes in agglomeration economies, indicating that major cities with a stronger base of agglomeration economies receive more benefits from HSR service.

All other significant variables are similar to the results in the previous section. The adjusted R-squared value is much higher than that in the previous model, suggesting that the added variable is highly correlated with the dependent variable, which is the change in agglomeration economies over the past thirty years.
Table 6-4: Aggregate Estimate of Panel Data from the Base Value

<table>
<thead>
<tr>
<th>Categories</th>
<th>Dependent Variables: Present Level of Agglomeration Economies</th>
<th>OLS+IVs</th>
</tr>
</thead>
<tbody>
<tr>
<td>HSR Features</td>
<td>Initial Agglomeration Economies</td>
<td>0.86***</td>
</tr>
<tr>
<td></td>
<td>Travel Time Savings to/from Paris</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>Level of HSR Train Frequencies</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>Level of All Rail Train Frequencies</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>Market Access Index</td>
<td>–0.01</td>
</tr>
<tr>
<td></td>
<td>TGV</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>LGV</td>
<td>–0.01**</td>
</tr>
<tr>
<td></td>
<td>HSR Station Location</td>
<td>0.01</td>
</tr>
<tr>
<td>EconControl</td>
<td>Human Capital</td>
<td>0.05***</td>
</tr>
<tr>
<td></td>
<td>Population Density</td>
<td>0.12***</td>
</tr>
<tr>
<td></td>
<td>Housing Vacancy Rate</td>
<td>0.02**</td>
</tr>
<tr>
<td>CityControl</td>
<td>Capital City</td>
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</tr>
<tr>
<td></td>
<td>Ocean City</td>
<td>0.00</td>
</tr>
<tr>
<td>GeoControl</td>
<td>NB_BEL</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>NB_CHE</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>NB_DEU</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>NB_LUX</td>
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</tr>
<tr>
<td></td>
<td>NB_ITA</td>
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<td></td>
<td>NB_ESP</td>
<td>0.01</td>
</tr>
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<td>GC Index</td>
<td>Y</td>
</tr>
<tr>
<td></td>
<td>Elevation</td>
<td>Y</td>
</tr>
<tr>
<td>Adjusted R-squared</td>
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<td>0.99</td>
</tr>
<tr>
<td>Observations (N)</td>
<td></td>
<td>321</td>
</tr>
</tbody>
</table>

Note: Coefficients are indicated by *, **, *** for significance at the 10%, 5% and 1% levels, respectively.
6.6.3. Estimates by Time Period

As mentioned previously, 107 cities were observed from 1982 to 2009, and the time period was further divided into three time periods: 1982–1990, 1990–1999 and 1999–2009 based on the structure of the French population census. Within each time period, the changes in the agglomeration pattern are not only due to the outcome of trade-offs between agglomeration economies and transport cost diseconomies but are also influenced by the overall economic environment in France. Figure 1 presents the trend of changes in agglomeration economies in the past three decades. Overall, the margin of agglomeration economies in many cities remains the same across the three time periods. However, there was a slight decreasing trend in the agglomeration economies from 1990 to 1999; this increased significantly in the subsequent ten years.

![Figure 6-1 Changes in Agglomeration Economies by Time Period](image-url)
It is worth noting that France has experienced two strong economic slowdowns as reflected by the GDP growth rate from INSEE. The first period was 1990–1994 during which the GDP growth rate fell from +0.7% to –0.7%. The second period was 2008–2009; the INSEE report shows that the economy dramatically declined and reached a record low of –1.58% within that 15-month period. The recession time periods are highly correlated with the margin of the agglomeration economies, especially in the period 1990–1999. The second recession was short and close to the last observational year of the study so that this decline is not evident in Figure 1. Taking into consideration these two great recessions help to explain the estimate the effect of HSR service on agglomeration economies and assess the model fitness.

Table 5 displays the summary statistics of HSR-induced agglomeration economies by time period; the same regression is used as the OLS model for the aggregate estimate by controlling for economic performance, city characteristics, geographic location and IVs. The model of fitness indicator—the adjusted R-squared value—shows that each listed explanatory variable can explain about 35% and 47% of the 1982–1990 and 1999–2009 models, respectively. However, the 1990–1999 model represents an extreme case. The negative adjusted R-squared value of –0.023 suggests that no variable can predict the changes in agglomeration economies during the French economic recession period. Moreover, none of the variables listed in that model are statistically significant. The results in the model of 1990–1999 further imply that the effects of HSR on agglomeration economies are mixed across 107 cities. Even when associated with more than 40 HSR

\[26\text{ Data source: INSEE}\]
operating stations, the changes in agglomeration economies cannot be reasonably predicted by improved HSR service in 1990–1999. Hence, this study can conclude that the impact of HSR investment on local agglomeration economies also depends on the level of the whole French economic environment.

In columns 1982–1990 and 1999–2009, the corresponding estimates are consistent with the aggregate estimate of the panel data (Table 3). The corresponding coefficients of variables in these two columns suggest that the magnitude of HSR investment varies across time periods. This is similar to the findings for transport development in the United States by Giuliano (1989) who suggested that when the urban land-use pattern is well developed, the potential rate of land-use change is much lower than in undeveloped areas. In the present study, the third time period of HSR development had relatively lower impacts on agglomeration economies, which is also reflected in the relatively smaller coefficients for the other parameters. For example, the estimate of HSR train frequencies for 1982–1990 is about 43%, which is significantly greater than the 38% of 1999–2009.

The significant difference between columns 1982–1990 and 1999–2009 is the level of market access. The level of market access in a given city, represented by the accessibility index, is calculated by using real HSR train time weighted by the population size of that city to the other 106 cities. For 1982–2009, the market access index negatively and significantly predicts the changes in agglomeration economies at a significance level of 1%. In other words, as market access to that city increased, fewer changes to the agglomeration economies took place, suggesting that the introduction of HSR service was the driving force to decentralize local agglomeration. This is similar to the findings by Summers (1999) who noted that French metropolitan expansion was due more to the
policies of “regionalization” from improved transport infrastructure under government encouragement. In 1982, France started political decentralization and encouraged metropolitan sprawl. As Summers stated, “the construction of TGV is one of the strong signals of decisive political decentralization.”

However, in the 1999–2009 model, the corresponding coefficient of market access is positive at the 1% significance level, which can possibly be explained by two reasons. First, during 1999–2009, around 21 new HSR stations (in the study sample) were added to the existing HSR system, but this number was not sufficient to disperse the local agglomeration economies when compared to the more than 40 stations built in 1982–2009. Second, in the following economic recession period, unobserved indicators, such as economic recovery-related policies or transport policies, were not well captured in this model. Overall, however, increases in the level of market access have an ambiguous effect on changes in agglomeration economies during the three observational time periods.
Table 6-5: HSR-Induced Agglomeration Effect by Time Period

<table>
<thead>
<tr>
<th>Variables</th>
<th>Changes in Agglomeration Economies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel Time Savings to/from Paris</td>
<td>–0.01</td>
</tr>
<tr>
<td>Train Frequencies of HSR Service to/from Paris</td>
<td>0.43**</td>
</tr>
<tr>
<td>All Rail Train Frequencies to/from Paris</td>
<td>–0.3**</td>
</tr>
<tr>
<td>Market Access Index</td>
<td>–0.64***</td>
</tr>
<tr>
<td>HSR</td>
<td>–0.12</td>
</tr>
<tr>
<td>LGV</td>
<td>–0.14</td>
</tr>
<tr>
<td>EconControl</td>
<td>Y</td>
</tr>
<tr>
<td>CityControl</td>
<td>Y</td>
</tr>
<tr>
<td>GeoControl</td>
<td>Y</td>
</tr>
<tr>
<td>Instrumental Variables</td>
<td>Y</td>
</tr>
<tr>
<td>Adjusted R-squared</td>
<td>0.349</td>
</tr>
<tr>
<td>Observations (N)</td>
<td>107</td>
</tr>
</tbody>
</table>

Note: Coefficients are indicated by *, **, *** for significance at the 10%, 5% and 1% levels, respectively.

6.6.4. Estimate by City Size

Based on the definition of city size provided in earlier chapters, this study grouped 107 cities into four categories based on the level of the 2009 population: above 100,000 inhabitants (“major city,” n=29), 50,000–100,000 inhabitants (“big-medium city,” n=26), 25,000–49,999 inhabitants (“small-medium city,” n=28) and less than 25,000 inhabitants (“small city,” n=24).

This study explores the impact of improved market accessibility on agglomeration economies for cities in each category. Figure 2 displays the accessibility elasticity of the mean growth of agglomeration economies. The results show that major, small-medium and small cities have similar elasticities of agglomeration growth due to improved accessibility.
by HSR investment. The elasticities are approximately 24% to 30% at the 5% significance level. Surprisingly, the big-medium cities, which have more than 50,000 inhabitants within the city, show only a 4% increase in agglomeration economies with a unit of improved accessibility. Moreover, this estimate is not statistically significant.

In order to more precisely explain this pattern, previous studies focusing on medium HSR service were examined; only two useful papers were identified. Mannone (1999) discussed the impact of TGV service on local mobility and territorial development and concluded that these impacts depend on the location of the HSR service. Based on his suggestions, the present study examined the sample of the big-medium cities and found that none were served by a central station, only by edge stations or periphery stations. Without an efficient connection between central stations and outlying stations, the influence of an HSR service is weak. In another study, Feliu (2012) examined medium-size European HSR cities from the perspective of stakeholders and urban development. Using Avignon as one of the examples, he concluded that medium-size cities receive mobility benefits from HSR investment, but the degree of economic development is based on the stakeholder capacity in the local community.
6.6.5. Elasticity of Specialized Labor Market to HSR Service

Table 6 summarizes the elasticity of specialized labor market to the introduction of HSR service. The parameter estimates are consistent with aggregate effects discussed previously, but evidence suggests a variation between different types of service. In particular, results suggest the level of HSR train frequencies can be a strong predictor to estimate the changes in agglomeration in knowledge-based, tourism-oriented and public and social service. However, the HSR-induced effects are stronger in knowledge-based services. Moreover, the introduction of LGV service since the early 1980s can positively and significantly induce job concentration in knowledge-based services at the local level. Nonetheless, these induced effects are not observed in other areas of the labor market.
Table 6-6: Elasticity of Specialized Labor Market to HSR Service

<table>
<thead>
<tr>
<th>Variables</th>
<th>Knowledge-Based Service</th>
<th>Tourism-Oriented Service</th>
<th>Public and Social Service</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel Time Savings to/from Paris</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Level of HSR Train Frequencies</td>
<td>1.91***</td>
<td>0.99***</td>
<td>0.77**</td>
</tr>
<tr>
<td>Level of Regular Rail Train Frequencies</td>
<td>0.53</td>
<td>-0.19</td>
<td>0.16</td>
</tr>
<tr>
<td>Market Access Index</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>HST</td>
<td>-6.7</td>
<td>-2.14</td>
<td>-0.23</td>
</tr>
<tr>
<td>LGV</td>
<td>19.28**</td>
<td>-1.12</td>
<td>4.28</td>
</tr>
<tr>
<td>Center Station</td>
<td>-10.09</td>
<td>1.27</td>
<td>7.7</td>
</tr>
<tr>
<td>Edge Station</td>
<td>2.44</td>
<td>-1.73</td>
<td>-5.81</td>
</tr>
<tr>
<td>Periphery Station</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>EconControl</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>CityControl</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>GeoControl</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Instrumental Variables</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Observations (N)</td>
<td>321</td>
<td>321</td>
<td>321</td>
</tr>
</tbody>
</table>

Note: Coefficients are indicated by *, **, *** for significance at the 10%, 5% and 1% levels, respectively.

6.7. CHAPTER CONCLUSION

In this paper I identify the key feature of HSR service and examine the relation between access to economic activity and agglomeration economies using a panel estimation. To deal with the endogenous bias (i.e., urban agglomeration is a consequence of HSR investment rather than a cause), I take an IV approach and also use the changes in access to economic mass and in agglomeration economies, as suggested by Venables (2007). To deal with the correlation between cities and also within cities of different time periods, I used a linear mixed model.
After controlling for these heterogeneity issues, a number of findings are worth highlighting. First, the most important determinant to boost agglomeration economies is the level of HSR train frequencies to/from Paris rather than travel time savings. There is no doubt that HSR has generated significant impacts in improving mobility to/from Paris. However, only one or two daily HSR frequencies cannot maximize the economic benefits in travel time savings.

Second, based on the aggregate estimate of the panel data and the estimate by time period, the evidence on the impacts of HSR investment on agglomeration economies is mixed and location specific. Whether HSR service is a driving force to disperse or assemble local agglomeration depends on the whole French economic environment, the observational time period, the type of HSR system (TGV or LGV) and also supplemental local political policies.

Third, results on the impact of HSR service on the knowledge-based job market are conclusive. HSR service drives knowledge-based job concentration at the local level to enjoy the benefits of “sharing,” “match” and “learning.”

Fourth, this study suggests that the development of HSR service might be harmful to big-medium HSR cities due to the location of stations and also the local stakeholder capacity.

Last, the results from this empirical panel study are suggestive. Within the past three decades, there has been no clear and strong evidence that having an HSR service has an overall net impact on local agglomeration economies. However, this study has limitations. I believe the priority for future work should be to develop more sophisticated approaches to deal with reverse causality and unobserved estimation.
CHAPTER 7 : SPATIAL COMPETITION EFFECT OF HSR INVESTMENT: A PRACTICAL SURVEY ON FIRM’S LOCATION CHOICE

7.1. INTRODUCTION

This chapter focuses on the spatial competition effect of HSR services on the location choices of firms, paying special attention to French knowledge-based firms. As the findings in the previous chapter suggest, the availability of HSR does not significantly boost urban agglomeration economies—only the level of HSR train frequency does. To reinforce this argument, the purpose of this chapter is to add more descriptive evidence, through designing a practical survey and developing an in-depth interview, to confirm that the availability of HSR services is not a decisive factor in the location choices of high-skill firms.

The results of the survey are consistent with the findings in the previous chapter. Most firms do not believe that HSR itself could influence location choice or make a significant contribution to firm growth. Given the long history of French HSR development, the level of HSR accessibility has improved in most French cities. Land value-related factors are the most influential determinant in the distribution and relocation of firms, particularly knowledge-based firms, such as favorable rent or commercial lease terms and the availability of appropriate commercial space. Compared with other travel modes, survey participants indicated that the introduction of HSR services was as important as proximity to highways, urban metro, and public transport services. Moreover, the evidence
from survey suggests that the relocation effect of HSR services is weak; as a result, only 12 firms out of 99 have relocated to other HSR cities. Thus, HSR is vital, but does not drive firm relocation or determine location choices.

This chapter is organized as follows. Section 2 introduces the theory and empirical French evidence on the HSR-induced spatial competition effect. Section 3 describes the research approach used in this chapter. Section 4 is the summary of responses from the survey and in-depth interview. Section 5 discusses the basic information of the participating firms, as well as their movement over time. Section 6 discusses the evidence of HSR’s spatial competition effects on firm location choice, including the major determinants for firm location, travel mode share for customer and employees’ work trips, and so on. Section 7 summarizes the main conclusions.

7.2. EMPIRICAL EVIDENCE OF HSR INDUCING THE SPATIAL COMPETITION EFFECT

Theoretically, a significant transport investment could lead to higher-density employment clusters and the redistribution of economic activities (Banister & Berechman, 2000; Boarnet & Haughwout, 2000; Paez, 2004). In other words, the potential economic growth stimulus of a transport investment can be found through quantifying the number of new jobs and people, but also by its relative distribution of economic activities, such as the locations of new jobs and the locations of service firms, in different regions.

In empirical studies, the impact of HSR on French firms’ location decisions seems negligible. The initial study was done by Bonnafous (1987), who designed a survey to predict firm relocations before and after the inauguration of the Paris–Lyon HSR line.
Bonafous paid special attention to 10 cities in Burgundy and the Rhone-Alps Region. He concluded that, during a period of economic recession, government intervention or economic recovery policies seem to play a more important role in location decisions than did the availability of HSR service. However, Bonnafour noted that it is a challenge to isolate the effects of a new HSR service while track firm movement just two or three years after the inauguration of a HSR service. Two or three years might be too short a time to observe relocation patterns.

The other meaningful study was done by Mannone (1995). He also designed a survey to explore the linkage between HSR service and firm locations. He concluded that there is no evidence that the introduction of the Paris–Lyon HSR line prompted firms to move from Lyon to Paris or from Paris to Lyon. In fact, many firms might decide to take advantage of the fact that Paris is now more acceptable.

Mannone (1995) focused on Dijon, the capital of the French region of Bourgogne, and paid attention only to firms established in Dijon between 1981 and 1994. As a result, Mannone concluded that few firms considered HSR as a factor in choosing firm location, while most did not. Only 4 firms out of 663 clearly stated that HSR service is a key determinant in their choice of location. Similarly, similar studies in Valence and Avignon uncovered the same evidence.

Although HSR service is not a decisive factor in driving firm relocation, it has relocation effects within the regions of HSR cities. For example, Nyfer (1999) used Lyon as an example to show how regional competing cities entice many firms to relocate near HSR stations. He mentioned that the Part Dieu station, a TGV station in Lyon, attracts a significant number of firms. For instance, the occupancy rates of office buildings increased
about 40% between 1983 and 1990. Nyfer explained that this attraction is a result of improved accessibility. Eventually, he concluded that HSR service has made a contribution to attracting firms, but that it is not a main factor. One the other hand, Plassard (1989) also argued the attraction this location already had before the introduction of HSR service. In other words, a large amount of firms were already located in the area, which attracts even more firms. Therefore, the introduction of HSR service plays an important role in driving firm movements, but the final movement or relocation decision does not rely on the presence of HSR stations.

7.3. RESEARCH APPROACH

To track firm relocation patterns, Willigers and Wee (2003) pointed out that surveys are regularly used to identify such movement and examine whether the driving force behind them is the presence of HSR service. Based on his suggestion, this study used a mixed research approach, including a survey and in-depth interview to add recent evidence to the topic. The logic of this study is shown in Figure 1.
The purpose of this study is to explore how knowledge-based firms adjusted to the introduction of HSR service in terms of their location choices, and to seek a professional opinion to explain this reaction. To do so, this study used a questionnaire with three main purposes:

- obtain information about participating firms, such as firm size, location information, the nature of the firm, and historical firm movement;
- elicit information about HSR mode market shares, business location decisions (e.g., customer and employee travel mode shares), and how these factors affect firms’ decisions to locate at their current sites or cities; and
• acquire general comments from firms to identify the advantages and disadvantages of existing HSR services for their firms.

The targeted participants come from two groups. The first group used a Chamber of Commerce database to select a set of firms, paying special attention to knowledge-based firms, including consulting firms, finance/investment banks, accounting firms, and real estate investment services. Examples include Mckinsey, Boston Consulting, Capgemini, Grant Thornton LLP, and Crédit Agricole Corporate & Investment Bank. The study preferred participants who were fully employed in these knowledge-based firms and had clear ideas on the travel behaviors of employees and customers, or had been involved to a great extent in the location decision process. The online questionnaires were administered using Survey Monkey, a professional web survey development cloud. All requests were sent via email or phone call. The request email is shown in the Appendix.

However, conducting such a survey is a serious challenge. The low response rate spurred the author to seek other ways to find participants. Therefore, the second group was targeted and randomly selected by Quatrics, a private online market research company. Associated with the same research purposes, Qualtrics randomly drew a sample from its French consumer panelists, based on two criteria: (1) people who worked full-time for knowledge-based firms and (2) firms located in large or medium-sized cities serviced by an HSR service.

To control bias, the study included “No opinion” and “Don’t know” answers for every main question. If the participants chose one of them, the response was invalid and was not counted in the final report. Moreover, according to some firms’ policies, the responses had to be anonymous or the respondents would not be allowed to participate.
One the other hand, this study also used in-depth interview questionnaires for professors or professional experts in the field of HSR investment. The purpose of this formative, qualitative study was to add important insights into current explanations of firms’ relocation patterns, and to predict future firm distribution patterns and the economic potentials of various types of French cities. The interview questionnaire is included in the Appendix.

7.4. OVERVIEW OF RESPONSES

Table 1 shows the response summary of the qualitative analysis of HSR’s spatial competition effects. The qualitative in-depth interview discussion was conducted from October 2013 to February 2014, and consisted of a detailed qualitative discussion held with a selected interviewee. Interviews were done by phone, and interview questions focused on their expertise with respect to the importance of HSR service and the economic potential of HSR-linked cities.

Table 7-1: Summary of the Qualitative Analysis

<table>
<thead>
<tr>
<th>Summary of the Qualitative Analysis</th>
<th>By Interview</th>
<th>By Survey</th>
</tr>
</thead>
<tbody>
<tr>
<td>Categories</td>
<td>By Interview</td>
<td>By Survey</td>
</tr>
<tr>
<td>Requested Approach</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Responses</td>
<td>6 out of 32</td>
<td>Email or Phone Call</td>
</tr>
<tr>
<td>Valid Responses</td>
<td>6</td>
<td>36</td>
</tr>
<tr>
<td>Response Rate</td>
<td>19%</td>
<td>23%</td>
</tr>
</tbody>
</table>

Only 6 of 32 invitees granted interview requests:

- Prof. Yves Crozet, French economist and specialist on transport economics,
professor at Sciences Po Lyon and the Lyon II University, chair of the Transport Economics Laboratory (LET), and director of Réseau Ferré de France (RFF);

- Prof. Roger Vickerman, professor of Regional and Transport Economics and professor of European Economics;

- Prof. Moshe Givoni, visiting research associate at the University of Oxford and senior lecturer at Tel-Aviv University, Israel;

- Dr. Chia-Lin Chen, research associate, University College London;

- Jessica Fang, Team Leader at Crédit Agricole Corporate & Investment Bank; and

- Jacques Rabouel, director expert at Systra Consulting and previous SNCF employee.

On the other hand, 120 participants fully completed the survey; 99 responses were valid. The overall response rate was greater than 50%. The responses cover 35 major and medium-sized French cities, such as Paris, Lyon, Marseille, and Valence. The distribution of responses by city is included in the Appendix.

Figure 2 shows the number share of responses by industry. Given the purpose of this study, the survey paid special attention to knowledge-based firms. As a result, 43 participants are from consulting firms, while 32 are from investment banking or finance firms. Unfortunately, we only received 6 responses from real estate investment services and accounting firms, and only 12 responses from other industries. For instance, only seven participants represent manufacturing industries.
7.5. **FIRM INFORMATION AND RELOCATION MOVEMENTS**

With the 99 valid responses, the first objective was to understand the basic information of participating firms, such as firm size, and trace the movements of each firm’s locations over the past 30 years. The study also paid attention to whether these movements happened before or after the inauguration of the HSR service.

As a result, nearly half of the responses come from either the French headquarters of international firms or the branch offices of global firms, as shown in Figure 3. More than 45 participants work for firms with more than 1,000 employees. However, most participants’ firms are either small (e.g., 1–10 employees) or large (10–100 or 100–500 employees) French international branch offices or domestic firms. For example, 54 participants work in their firms’ Paris headquarters or in other HSR cities, while 33 work in branch locations. Only seven participants noted that they work in specialized offices, such as IT, in non-headquarters cities.
The statistical responses on firms’ location movements show that nearly 70 firms were open more than 10 years on their current sites, as shown in Figure 4. Only two or three were brand-new, or only open for 2–3 years, in their current locations. When expanding the observation period past 30 years, the study surprisingly found that nearly half were in their original locations. In addition, 45 participants indicated that their firms had relocated within that city rather than from that city to others. Only 12 firms had been relocated to their current cities. Most relocations were moves from major French cities to regional capital cities. This evidence is consistent with the suggestion provided by Nyfer (1999): HSR service has a relocation effect within the regions of HSR cities. However, evidence from this study can only describe firms’ movements. It is not clear whether the major driving force behind relocation was the introduction of HSR services or not.

In in-depth discussion, Prof. Crozet mentioned that HSR’s relocation effects are very weak. Almost no firms will relocate from one city to another due to the introduction of HSR services. Most firms prefer to be close to major cities or regional capitals, rather
than moving to cities with cheap land costs and high levels of accessibility. The major reason for this is that the latter cities have little to no economic potential.

![Business Relocation Pattern](image)

**Figure 7-4: Statistical Survey Relocation Pattern**

### 7.6. RESPONSES FROM SURVEY MONKEY

#### 7.6.1. Location Determinants for Firms

The Survey Monkey survey on location determinants from specific selected firms shows very interesting information, shown in Figure 5. Overall, the most important factors for the location choices of knowledge-based firms were (1) the availability of appropriate commercial space, 2) the availability of subway or regional commuting service and also 3) favorable rent. This is consistent with the location theory suggested. The locations of economic activities are based on a trade-off between land value and transport cost. Given the high-level, relatively stable accessibility pattern in France, land cost/availability seems to be the only important factor in the location choices of knowledge-based firms. This fact
also helps explain why firms relocated near HSR cities. Under the pressures of high land values and the constraints of land availability, most responses noted that their firms had relocated to the outskirts of their cities, but were still within the region of those HSR cities.

The importance of transport services, such as HSR services, the Metro system, and the highway system, was the second-most important determinant of location choice. Surprisingly, the importance of HSR service availability was rated at 3 out of 5, which is slightly lower than that of highway proximity, the availability of subway stations, and the availability of regional Metro service. The responses from firms show that intra-city transport service is more important in determining location choice for a specific city than inter-city HSR service. Although most participating cities are not car-oriented, the responses indicate that highways are still the most important element in choosing a firm’s location.
The availability of HSR service is not the most decisive factor in locating knowledge-based firms. More evidence of this could be found through investigating the travel mode shares of firms’ customers and employees (see Figures 6 and 7). The travel mode share by customers, shown in Figure 6, suggests that cars are the primary travel mode for accessing knowledge-based firms, reflecting the fact that 28 responses note that more than 51% of their business travel is done by car. Meanwhile, only eight participants indicated that their major business trips were completed by HSR service; most of these were investment banks or consulting services located in Lyon and Paris. Meanwhile, a considerable number of participants (20% responses) noted that less than 10% of their
customer business trips or none trips were made via HSR service. In addition, about 10 responses stated that 26%–50% of their business travel was done via HSR. Hence, although the market share of HSR service is mixed across 36 valid responses, it is not the primary travel mode for business trips made by employees of knowledge-based firms.

![Travel Mode Share of CUSTOMERS Arrive_Survey Monkey](image)

**Figure 7-6: Travel Mode Shares of Customer Arrivals**

A similar pattern can be observed in the pattern of travel share mode by employees, shown in Figure 7. More than 51% of employees arrived by car, rather than HSR. However, about 13 participants indicated that the local Metro system or public transport service was the leading travel mode for their employees’ daily commuting trips.
The previous quantitative analysis suggests that knowledge-based services receive the most benefits from the introduction of HSR service. The improved accessibility expands the market shares of these service and boosts cities’ knowledge-based agglomeration economies. However, the results of the practical survey from survey monkey suggests that the travel mode shares of HSR services were not consistent. Given the geographical context in France, cars are the leading transport mode for both business trips and employees’ daily commuting trips.

7.6.3. Effects of HSR Services on Firm Growth

The further evidence reinforces the argument on the importance of the availability of HSR service, as shown in Figure 8. Nearly 44% of survey participants believed that the
introduction of HSR service is not important to the recent growth of their companies, while 25% of firms think that it is somehow important, and 25% strongly emphasized the importance of HSR service. Most of these positive responses came from consulting firms.

When firms grow, they may expand or relocate to other sites or cities. The survey further investigated whether the availability of HSR service would be important in deciding where to expand or relocate. About 36% of responses indicated that it is very important, while 14% believed that it is not important at all. Overall, the major participating firms believe that the availability of HSR service does not play an important role in the recent growth of their firms, but that they may consider it when expanding or moving to a new city.

Figure 7-8: Effect of HSR Service Availability on Firm Growth and Decisions on Future Firm Locations
7.7. RESPONSES FROM QUALTRICS

7.7.1. Location Determinants for Firms

In terms of location determinants, the responses from random selected firms in Qualtric show slightly different patterns as that in Survey Monkey. Overall, the most important factors for the location choices for knowledge-based firms were 1) the availability of appropriate commercial space, 2) favorable rent or commercial lease terms, and 3) proximity to customers, shown in Figure 9. However, the most important determinant on that city is favorable rent or commercial lease terms. It is different that the most important factor is noted to proximity to customers in the Survey Monkey. Besides that, all other factors are voted as the same pattern as results in Survey Monkey.

In addition, the travel mode pattern for firms selected in Qualtrics has similar pattern as the responses in Survey Monkey. Here, the graphs are not provided here again and will display in the Appendix.
In the Qualtrics, this study also asks the important of HSR service on firm growth. The responses are mixed, shown in Figure 10. 18 out of 63 responses indicate the availability of HSR service is not important to firm growth while about 13 responses think it is very important in promoting firm growth. Moreover, about 8 responses consider it is extremely important in helping firms. Of course, on the other side, about 9 and 6 responses think the introduction of HSR service is slightly important but not key factor. The responses
are similar as the results from previous quantitative analysis. HSR service is vital, but itself is not power enough in promoting economic development and increasing job density.

![Diagram](image_url)

**Figure 7-10: Important of HSR Service on Firm Growth**

### 7.8. IN-DEPTH INTERVIEW DISCUSSION

This section presents findings from the qualitative in-depth interview component of the French HSR study. Three key discussions can be summarized in three groups: (1) the role of travel time savings in knowledge-based firms, (2) the role of HSR services in firm growth, and (3) future firm location choices made due to the presence of HSR service.
7.8.1. The Role of Travel Time Savings in Firms

All interviewees argued that the benefits of travel time savings can be significantly identified; however, the role of travel time savings in the productivity of knowledge-based firms is unclear. There is no doubt that the introduction of HSR service provides larger time savings due to its 250 km/h operational speed being faster than traditional rail’s operating speeds of up to 160 km/h. Within the 800-km distance threshold, HSR is faster than cars and beats the advantage of air travel through reduced check-in and security time. These direct travel time benefits can be clearly observed and measured.

However, the economic value of travel time savings is difficult to evaluate, especially in business travel. For instance, Prof. Vickerman said, “Business travelers have to work on the train. They may have to stay in contact. Because they have smartphones and there is Wi-Fi on trains now, they can keep in touch with their business and continue to work while they are on the train.” Similarly, Prof. Crozet argued that “time is a scarce resource. Time spent working on the train is not wasted, and people can work on reports or send emails. Although it is not very productive work, business travelers still work on the train.” In his presentation at the International Transport Forum, Prof. Crozet said, “In general, the time spent travelling does not decrease” because the short travel time enables travelers to perform multiple activities during a trip or to take multiple trips in a day. Travel time is not really reduced in such cases. Therefore, it is difficult to define the travel time saved and evaluate the associated economic benefit.
7.8.2. **The Role of HSR Services in Firm Growth**

Similarly, this study asked interviewees to rate the importance from 1 to 10 of transport elements in the economic growth of knowledge-based French firms; 1 indicates that the factors is not important at all, while 10 is extremely important. These elements include (1) HSR train frequency; (2) train ticket prices; (3) travel times between cities; (4) supplementary urban transport networks (e.g., subway, bus, tram, etc.); (5) the whole-city economic environment, including economic potential; and (6) others.

Figure 11 shows the results of rating the importance of these determinants in firm growth. As with the findings from the practical survey, city economic environment was the most decisive factor for firm growth, followed by HSR train frequency and intra-city transport services. Moreover, HSR train frequency was rated 7.0, which means that it is a significant factor in improving firm growth. This is consistent with the conclusion generated from the regression model in the previous chapter.
Ticket prices for HSR service are not a major factor for knowledge-based firms. Jessica Fang said, “Never consider the ticket price. We only consider the travel convenience and travel time.” Jacques Rabouel said, “For business trips within France, TGV ticket prices are reasonable. TGV trains have two classes—first and second. Many TGV trips are short, let’s say one or two hours. Companies send their representatives/staff in second class rather than first. The reserved ticket price is even lower than the price before the HSR service.”

The locations of HSR stations are also important. For instance, “Building the HSR in the east doesn’t benefit cities like Metz and Nancy. They get relatively good economic performance because they are located close to Germany, rather than due to the stimulus of HSR service. Because the rail station is located between two cities, becoming HSR cities is not beneficial to Metz or Nancy.”

Figure 7-11: The Importance of Determinants for Firm Growth
7.8.3. **Types of City and Firms Relocations**

All interviewees confirmed that the power of HSR stations is not sufficient to spur firm relocation. “If the firms relocate, it must be due to something other than HSR service.” This is because “Firms don’t respond to marginal changes. Sometimes some marginal changes lead firms to move, but that is simply because the accumulation of whole-sector factors causes firms to think about moving, and then accessibility becomes important in choosing a new location.”

This study further investigated which types of cities might have attractive potential when firms relocate. To do so, it grouped French HSR cities into four categories: (1) highly productive, high-access (HH) cities; (2) highly productive, low-access (HL) cities; (3) low-productivity, high-access (LH) cities; and (4) low-productivity, low-access (LL) cities. All responses in the in-depth interview discussions noted HH cities have, due to the highly concentrated economic activities already there, rather than their high levels of accessibility.

However, for the other types of cities, “there is no economic potential or weak potential.” However, they could also have successful growth in the future, depending on whether local governments can develop attractive land-use policies, and whether locally integrated transport systems or alternative travel modes are available (summarized from Dr. Chia-Lin Chen’s opinion). For example, “Back in 1990, the real estate market in Lyon was depressed. The new land-use redevelopment plan in Lyon’s downtown did attract new firms.” Similarly, “Le Man provided favorable local tax policies and developed new office buildings when TGV service came, and later attracted many insurance companies to the city.” Dr. Chen further discussed HL cities: “There are other efficient travel modes in that
city besides high-speed rail service, such as regional rail systems or air travel.” Therefore, having other efficient travel modes could also be promising for economic growth.

Regardless of city type, Prof. Givoni said, “The major benefits of HSR service go to medium cities. But it could be positive or negative depending on local investment conditions.” However, “if the medium cities received benefits, the impacts of those benefits are huge. For example, Cuidad Real is successful because HSR makes it closer to Madrid.” For big cities like Paris and Madrid, “HSR has no effect. But if the city is more dispersed, HSR service will make it less dispersed.” Moreover, within each city, “employment density will increase around HSR stations, while the rest of these cities may have disagglomeration economies.”

7.9. CONCLUSION

This analysis was descriptive; however, it systematically assessed whether the availability of HSR services was the most important factor in firms’ location choices and in driving firm relocation. This study looked at firm movement history and travel modes for participating firms. The main findings in this chapter can be summarized in three detailed points.

First, this study found that the choice of knowledge-based office location may indeed be influenced by the improved accessibility by HSR, but it remains likely that land value and availability are more important in determining location than whether there is an HSR service or not.

Second, HSR services are only important in specific cases. For example, the availability of HSR services is important when a firm is seeking to relocated, but the
existence of an HSR service will not on its own cause firms to relocate. HSR train frequency is almost equally as important as the city’s economic environment in spurring the economic growth of knowledge-based firms. Third, different types of cities may have different responses to the introduction of HSR services.

Major cities will continue grow whether there is an HSR service or not. In-depth interview discussions indicate that medium-sized cities may receive more benefits from HSR services, but these benefits could be positive or negative based on economic growth, which depends on local planning policies and investment conditions. There will also be no surprise impacts from HSR services on small cities whose economic potential is weak.

This small qualitative study cannot make causal claims. Therefore, the survey and In-depth interview analysis in the study should be read as helpful descriptions to aid in understanding the role of HSR services in knowledge-based firms.

As in other qualitative works, this analysis faces a shortfall in valid responses. Given that more than 50 major and medium-sized cities are served by HSR services, the 99 total responses are insufficient for proper analysis. It is thus necessary to obtain more significant responses for further study. The other challenge of the survey is obtaining preferred participants. It is difficult to target people who have clear ideas on the travel behaviors of employees or customers, or have been involved to a great extent in the relocation decision process.
CHAPTER 8 : CONCLUSION

France, one of leading contributors to HSR development, built more than 200 TGV stations and 2037 km of the LGV line between 1982 and 2009. In Europe, only Spain developed more line (2,144 km). Moreover, the HSR lines currently under construction will bring France’s total to 2600 km by 2017. Already, France carries far more passengers than any other European country. According to the INSEE,27 domestic passenger ridership on LGV lines has increased 100 times since the introduction of LGV service in 1981.

The rapid and significant HSR investment in France is associated with the changing pattern of agglomeration economies. Over the past thirty years, the average travel time for HSR cities to Paris has been reduced by more than 30%. Moreover, each newly opened HSR station causes a ripple effect, influencing not only the city where the stations are located but also the nearby region. On the other hand, the economic structure of French cities is evolving from manufacturing industries to knowledge-based activities and tourism. This change in the variety and specialization of the job markets in HSR cities leads to higher job growth, and most importantly, facilitates learning, sharing, and knowledge matching. There is no doubt that the changes in travel time patterns and job markets are related. Therefore, a greater understanding of how agglomeration economies are associated with HSR service is critical.

To do so, the main research chapters of this dissertation have investigated the role of HSR investment in aiding the transformation process of urban agglomeration economies by observing French HSR cities, emphasizing the city level. Chapter 3 described the

27 INSEE: National Institute of Statistics and Economic Studies

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background investigation on the development of the HSR system and its economic performance in France. Then, Chapters 4 to 7 framed and explored three questions about the relationship between HSR investment and agglomeration economies:

1) How has HSR investment impacted the reshaping of accessibility patterns in France?
2) Does HSR investment induce agglomeration economies? How? What is the magnitude of that effect? What kinds of cities will enjoy more benefits?
3) What is the effect of the spatial competition effect of HSR investment on the location choices of French firms?

At the end of this study, the major findings are synthesized into a detailed conclusion of the preceding five chapters, and three principal implications for the development of HSR investment and urban development policy are recommended. The detailed conclusion is provided at the end of each previous chapter.

8.1. SUMMARY OF KEY FINDINGS

This study uses commune-level panel data to examine the economic performance of HSR cities from 1982 to 2009, utilizing real HSR train times and frequencies in 107 French cities. New empirical evidence has been produced through well-designed quantitative and qualitative methods. These research findings meaningfully fill a gap in the literature and can be summarized into six major points:

Firstly, there is no doubt that the introduction of HSR service improved the level of mobility and accessibility, either from cities to Paris or within cities, albeit unequally, depending on the location of cities relative to the newly built HSR line. As expected, the
accessibility pattern indicates that the spatial extension of the LGV network improved the linkages of major cities to Paris. The absolute changes and relative increases in economic potential show that cities located on the LGV network or its extensions experienced greater gains than other cities. Moreover, big-medium or small-medium cities had relatively larger changes in accessibility due to the development of the HSR network. Surprisingly, however, the overall pattern of economic potential remains the same, despite the fact that the HSR network has improved the level of accessibility over the past thirty years. Only a few cities, such as Montpellier, Metz, and Nancy, showed significant improvements in accessibility. Moreover, the HSR network has not reduced accessibility inequalities between French cities.

Secondly, there is no clear and strong evidence demonstrating the overall net impact of HSR service on local agglomeration economies. In other words, HSR service by itself is not a sufficient factor in increasing employment agglomeration. Non-HSR cities with efficient alternative travel modes to Paris or regional capital cities still show competitive job growth. However, a lack of significant transport infrastructure can definitely act as a severe constraint to the development of the labor market.

Thirdly, although having HSR service is not a guarantee, it is an efficient tool for promoting agglomeration economies. For instance, the panel estimation model in this study concludes that the level of HSR train frequencies to and from Paris is the most important determinant for predicting the growth of agglomeration economies. The number of frequencies reflects the potential opportunities a city could receive from savings in travel time. In addition, the evidence evaluating the causality between HSR investment and agglomeration is mixed and location-specific. Whether HSR service serves as a driving
force to disperse or assemble local agglomeration depends on the greater French economic environment, the observational time period, the type of HSR system (TGV or LGV, in France), and local supplemental political policies.

Fourthly, the results of the impact of HSR service on the knowledge-based job market are conclusive. HSR service drives knowledge-based jobs concentrated at the local level, resulting in the benefits of “sharing,” “matching,” and “learning,” especially in major cities. Tourism-oriented agglomeration could also be promoted, but this effect is not consistent across various types of cities and time periods.

Fifthly, the HSR investment is more about retaining the existing spatial economic geography, not changing it. In other words, the hierarchy of the urban system did not change or re-order due to the presence of HSR service. Major cities such as Lyon and Marseille are still more productive than other cities, regardless of whether or not they have HSR service. However, the elasticity of agglomeration economies, based on city size, suggests that the development of HSR service might be harmful to big-medium HSR cities due to the location of stations, the level of HSR service, and the capacity of local stakeholders. In addition, this study suggests that small cities may remain more or less the same; HSR service will not magically upgrade them, at least not in France.

Sixthly, a practical survey and in-depth interview discussion in this study led to the conclusion that the choosing of knowledge-based office locations could indeed be influenced by improved accessibility due to HSR, but it remains likely that land value and availability are more important determinants than the presence of HSR service. A firm will consider the availability of HSR only when it is seeking relocation. Still, the presence of HSR service cannot solely cause firms to relocate to a particular location.
8.2. POLICY IMPLICATIONS

Based on the findings of this study, two principal policy recommendations could be made. First, investment in high-speed rail service needs to be rationally considered. The introduction of HSR service cannot be used as a “magic stick” to promote local agglomeration economies. Many features associated with HSR investment must be considered: 1) The optimal competitive advantage of HSR occurs within distances between 150 and 800 km. If the trips are longer or shorter, this advantage completely vanishes. 2) A sufficiently large population is fundamental to economic growth. The purpose of HSR investment is to connect major cities, not promote small or medium cities, which have weak economic potential. 3) The key aspect of HSR service is daily train frequency rather than speed. Most recent HSR studies overemphasize the importance of speed. While speed is important, it is meaningless without sufficient travel frequency.

Second, it is necessary to focus transportation policy on improving local and regional integrated transport services. Regardless of where the HSR station is located, a local transportation service could maximize the benefits of the HSR service and expand the market coverage by efficiently bringing people into the city or distributing them from the center of the city to other regions. Also, an efficient integrated transport service could help non-HSR cities linked to Paris or regional capital cities receive economic benefits from those major cities.

Although based on French cities, the findings and suggestions of this dissertation could also be applied to the development of HSR systems in the United States, such as in the Northeast corridor, linking Boston to Washington D.C., and in the California region. A
better understanding of how to efficiently use HSR as a tool to promote agglomeration economies is critical before real investment happens. A well-prepared location transport policy could maximize the spatial economic benefits related to the presence of HSR service.
APPENDIX 1: SURVEY REQUEST LETTER (ENGLISH)

Dear Sir/Madam,

I am a University of Pennsylvania PhD student conducting research into the economic impacts of high-speed rail service, and paying special attention to France. As part of my research, I am trying to better understand the role of TGV (and other similar) high-speed rail services on the location decisions of major French businesses.

Your help in completing the following survey would be most appreciated. The survey should take a total of 5 to 10 minutes to complete, and should not require additional research on your part. If you have any questions about the survey questions, please feel free to e-mail me at mengke@design.upenn.edu.

Please click this link to fill out the survey:
www.surveymonkey.com/s/Upenn_TGV_Firms_EN
or https://upenn.co1.qualtrics.com/SE/?SId=SV_eL3YhmFkBZGJkcB

All responses will be completely confidential and anonymous, so please do not indicate the name of your business. If you would like me to share the completed survey results with you, please check the box at the end of the survey, and I will use your e-mail address to send you the results.

Thank you very much in advance for your help.

Mengke Chen
Doctoral Candidate
Dept. of City & Regional Planning
University of Pennsylvania
127 Meyerson Hall
APPENDIX 2: SURVEY REQUEST LETTER (FRENCH)

Madame, Monsieur,

Bonjour,

Dans le cadre de mon doctorat à l’Université de Pennsylvanie, je conduis une recherche sur les effets économiques du réseau de lignes à grande vitesse, et ce tout particulièrement en France. Je cherche notamment à mieux comprendre le rôle que jouent les services de grande vitesse ferroviaire tels que le TGV sur les décisions d'implantations des grandes entreprises françaises.

Votre participation à l’enquête suivante m’apporterait une aide précieuse dans ma recherche. Cette enquête ne devrait pas vous prendre plus de 5 à 10 minutes et ne nécessite aucune recherche supplémentaire de votre part. Si vous avez des questions concernant les questions de cette enquête, n’hésitez pas à me contacter à l’adresse e-mail suivante mengke@design.upenn.edu.

Veuillez cliquer sur ce lien pour accéder au questionnaire:
https://www.surveymonkey.com/s/Upenn_TGV_Firms
https://upenn.co1.qualtrics.com/SE/?SID=SV_eL3YhmFkBZGJkcB

Pour garantir la confidentialité et l’anonymat de vos réponses, veuillez ne pas communiquer le nom de votre entreprise. Si vous souhaitez recevoir les résultats de cette enquête une fois qu’elle sera terminée, veuillez cocher cette option à la fin de l’enquête, et je vous les ferai parvenir par e-mail.

Je vous remercie par avance de votre aide.

Mengke Chen
Doctoral Candidate
Dept. of City & Regional Planning
University of Pennsylvania
127 Meyerson Hall
APPENDIX 3: SURVEY FOR FIRMS (ENGLISH)

Dear Sir/Madam,

I am a University of Pennsylvania PhD student conducting research into the economic impacts of high-speed rail service, and paying special attention to France. As part of my research, I am trying to better understand the role of TGV (and other similar) high-speed rail services on the location decisions of major French businesses.

Your help in completing the attached survey would be most appreciated. The survey should take a total of 5 to 10 minutes to complete, and should not require additional research on your part. If you have any questions about the survey questions, please feel free to e-mail me at mengke@design.upenn.edu.

All responses will be completely confidential and anonymous, so please do not indicate the name of your business. If you would like me to share the completed survey results with you, please check the box at the end of the survey, and I will use your e-mail address to send you the results.

Thank you very much in advance for your help.

PART ONE: INFORMATION ABOUT YOUR BUSINESS

1. What business is your company or firm in?
   - Banking and/or finance
   - Real estate
   - Professional or business services
   - Public and social service
   - Telecommunications or information technology
<table>
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<th>Industry Type</th>
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<td>Manufacturing service</td>
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<td>Goods-Producing Industries</td>
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<td>Retail and wholesale Industries</td>
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<td>Other (please specify)</td>
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</table>

2. **WORLDWIDE, how many employees does your company or business have?**
   - 1 to 10
   - 11 to 100
   - 101 to 500
   - 501 to 1000
   - More than 1000

3. **How many employees does your company or business have at this LOCATION?**
   - 1 to 10
   - 11 to 100
   - 101 to 500
   - 501 to 1000
   - More than 1000

4. **Which city are you currently located?**
   - Paris
   - Lyon
   - Marseille
   - Le Mans
   - Tours
   - Metz
   - Metz
   - Lille
   - Other (please specify)

5. **Please characterize this location’s role in your company or business:**
6. How many years has your business or company been in this CITY or MUNICIPALITY?
   - Less than one
   - 1 to 2 years
   - 3 to 5 years
   - 6 to 10 years
   - More than 10 years

7. How many years has your business or company been in or at THIS LOCATION?
   - Less than one
   - 1 to 2 years
   - 3 to 5 years
   - 6 to 10 years
   - More than 10 years

8. Has the location of this office changed over past thirty years?
   - No
   - Yes, relocated within the same city
   - Yes, relocated from other city
   If it relocated from other city, please specify

PART TWO: INFORMATION ABOUT HIGH-SPEED RAIL AND YOUR BUSINESS LOCATION DECISION

9. On a scale of 1 (unimportant) to 5 (extremely important), how important was the availability of TGV or high-speed rail service to your business’s choice of its current location?
10. Please rate the following factors as they affected your business’s decision to locate in this CITY or MUNICIPALITY on a scale of 1 (unimportant) to 5 (extremely important).

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<th>Factor</th>
<th>1</th>
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<th>No opinion</th>
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<td>Favorable rent or commercial lease terms</td>
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<td>Availability of business-specific infrastructure</td>
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<td>Availability of subway or regional rail commuting service</td>
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11. Please rate the following factors as they affected your business’s decision to locate at THIS LOCATION on a scale of 1 (unimportant) to 5 (extremely important).

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<td>Proximity to head office or owner’s residence</td>
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please specify: 

12. Approximately what share of your CUSTOMERS arrive (please check appropriate percentage):

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<tr>
<th></th>
<th>None</th>
<th>Less than 10%</th>
<th>10-25%</th>
<th>26-50%</th>
<th>51%+</th>
<th>Don’t know</th>
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<td>By TGV or high-speed rail:</td>
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<td>By other rail or bus:</td>
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<td>By walking or biking:</td>
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13. Approximately what share of your EMPLOYEES arrive (please circle appropriate percentage):

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<th></th>
<th>None</th>
<th>Less than 10%</th>
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<th>26-50%</th>
<th>51%+</th>
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14. How important is the availability or TGV or high-speed rail service to the recent growth of your company or business?
- Not important
- Somewhat important
- Very important

15. If your business were to EXPAND or RELOCATE to another city or municipality, how important would the availability or TGV or high-speed rail service be to your decision where to expand or relocate?
- Not important
- Somewhat important
- Very important

PART THREE: GENERAL COMMENTS

16. What competitive or quality of life ADVANTAGES does the availability or TGV or high-speed rail service have for your business or company?

17. What competitive or quality of life DISADVANTAGES does the availability or TGV or high-speed rail service have for your business or company?

THANK YOU! I would deeply appreciate your precious thoughts and your time!

18. Would you like receive the completed survey results from me?
- No, I don't
Yes, I would like to receive the completed survey results. Please send survey results to this email:

APPENDIX 4: SURVEY FOR FIRMS (FRENCH)

Madame, Monsieur,

Dans le cadre de mon doctorat à l’Université de Pennsylvanie, je conduis une recherche sur les effets économiques du réseau de lignes à grande vitesse, et ce tout particulièrement en France. Je cherche notamment à mieux comprendre le rôle que jouent les services de grande vitesse ferroviaire tels que le TGV sur les décisions d’implantations des grandes entreprises françaises.

Votre participation à l’enquête suivante m’apporterait une aide précieuse dans ma recherche. Cette enquête ne devrait pas vous prendre plus de 5 à 10 minutes et ne nécessite aucune recherche supplémentaire de votre part. Si vous avez des questions concernant les questions de cette enquête, n’hésitez pas à me contacter à l’adresse e-mail suivante mengke@design.upenn.edu.

Pour garantir la confidentialité et l’anonymat de vos réponses, veuillez ne pas communiquer le nom de votre entreprise. Si vous souhaitez recevoir les résultats de cette enquête une fois qu’elle sera terminée, veuillez cocher cette option à la fin de l’enquête, et je vous les ferai parvenir par e-mail.

Je vous remercie par avance de votre aide.

1ère PARTIE : RENSEIGNEMENTS CONCERNANT VOTRE ENTREPRISE

1. Quel est votre secteur d’activité ?
   - Banque et/ou finance
   - Immobilier
   - Services
   - Fonction publique
   - Informatique, Internet et télécoms
   - Industrie
Agriculture et artisanat

Commerce de détail et commerce de gros

Autre (veuillez préciser)

2. À L’ECHELLE MONDIALE, combien votre entreprise compte-elle d’employés ?

- de 1 à 10
- de 11 à 100
- de 101 à 500
- de 501 à 1000
- Plus de 1000

3. Combien d’employés travaillent-ils dans SUR VOTRE SITE?

- de 1 à 10
- de 11 à 100
- de 101 à 500
- de 501 à 1000
- Plus de 1000

4. Dans quelle ville êtes-vous actuellement implanté ?

- Paris
- Lyon
- Marseille
- Le Mans
- Tours
- Metz
- Lille

Autre (veuillez préciser)

5. Quel est le rôle de cet établissement au sein de votre entreprise :
Sûrge social ou établissement principal
Succursale
Fonctions particulières (par exemple : Département informatique)
Autre (veuillez préciser)

6. Depuis combien d’années votre entreprise est-elle implantée dans cette ville ?
- Moins d’un an
- de 1 à 2 ans
- de 3 à 5 ans
- de 6 à 10 ans
- Plus de 10 ans

7. Depuis combien d’années votre entreprise est-elle installée SUR CE SITE ?
- Moins d’un an
- de 1 à 2 ans
- de 3 à 5 ans
- de 6 à 10 ans
- Plus de 10 ans

8. L’emplacement de cet établissement a-t-il changé au cours des 30 dernières années ?
- Non
- Oui, au sein de la même ville
- Oui, dans une autre ville
Si vous avez changé de ville, veuillez préciser

2e PARTIE: RENSEIGNEMENTS CONCERNANT LES LIGNES A GRANDE VITESSE ET LA DECISION D’IMPLANTATION DE VOTRE ENTREPRISE

9. Sur une échelle de 1 (pas important du tout) à 5 (extrêmement important), la proximité du TGV ou d’une ligne à grande vitesse a-t-elle été importante dans le choix d’implantation actuelle de votre entreprise ?
10. **Veuillez noter les facteurs suivants sur une échelle de 1 (pas important du tout) à 5 (extrêmement important) selon l'importance qu’ils ont eu dans votre décision d’implanter votre entreprise dans cette ville.**

<table>
<thead>
<tr>
<th>Facteur</th>
<th>1</th>
<th>2</th>
<th>3</th>
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<th>Sans opinion</th>
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<tbody>
<tr>
<td>Emplacement traditionnel ou historique</td>
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<td>Proximité des clients</td>
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<td>Proximité des employés</td>
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<td>Disponibilité de l’espace commercial adéquat</td>
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<td>Loyer ou conditions du bail favorables</td>
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<td>Disponibilité d’infrastructures spécifiques à votre activité</td>
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<td>Proximité du métro ou de services ferroviaires régionaux</td>
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<td>Proximité de l’autoroute</td>
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<td>Veuillez préciser :</td>
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11. **Veuillez noter les facteurs suivants sur une échelle de 1 (pas important du tout) à 5 (extrêmement important) selon l'importance qu’ils ont eu dans votre décision de vous implanter à CET EMPLACEMENT.**

<table>
<thead>
<tr>
<th>Facteur</th>
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<td>Proximité de la résidence du directeur ou propriétaire</td>
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<td>Imposition favorable</td>
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<tr>
<td>Proximité du TGV ou de lignes à grande vitesse</td>
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<td>Veuillez préciser:</td>
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**12. Quel pourcentage de vos CLIENTS arrivent (veuillez cocher le pourcentage correspondant):**

<table>
<thead>
<tr>
<th>Par TGV ou ligne à grande vitesse :</th>
<th>Aucun</th>
<th>Moins de 10%</th>
<th>10-25%</th>
<th>26-50%</th>
<th>+ de 51%</th>
<th>Ne sait pas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Par avion :</td>
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<td>☐</td>
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<tr>
<td>Par bus ou autre moyen ferroviaire :</td>
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<td>☐</td>
<td>☐</td>
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<td>En voiture :</td>
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<td>☐</td>
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<tr>
<td>A pied ou en vélo :</td>
<td>☐</td>
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<td>☐</td>
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<td>☐</td>
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</tbody>
</table>

**13. Quel pourcentage de vos EMPLOYES arrivent (veuillez cocher le pourcentage correspondant):**

<table>
<thead>
<tr>
<th>Par TGV ou ligne à grande vitesse :</th>
<th>Aucun</th>
<th>Moins de 10%</th>
<th>10-25%</th>
<th>26-50%</th>
<th>+ de 51%</th>
<th>Ne sait pas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Par avion :</td>
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</tbody>
</table>
Par bus ou autre moyen ferroviaire :

En voiture :

A pied ou en vélo :

14. La proximité du TGV ou d’une ligne à grande vitesse joue-t-elle un rôle dans la croissance récente de votre entreprise ?
- Pas de rôle
- Un rôle assez important
- Un rôle très important

15. Si votre entreprise devait SE DEVELOPPER ou DEMENAGER dans une autre ville, la proximité du TGV ou d’une ligne à grande vitesse jouerait-elle un rôle dans le choix de votre nouvelle implantation ?
- Pas de rôle
- Un rôle assez important
- Un rôle très important

3È PARTIE : CONSIDERATIONS GENERALES

16. Quel AVANTAGE concurrentiel ou quel aspect de qualité de vie la proximité du TGV ou d’une ligne à grande vitesse confère-t-elle à votre entreprise ?

17. Quel INCONVENIENT en termes de concurrence ou de qualité de vie la proximité du TGV ou d’une ligne à grande vitesse confère-t-elle à votre entreprise ?
MERCI Je vous remercie sincèrement d’avoir pris le temps de partager ces renseignements !

18. Souhaitez-vous recevoir les résultats de cette enquête?

☐ Non merci
☐ Oui, je souhaiterai recevoir les résultats de l’enquête,

Veuillez les envoyer à l’adresse e-mail suivante :
APPENDIX 5: IN-DEPTH INTERVIEW QUESTIONNAIRE

FOR SCHOLARS

Research Topic:

- Impacts of HSR Investment on Agglomeration Economies in France

Research Purpose:

- What are the impacts of HSR on behavior of knowledge-based firms and their productivities?
- Combined with economic indicators of HSR cities, the result of interview is also going to conclude what type of cities could enjoy more benefits from HSR investment.

Interview Record:

Date:_________________________________________________________________
Time:_________________________________________________________________
Interviewee:____________________________________________________________
Title:______________________________________________________________
Company/Organization:____________________________________________________
Voice Record: Yes____ or No____
Language: English___ or French____

Interview Questions:

Part One: The Role of HSR in Firm Growth

1. HSR generates significant saving on travel time, and especially benefits for business trips. In general, could you please provide your view and expectation on how these travel time savings influence knowledge-based firm productivity, such as accounting firms, investment banking, consulting and real estate service firms?

2. In your view, what is your argument on impact of high-speed train (HST) investment on urban agglomeration economies?
3. Regarding current level of HST service, on general, what are potential limitations for economic growth of these types of French firms? Please rate the following reasons with a scale from 1 to 10. (1 = not important at all and 10 = extremely important)
   - HST Train Frequencies
   - Ticket Price
   - Travel Time among Major Cities
   - Supplementary Urban Transport Network (e.g., subway, bus, tram, etc.)
   - Whole City Economic Environment
   - Others

Part Two: Firm Future Location Choices
1. According to level of accessibility and urban productivity, cities can be categorized into four types:
   - HH cities (high access and high productivity)
   - HL cities (high access and low productivity)
   - LH cities (low access and high productivity)
   - LL cities (low access and low productivity)

This chart will be explained in details during the process of interview.

1.1. In your view, do you think if firms are willing to relocate or open a new branch in other HH (high access and high productivity) cities, such as Metz, due to the high level of accessibility and relatively lower office rent if compared to Lyon and Paris?
1.2. How about HL cities ((high access and low productivity) or LH cities (low access and high productivity)? What kinds of transport planning policy are you going to recommend in order to promote economic development for these two types of cities? Which type of cities do you think will be easier for you to achieve your goals?

1.3. Do you think if there is any chance for LL cities ((low access and low productivity), and why?

2. My previous research has shown that new economic activities are highly concentrated on southern region of France in the past 10 years. In your view, do you know if French firms will have any reaction to this trend?

I would deeply appreciate your precious thoughts and your time!
APPENDIX 6: DISTRIBUTION OF RESPONSES BY CITY
APPENDIX 7: TRAVEL MODE SHARES FROM QUALTRICS

Travel Mode Share of CLIENTS Arrive_QUALTRICS

Travel Mode Share of EMPLOYEES Arrive_QUALTRICS
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