Journal of Transport Geography 72 (2018) 106–118

Contents lists available at ScienceDirect

Journal of Transport Geography

journal homepage: www.elsevier.com/locate/jtrangeo

High-speed rail and urban expansion: An empirical study using a time series of nighttime light satellite data in China

Fenjie Long[a,b], Longfei Zheng[a,*], Zhida Song[a]

[a] Hang Lung Center for Real Estate and Department of Construction Management, Tsinghua University, Beijing, China
[b] Guizhou Institute of Technology, Guiyang, China

ARTICLE INFO

Keywords:
Land development
Urban growth
Spatial expansion
DMSP/OLS
Difference-in-differences
Propensity score matching

ABSTRACT

Transportation, especially high-speed rail (HSR), plays a key role in urban development. Although many empirical studies have substantiated the impact of HSR on urban economic outcomes, the role of HSR in urban spatial expansion is seldom empirically measured. Previous studies have shown that the improvement of transportation infrastructure and technology can promote the expansion of cities, mostly on the construction land area announced by the government. This study, which is based on high-precision calibrated nighttime light satellite images, accurately measured the impact of HSR on urban expansion. We estimated a difference-in-differences model after eliminating selection bias by propensity score matching. HSR has a positive effect on urban expansion with an elasticity of 0.12–0.13. In addition, HSR is almost twice as successful at promoting urban expansion in the underdeveloped central and western cities as in the developed eastern cities in China. Governments should consider the varying responses of cities at different levels of development when using HSR to promote urban development. For future HSR line planning in China, the governments should appropriately focus on the central and western regions in order to achieve the most efficient use of resources and balanced regional development.

1. Introduction

Transportation is a key driver of urban spatial expansion in the location theory of economic geography (Glaeser and Kohlhase, 2004). Over the past two hundred years, the means of moving passengers and goods have changed dramatically, and movement speed has greatly increased, while transportation costs have decreased. The decline in transportation costs greatly encourages agglomeration economics and urban expansion, increases international competition and improves productivity (Scott, 2008). In particular, the rapid expansion of rail systems (especially HSR) in the past few decades indicates that these improvements will continue (Huang et al., 2016).

Many studies have explored the impact of HSR on urban development. These studies often conduct empirical analyses with statistical data such as gross domestic product (GDP) and employment rates and wages, at national, regional, urban and local levels (Banister and Berechman, 2003; Givoni, 2006; Iacono, 2008). Several studies have also investigated the impact of HSR on urban spatial expansion, which is an important dimension of urban growth. Urban expansion is closely related to the industrial structure, land planning and development strategy of the city. Currently, despite the rapid development of communication technologies via the internet that allow information to be shared freely, face-to-face communication is still essential for high-value-added innovation activities. In this process, HSR promotes the dissemination of knowledge, leading to increases in knowledge spillover and industrial upgrading. Early studies have shown that transport investments, such as HSR, have a positive effect on economic outputs, and that there are heterogeneous effects among regions at different distances from the coastline (Albalate and Fageda, 2016; Lin et al., 2015). However, these studies have not revealed the impact of HSR on urban space (Banister and Berechman, 2012) due to limitations in traditional economic statics that do not reflect the spatial changes of cities. According to the urban location theory, the reduction of transportation costs can promote urban spatial expansion. Previous studies primarily focused more on the impact of intra-city transportation on urban expansion, but few studies focused on inter-city transportation.

This paper addresses the gap by studying the direct effects of HSR on urban spatial expansion. It is measured by the nighttime light imagery over ten consecutive years. Based on calibrated images, we can identify the urban expansion of cities over time (Elvidge et al., 1997; Henderson et al., 2012). In particular, this paper studies the case of the construction of HSR at a large scale in China. We conducted an analysis

* Corresponding author at: Room 3-405, West Main Building, Tsinghua University, Beijing 100084, China.
E-mail address: zhenglf17@mails.tsinghua.edu.cn (L. Zheng).

https://doi.org/10.1016/j.jtrangeo.2018.08.011
Received 4 June 2018; Received in revised form 14 August 2018; Accepted 20 August 2018

at the city level via the difference-in-differences (Diff-in-Diff) empirical strategy based on panel data. Cities with and without HSR were divided into treatment and control groups to separate the impacts of HSR on urban spatial expansion from rapid urbanization. Then, we determined the causal effect of HSR on urban expansion, and the heterogeneous effects were explored in different types of cities.

The rest of this paper is organized as follows. Section 2 provides the related literature about impact of HSR on urban expansion. Section 3 describes the construction of China's HSR network and associated influence mechanisms. Section 4 contains data preparation. The empirical strategy and main results are presented in Section 5, and Section 6 is the further discussion. The last section concludes.

2. Literature review

Urban growth includes not only economic development but also spatial expansion. Many studies have demonstrated the impact of HSR on economic outcomes. However, few studies have paid attention to the relationship between HSR and urban expansion.

Previous studies have focused on the impact of HSR on the expansion of the economy, population, knowledge and other factors, regarding the city as an observation point. The reduction in transportation costs can promote the economy and change urban spaces, according to the monocentric urban models (Glaeser and Kohlhase, 2004). A fundamental study proved that investment in transport infrastructure could improve the accessibility and economic growth of a region (Johansson, 1993). Then, Banister and Berechman (2003) described and explained the influencing mechanism of transport investment on economic development in detail. As a modern mode of travel, HSR has undoubtedly contributed to regional accessibility and economies. Blum et al. (1997) reported economic growth in HSR corridors via the integrations of goods, service markets, labor markets, private services and leisure activities. Subsequently, empirical evidence from different countries and regions confirmed this growth. Gutiérrez (2001) evaluated the predicted accessibility effects of HSR at the Madrid-Barcelona-French border and found reductions of 1.87% in travel times and 2.3% in daily accessibility. Similar roles of HSR in Asia, Europe and other region have also been found (Shin, 2005; Sasaki et al., 1997; Shao et al., 2017). Especially in China, many recent studies have shown that the construction of HSR plays a significant role in the promotion of economic growth, the reduction of emissions, the transfer of international technology, knowledge spillovers and talent flow (Lanjian and Wei, 2015; Ke et al., 2017; Sun and Mansury, 2016). Meanwhile, several studies have shown that HSR has widened the disparity of development between cities with and without HSR, as HSR can create new location advantages, but simultaneously creates disadvantages for cities not served by HSR networks. (Yin et al., 2015)

However, a city is a geospatial entity with various economic markets. Each city has its own spatial hierarchy, and a decline in transportation costs promotes urban sprawl (Glaeser and Kohlhase, 2004). Previous studies have focused primarily on the promotion of urban expansion by reductions in transportation costs for private cars and subways within cities. However, HSR is emerging as an inter-city transportation, and its impact on urban spatial expansion has received little attention. The location theory holds that residents often choose residences by comparing the marginal benefits and marginal costs of a residential location (Alonso, 1964). In general, urban expansion is the result of capital investments pursuing the maximization of profits (Blackmar and Harvey, 1985). On the one hand, as residents' incomes increase, their living amenity demands and residence search area also increases, which leads to the rapid expansion of urban space (Wheaton, 1974). On the other hand, technological innovation has reduced the monetary and time costs of commuting. Government policies and corporate pressure have also dramatically shaped the way people go to work. (Adler, 1991) The widespread use of private cars and the development of new transportation systems have reduced the cost of commuting from suburban areas to city centers, thus promoting urban spatial expansion (Cao, 2015; Deng et al., 2008; Glaeser, 2005). As a modern form of innovative inter-city transportation, HSR connects the resources of surrounding cities. With the operation of HSR, urban agglomerations gradually form a unified labor market. In the pursuit of higher amenities, some employees have become accustomed to working and living in different cities, which can also promote urban expansion. (Banister and Berechman, 2012) Nevertheless, few studies have empirically measured the effect of HSR on urban expansion because of the unavailability of time-series data for urban areas.

This study attempts to fill this specific gap by exploring the impact of HSR on urban expansion. Different from previous studies, we use nighttime light imagery to monitor the expansion of urban space over ten consecutive years. Based on the results, we employed a Diff-in-Diff quasi-experimental strategy to measure the exact impact of HSR on urban expansion. More importantly, this study supports the urban location theory, which claims that the reduction of transportation costs can promote urban spatial expansion.

3. Background and mechanisms

3.1. HSR in China

HSR is a modern and efficient mode of transportation that has a strong competitive edge among methods of intermediate-distance travel. Especially in China, the rapid development of HSR has continued over the last decade simultaneously with rapid urbanization. The flows of passengers, capital and goods between cities are consequently higher and more frequent. According to many academic research questionnaires, (Lin, 2016) the purposes of traveler are mainly business and commuting in the metropolitan area. In the middle and long distance travels more than 500 km, travel is mainly for non-commute business and leisure.

China is ideal for exploring the impact of HSR on urban expansion considering the following features. First, according to the data and reports from the China State Railway Administration, the total operating kilometers of HSR reached 11,208 by 2013, and 12,000 km are currently being constructed. The HSR in China represents the largest HSR network under construction in the world. Second, since 2008, new HSR lines have gone into operation, and the number of cities with HSR has been increasing every year. As of the end of 2013, 103 cities of China's 285 prefecture-level cities were operating an HSR line, which is a suitable number for quasi-experiments.

Furthermore, compared with that in Japan, France and Spain, the development of HSR in China started late and has been developing rapidly. In the early 1990s, China began planning and exploring HSR, built the Qinhuangdao-Shenyang Passenger Dedicated Railway as an experiment. In 2008, the Beijing-Tianjin Express Railway with a speed of 350 km/h, was put into operation. The express railway reduced the travel time from approximately 2 h to 30 min. Then, the Beijing-Shanghai HSR, the world's longest one-stage HSR line with a length of 1318 km, opened to traffic in 2011. According to China's 13th Five Year Plan, by 2020, the high-speed railways will be 30,000 km, as shown in Fig. 1, of which 25,000 km were put into operation by the end of 2017.

3.2. Mechanisms

According to the theory of economic geography, the reduction in transportation costs will speed up the agglomeration of industry, which is considered to play a key role in driving urban expansion (Glaeser and Kohlhase, 2004).

Many studies have theoretically shown the socio-economic impacts