Transportation Research Part A 138 (2020) 158–171

Contents lists available at ScienceDirect

Transportation Research Part A

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

Impacts of high-speed railways on economic growth and disparity in China

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ARTICLE INFO

Keywords:
High-speed railways
Economic growth
Economic disparity
Spatial spill-over effect

ABSTRACT

China's high-speed railways (HSRs) networks have dramatically expanded since 2008, which is widely believed to have promoted economic growth. This study empirically tests this hypothesis and analyses the impact of HSRs on economic disparity between 2002 and 2016 in China using a spatial econometric model. The results confirm the role of HSRs as a driving force in promoting local economic growth, although the spill-over effect is found to be insignificant. However, the cross-city analysis suggests there are heterogeneous effects of HSRs on economic growth. By dividing the sample into small-medium cities and large-mega cities, as well as least-developed, developing, and developed cities, this study finds that HSRs make a significant positive contribution to economic growth in large-mega cities and developed cities but has insignificant effects in other cities. The results indicate that HSRs can widen economic disparity in China. Our findings not only advance the understanding of the role of HSRs in promoting China's economic growth but also provide insights for planning future HSR networks. This study concludes that each city should reasonably plan its HSR network to promote economic growth and reduce economic disparity by accounting for different resource endowments, especially geographic and population factors.

1. Introduction

The first high-speed railway (HSR) emerged in Japan in 1964 with the formal opening of the Shinkansen. The bullet trains on an HSR rail system's new lines have a maximum speed of at least 250 km per hour (km/h), and those on upgraded existing lines have an average design speed of 200 km/h (UIC, n.d.). HSRs have several obvious advantages over conventional transport such as traditional railways and highways, including high speed, greater comfort, and almost exclusive use as a passenger transport mode (Diao, 2018). Thus, HSRs are considered an important technological breakthrough in the development of passenger transport in the 20th century (Campos and De Rus, 2009; Zheng and Kahn, 2013).

Since the opening of the Shinkansen in Japan, many countries have gradually adopted HSR networks. The first is France, which launched HSR service between Paris and Lyon in 1981 (Vickerman and Ulied, 2006). Other countries subsequently started HSR projects, such as Italy and Germany in 1988, Spain in 1992, Belgium in 1997, the United Kingdom (UK) in 2003, South Korea in 2004,

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https://doi.org/10.1016/j.tra.2020.05.013
Received 13 October 2019; Received in revised form 10 May 2020; Accepted 14 May 2020
Available online 15 June 2020
0965-8564/

China in 2008, the Netherlands in 2009, and Turkey in 2009 (UIC, 2015). Currently, there are more than 20 countries with HSR projects in operation or under construction worldwide.

China has drastically expanded its HSR networks since 2008, despite a slow start. Its HSR development initially lagged behind some developed countries by several decades (Qin, 2017). According to estimates, the total investment in the HSR system during China's 12th Five-Year Plan (2011–2015) was over 1.8 trillion yuan (SINA, 2011). By the end of 2017, China's HSR network ranked first globally by length with 25,000 km of finished lines, accounting for about two-thirds of the world's total HSR network (Worldatlas, 2018). According to the Medium and Long-term Railway Network Plan, China's HSR networks are expected to reach 30,000 km by 2020, and a rail network dubbed 'eight vertical and eight horizontal'[1] is expected to be developed by 2030, as shown in Fig. 1 (NDRC, 2016).

As a new and crucial component of transport infrastructure, HSRs are believed to be a driving force for economic growth in China owing to their advantages in reducing travel time and cost, improving capacity utilisation and reliability, increasing accessibility, and raising productivity (Chen et al., 2016; Li et al., 2018b; Meng et al., 2018; Wu et al., 2014). HSRs can also be a tool to improve regional economic disparity and uneven population distribution by connecting China's underdeveloped and developed areas (Chen and Haynes, 2015).

Over a decade has passed since the 2008 opening of the first operating line (i.e. Beijing-Tianjin Intercity Passenger Dedicated Line) (Chen and Vickerman, 2017; Gao et al., 2018). Research on whether HSRs can promote economic growth in China has received increasing attention, along with a growing body of literature examining the impact of HSRs on economic growth in other countries. The present study adds to this developing research and makes three novel contributions as follows. First, this study examines the spatial spill-over effects of HSR on economic growth in China by adopting an economic distance-based spatial weight (EW) matrix instead of a binary contiguity-weighted (BW) matrix. The EW matrix can capture the relationship between non-adjacent cities. Second, by dividing cities into small-medium cities and large-mega cities according to permanent urban population size, a cross-city analysis is conducted to identify the types of cities that are more likely to obtain gains or to suffer losses. Third, by dividing the sample into least-developed cities, developing cities and developed cities based on ascending gross domestic product (GDP) ranking, this study examines the role of HSRs in influencing economic disparity in China. Our analysis not only advances knowledge of how HSRs affect economic growth and economic disparity at the city level but also helps policymakers to formulate appropriate regional development policies (Ke et al., 2017).

The rest of this study is organised as follows: Section 2 provides a review of previous studies, Section 3 presents the methodology, empirical results are shown in Section 4, and discussions and conclusions are given in Section 5.

2. Literature review

2.1. Effects of HSRs on economic growth worldwide

Although HSRs are believed to be an important factor of economic growth, the existing literature has yet to reach a consensus on the type and extent of their effects on economic growth. In Europe, HSRs have been in service for nearly 40 years, and many studies show that they have a positive impact on economic growth. For example, the introduction of Train a Grande Vitesse services between Paris and Lyon have led to significant transport benefits in France (Banister and Berechman, 2000). As suggested by Belin (2014), a high-speed line has positive effects on job creation but high-speed trains in part on a traditional rail line show negative effects, which means that the effects of HSR on economic growth are differentiated according to the nature of the service. In the UK, study demonstrates a causal effect of HSRs on economic growth by 8.5% and confirms their spill-over effect on peripheral regions due to knowledge diffusion, accessibility improvement, and transaction cost reduction (Ahlfeldt and Feddersen, 2017). As HSRs have important impacts on business passenger travel related to tertiary and quaternary economic activities, Albalate and Bel (2016) analyze two cases in the UK and point out that HSRs may have wider economic benefits that are not captured by a conventional cost-benefit analysis. After investigating the Northwest European HSR network and the UK's first high-speed line, Vickerman (2018) finds a transformative effect of HSRs on the economy when combined with other policy interventions. By employing a novel structural equation modelling approach, Chen and Silva (2014) find that Spain's HSR network has played a positive role in promoting provincial economies by increasing GDP and employment. Similarly, by examining the commuting time and commuter numbers in Germany, Heuermann and Schmieder (2019) find that small cities benefit from high-speed trains by gaining access to a wide pool of qualified workers who live in large cities. By analysing the trends, travel time and accessibility brought by HSRs in European countries, Banister and Givoni (2013) propose that HSRs must be planned appropriately to secure their potential, which involves developing the HSR stations as centres of economic activity and making the trains more attractive to a wide range of potential users and uses, rather than simply building new lines.

Turning to China, which is an emerging country that has been expanding its HSR network in the last decade, there is a different picture of the economic impacts of HSRs on economic growth from that of European countries. A growing number of studies identify

[1] Eight vertical HSRs are eight north–south corridors in China, including Coastal passageway, Beijing-Shanghai passageway, Beijing-Hong Kong (Taipei) passageway, Harbin-Beijing-Hong Kong (Macau) passageway, Hohhot-Nanning passageway, Beijing-Kunming passageway, Baotou (Yinchuan)-Hainan passageway, Lanzhou(Xining)-Guangzhou passageway; and eight horizontal HSRs are east–west ones in China, including Suifenhe–Manzhouli passageway, Beijing-Lanzhou passageway, Qingdao-Yinchuan passageway, Eurasia Continental Bridge passageway, Yangtze River passageway, Shanghai-Kunming passageway, Xiamen-Chongqing passageway, Guangzhou-Kunming passageway.

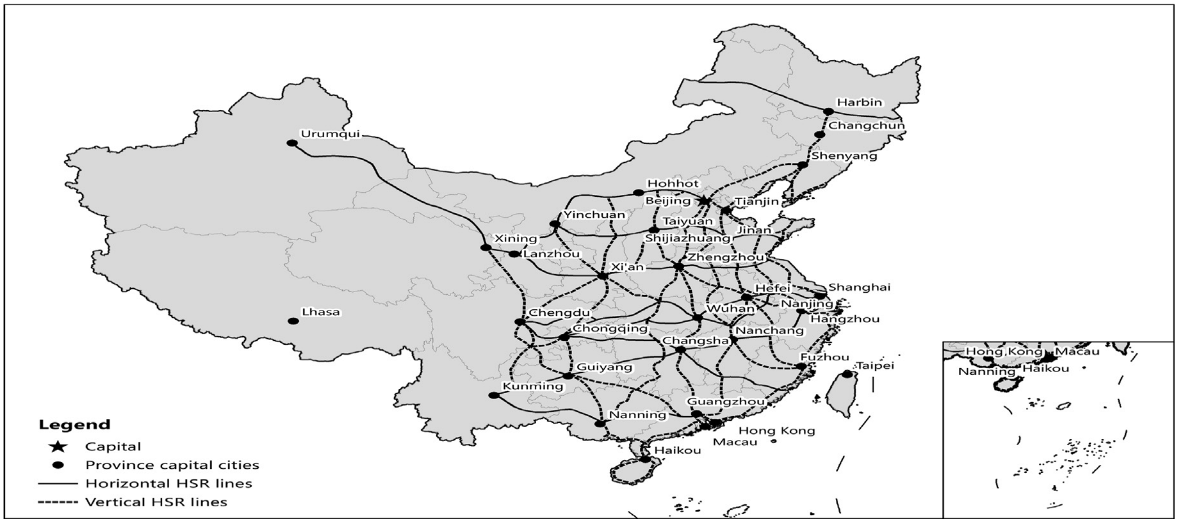

Fig. 1. China's high-speed railway planning map (2016–2030) Source: Drawing by authors based on data from the National Development and Reform Commission (https://www.travelchinaguide.com/china-trains/railway-map.htm).

both positive and negative effects of HSRs on economic growth. Most studies find a positive effect on the local economy. For example, using a computable general equilibrium model, Chen et al. (2016) suggest that investments in HSRs positively stimulate economic growth, primarily through induced demand and output expansion. Chen and Vickerman (2017) discuss the effects of HSRs on regional economic growth and their transformational impact on economic structures by analysing Kent in the UK and the Yangtze River Delta in China as two case studies. The authors find that HSRs have strengthened the economy of most HSR cities, thereby providing evidence of their positive role. Li et al. (2018a) construct an accessibility metric that considers the travel time and price of HSRs and find that an increase in HSR accessibility has significantly promoted the economic growth of 200 cities in China. Using county-level panel data from 2006 to 2014, Meng et al. (2018) verify that one HSR station can promote local economic growth by 14%. However, for surrounding counties within a radius of 30–110 km, HSR stations have had a negative redistribution effect on economic growth, mainly within counties having populations of 20–50 million, whereas there have been lesser effects on counties with populations of more than 50 million. The evidence of Lin (2017) shows HSR-induced expansion in market access and increased urban employment with an elasticity coefficient between 2 and 2.5. Specifically, industries with higher reliance on non-routine cognitive skills have been found to benefit more from HSR-induced market access to other cities. Some studies further discuss the spatial effects of HSRs in China. For example, Wei and Li (2018) investigate the spatial spill-over effect of HSRs on economic growth in the Beijing-Shanghai high-speed rail economic zone and confirm that HSRs have had a significant positive effect on economic growth in both local and neighbouring regions. Chong et al. (2019) focus on the connectivity improvement brought by HSRs and measure their impact on economic growth using a spatial econometric model. The authors confirm a positive impact of HSRs on economic growth, although this impact is derived from a local effect rather than a spill-over effect. Belin (2014) suggests that there are variables that influence both local economic growth and the probability that a city is connected to HSR network, which may result in endogeneity issue between infrastructure and economic growth. Albalate and Bel (2016) states that high-productivity areas are more likely to attract transport investments and will be promoted by such investments, leading to the presence of endogeneity between infrastructure and economic growth. To overcome the endogeneity problem, a range of methods have been employed such as instrumental variables (IV) and propensity score-matching difference-in-differential (PSM-DID) approach (Chong et al., 2019; Diao, 2018; Gao et al., 2018; Meng et al., 2018). On the contrary, some researchers suggest that HSRs have negative impacts on China's economic growth. The results of Qin (2017) reveal that the operation of HSRs has reduced the GDP of counties along the route by 3%–5% on average, mainly due to decreased fixed asset investments. Gao et al. (2018) find that HSRs have hampered the economic growth of cities within the Yangtze River Delta region by about 10% and that peripheral cities have suffered more significant negative effects than central cities close to provincial capitals. These authors point out two channels through which HSR connections impede economic growth: (1) the spatial reallocation of populations from HSR-connected counties to central cities and (2) the spatial restructuring of industries.

2.2. Effects of HSRs on economic disparity worldwide

In addition, as HSRs may create both convergence and divergence effects between remote locations and economic growth centres (Yao et al., 2019), several studies focus on its role in regional economic disparity. Some researchers suggest there are economic disparities among different regions when using HSRs as a tool to promote economic growth. For example, Givoni (2006) reviews the evidence in Japan and Europe and finds that the economic impacts of HSRs not only depend on the introduction of high-speed train (HST) but also on other prevailing conditions, and mainly the cities with a buoyant economy can take advantage of opportunities offered by the HST accessibility. By analysing three cases in Spain and France, Ureña et al. (2009) find that the effects of HSRs are more significant in medium-sized and large cities, mainly because HSRs improve urban accessibility and modernise the overall image of the cities involved, thereby enabling them to compete to attract high-level tertiary sector activities. Chen and Hall (2012) find that both the Lille region and Manchester region have benefited from the connection with the national capital by high-speed trains. However, some sub-regions around Lille and Manchester have not benefited, and a comparison between the two regions shows that the transformation of sub-regions towards the knowledge economy brought by HSTs is a difficult process. Chen and Vickerman's (2017) analysis of Kent in the UK and the Yangtze River Delta in China reveals two kinds of transformational effects of HSRs on different regions with varying development stages. Specifically, the authors find that HSRs can both promote convergence between cities on HSR networks and between cities on and off networks in more developed regions but find less convergence in economic structures in less developed regions.

China is much larger than Japan and European countries, which has contributed to the extensive and rapid development of HSR networks. China is also characterized by its wide economic growth gap, which may, in turn, result in large gaps in the development and social-economic effects of HSRs in different cities. Therefore, the empirical results of the effects of HSRs on economy disparity in China are mixed and controversial. Some studies use prefecture-level Chinese cities in their research samples to evaluate the effects of HSRs on economic disparity. For example, Ke et al. (2017) find heterogeneous effects of HSR treatment on the real GDP per capita across targeted city nodes due to several main factors, including location, region, industrial structure, and transport infrastructure. The authors also find that prefectural-level cities with highly industrialised economies and better supporting infrastructures are more likely to absorb labour into their service sectors than less industrialised cities and thereby gain more benefits from the HSR network. Meanwhile, Diao (2018) employs weighted average travel time to characterise accessibility and finds that HSR cities experience higher accessibility gains than non-HSR cities, which result from a significant increase in fixed asset investments after the inauguration of HSR services. However, the authors find that the treatment effect of HSRs on investments varies with city size. Second-tier cities with large populations tend to benefit more from HSRs than small cities and mega cities. Xu (2017) studies the aggregate and distributional effects of HSR connections on the Chinese economy and shows that HSRs have a significant positive impact and spill-over effect on a region's exports but that HSR-driven regional outsourcing is associated with an increase in national inequality. Conversely, Yao et al. (2019) find that HSRs promote regional economic convergence by accelerating the spill-over effects from economic growth centres to relatively less developed areas. Some studies are devoted to several HSR lines. For example, the results of Jia et al. (2017) show varying impacts of China's HSRs on economic growth for different HSR lines. In particular, the Beijing-Guangzhou line has had a positive effect on the real GDP per capita in the site cities, whereas the Beijing-Shanghai line has had a negative effect, thereby confirming the role of HSRs in reshaping China's regional spatial structure and economic disparities. However, Liang et al. (2020) use a typical HSR line (Guangdong-Guangxi-Guizhou line) that connects developed and less-developed areas in China as a research sample to evaluate the effectiveness of HSRs on regional economic growth and find that HSRs have a more significant impact on less-developed Guangxi areas and areas far from a regional centre city, thereby narrowing the development gap between central and peripheral areas. Overall, previous studies have not reached a consensus about the impact of HSRs on China's regional economic disparity, and the topic requires further research.

2.3. Contributions of this study

After reviewing the existing literature, the following two gaps can be identified. First, existing studies usually use the BW matrix to evaluate the spatial spill-over effects of HSRs on economic growth in China. In the BW matrix, it is assumed that cities spatially correlate only to adjacent cities but not to non-adjacent cities. In fact, some non-adjacent cities may have higher spatial correlation than adjacent cities, owing to their economic connection. To fill this gap, the current study uses spatial weight based on economic distance to evaluate both the impact of HSRs on local economic growth and their spill-over effect on neighbouring economies. Second, the effect of HSRs on economic disparity in China remains a question that requires further investigation, as previous studies neglect to research the effects of city size and local economic growth level. This study evaluates the role of HSRs in different regions with varying development stages by dividing the sample into several sub-samples according to population size and GDP level. By filling these gaps, this study not only advances policymakers' understanding of the role of HSRs in promoting economic growth in China but also provides insight into the planning of future HSR networks.

3. Methodology

3.1. Model specification

Considering that transport infrastructure in a region not only affects local economic growth but also the economic activities in neighbouring regions (Hulten and Schwab, 1991; Park et al., 2020), this study uses the spatial econometric model to examine the aggregate growth effect and potential spatial spill-over effect of HSRs. According to Anselin (2001), the premise of constructing the spatial econometric model is the presence of significant spatial autocorrelation in the dependent variable. The Moran coefficient (MC) can provide some preliminary evidence, as it is the most popular test for spatial autocorrelation. The MC is derived from Pearson's correlation coefficient and is defined as follows (Moran, 1948):

Table 1
Results of the Moran coefficient.

Year	BW matrix		EW matrix	
	Moran coefficient	Z statistics	Moran coefficient	Z statistics
2002	0.177	5.168***	0.563	9.816***
2003	0.191	5.554***	0.267	9.920***
2004	0.199	5.779***	0.271	10.093***
2005	0.100	5.001***	0.000	0.000***
2006	0.198	5.759***	0.259	9.629***
2007	0.196	5.684***	0.263	9.752***
2008	0.195	5.639***	0.274	10.111***
2009	0.184	5.318***	0.273	10.049***
2010	0.183	5.271***	0.277	10.179***
2011	0.175	5.009***	0.284	10.371***
2012	0.167	4.793***	0.286	10.409***
2013	0.163	4.667***	0.284	10.354***
2014	0.160	4.581***	0.280	10.194***
2015	0.158	4.522***	0.276	10.067***
2016	0.159	4.578***	0.268	9.779***

Note: *** indicates statistical significance at the 1% level.

$$MC = \frac{N\sum_{i=1}^{N}\sum_{j=1}^{N} w_{ij}(y_i - \bar{y})(y_j - \bar{y})}{\sum_{i=1}^{N}\sum_{j=1}^{N} w_{ij}\sum_{i=1}^{N}(y_i - \bar{y})^2}, \tag{1}$$

where y is the dependent variable and w_{ij} is the element of the spatial weight matrix. In addition, N is the number of spatial units indexed by i and j. Technically, the MC ranges from –1 to 1; a larger absolute value of MC indicates higher spatial autocorrelation in the data. This assumption can be tested using Z statistics with rejection of the null hypothesis test, indicating significant spatial autocorrelation in the data.

$$Z = \frac{MC - E(MC)}{\sqrt{Var(MC)}}. \tag{2}$$

For the spatial weight matrix, the following uses the EW matrix to examine the spatial effects of HSRs on economic growth.

$$d_{ij} = |G\bar{D}P_i - G\bar{D}P_j| \tag{3}$$

$$w_{ij} = \begin{cases} d_{ij}^{-1}, & if\ i \neq j \\ 0, & if\ i = j \end{cases}, \tag{4}$$

where $G\bar{D}P_i$ and $G\bar{D}P_j$ are the average outputs of cities i and j over the sample period, respectively, d_{ij} and $d_{ij}{}^{-1}$ indicate the economic distance and its inverse, respectively, and w_{ij} is the corresponding element of the spatial weight matrix based on economic distance.

Then, this study uses both the BW and EW matrices to calculate the MC. Table 1 shows the test results of the spatial autocorrelation in GDP, which is the dependent variable in this study.

As suggested by the Z statistics based on both the BW and EW matrices, the null hypothesis should be rejected in the sample period 2002–2016, indicating the existence of significant spatial autocorrelation in the GDP. Accordingly, this study must consider the role of neighbouring regions using an appropriate spatial econometric model when evaluating the impact of HSRs on a region's economy.

The spatial Durbin model (SDM) is constructed to detect and measure the local and spill-over effects of HSRs on economic growth (LeSage and Pace, 2009; Yu et al., 2013). Specifically, first, the Cobb-Douglas production function is adopted as the baseline model in this study and includes capital stock and labour input.

$$Y = \mathrm{f}(K, L), \tag{5}$$

where Y denotes the output, K denotes capital stock and L denotes labour input. Next, other important factors that have been proven in previous studies to affect economic growth are introduced in the function as control variables (Gao et al., 2018; Jia et al., 2017). The log-linearized specification is expressed as:

$$\ln Y = \alpha_0 + \alpha_1 \ln K + \alpha_2 \ln L + \beta \ln X + \varepsilon, \tag{6}$$

where X represents other control variables affecting economic growth. First, foreign direct investment (FDI) is selected because international trade significantly drives China's economic development and transition (Ke et al., 2017). Second, the industrial structure is also previously identified as an important factor affecting economic growth. The rapid development of the secondary sector and tertiary sector has significantly promoted China's economic growth in recent decades; therefore, the industrial structure is defined as the proportion of the value-added of the secondary sector (SP) and tertiary sector (TP) in the GDP, respectively (Jia et al., 2017; Ke et al., 2017; Li et al., 2018a). Third, considering the role of government in promoting economic growth, the public finance expenditure (PFE) is used to represent the degree of government intervention (Gao et al., 2018; Jia et al., 2017).

Further, HSR is incorporated into the model, which is the variable of interest in this study (Cantos et al., 2005; Li et al., 2018b). Then, the semi-log form of the SDM, which considers the spatial effects of both dependent and independent variables, is specified as follows:

$$\ln Y_{\mathrm{it}} = \rho \sum_{j=1}^{N} w_{ij} \ln Y_{jt} + \alpha_0 + \alpha_1 \ln K_{it} + \alpha_2 \ln L_{it} + \alpha_3 HSR_{it} + \beta \ln X_{it} + +\theta_1 \sum_{j=1}^{N} w_{ij} K_{jt} + \theta_2 \sum_{j=1}^{N} w_{ij} L_{jt} + \theta_3 \sum_{j=1}^{N} w_{ij} HSR_{jt} + \gamma_t + \eta_i + \varepsilon_{it}, \tag{7}$$

where HSR_{it} denotes the number of HSR lines; w_{ij} is the spatial weight matrix; $w_{ij}\ln Y_{it}$ is the neighbouring regions' GDP; ρ is the spatial autoregressive coefficient; $w_{ij}\mathrm{HSR}_{it}$ is the variable of interest, which represents a matrix of HSR line numbers in neighbouring regions; θmeasures the spatial spill-over effect of HSRs in neighbouring regions of city i; i and t denote city and year, respectively; and γ_t and η_i denote time fixed effects and city fixed effects, respectively. Compared with previous studies, the methodology in our study has been improved from the perspectives of model specification and spatial weight matrix. First, the SDM includes the spatial effects of both dependent and independent variables and can be treated as an unrestricted model to provide a complete and accurate picture of the spill-over effects. As a result, the spatial spill-over effects of the opening of an HSR on economic growth can be captured by the SDM. Second, previous studies focus mainly based on a binary spatial weight matrix, which ignores the potential spatial correlation between non-adjacent cities. This study constructs an alternative spatial weight matrix based on the inverted absolute differences in the GDP, which enables us to detect the spatial effects of HSRs between both adjacent and non-adjacent cities owing to their economic interactions.

3.2. Data source

Our sample includes 285 cities in China over the period from 2002 to 2016[2] and consists of municipalities (*Zhixiashi*), sub-provincial cities (*Fushengjichengshi*), other sub-provincial cities (*Shenghuichengshi*), and prefectural-level cities (*Dijishi*), as shown in Fig. 2. The GDP and control variable data are from the *China City Statistical Yearbooks 2003–2017*. The *China City Statistics Yearbook* is an annual statistical publication that comprehensively reflects the economic and social development of cities in China. The GDP at the city level in this study refers to the final products at market prices produced by all resident units in a city, which is measured as the value-added in three sectors (primary, secondary, and tertiary). The city level includes all districts, counties (Qi), and county-level cities under this city, which had been approved by the civil affairs department during the reporting period[3]. The missing data are supplemented with data from the *Provincial Statistical Year Book*. To obtain the real GDP, the nominal GDP data are adjusted based on the GDP index in 1978 to eliminate the influence of inflation. Capital investment is the capital stock in year t and is calculated by the perpetual inventory method (Shan, 2008). Labour input is the total number of employed people at the end of year t. The control variables are selected based on the extant literature. For example, owing to the significant role of the government in the Chinese economy, the PFE is adopted. Also, to reflect the importance of the industrial structure in economic growth, this study uses the proportion of the value-added of the SP and TP (Gao et al., 2018; Jia et al., 2017; Meng et al., 2018; Qin, 2017; VanCeylon et al., 2020). The main independent variable of interest is the number of HSR lines of city i in year t, which is calculated based on the exact times when HSRs started operating in city i. The exact time is defined as follows: If the HSR line is opened in the first half of year t, the opening year is year t, otherwise, it is year $t + 1$. The data are obtained from the HSR official website in China[4].

4. Empirical results

4.1. Impact of HSRs on economic growth

This study first uses Models I and II to detect the local and spill-over effects of HSRs on economic growth in all cities and examines how local effects differ when considering spatial effects. By denoting the dependent variable Y as the GDP, Model I is expressed as the following without spatial spill-over effects:

$$GDP_{\mathrm{it}} = \alpha_0 + \alpha_1 \ln K_{it} + \alpha_2 \ln L_{it} + \alpha_3 HSR_{it} + \beta \ln X_{it} + \gamma_t + \eta_i + \varepsilon_{it}. \tag{8}$$

Meanwhile, Model II is the SDM based on the EW matrix and is specified as:

[2] Owing to missing values in many years, the following 12 cities are excluded: Sansha, Danzhou, Bijie, Tong ren, Lhasa, Shigatse, Qamdo, Lyingchi, Lhoka, Haidong, Turpan, and Hami.

[3] Source: China City Statistical Yearbooks, 2017

[4] http://www.gaotie.cn/

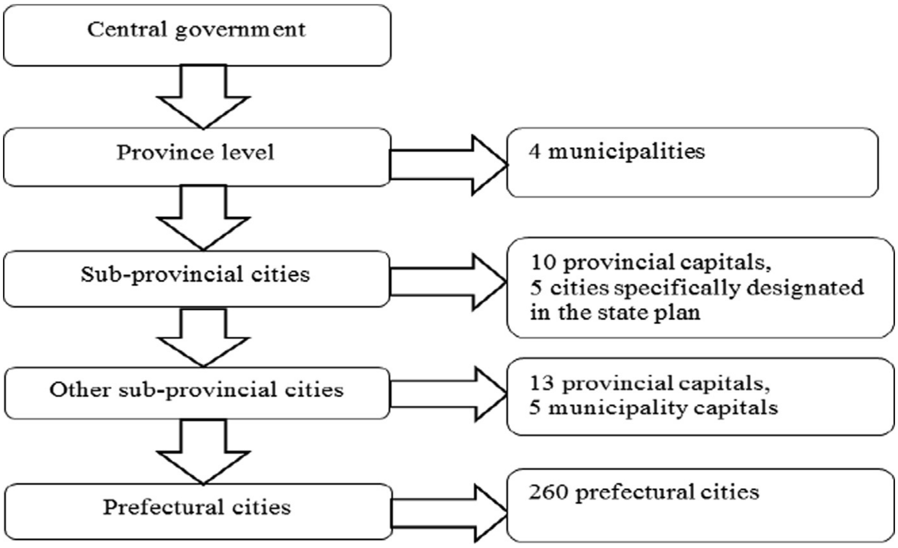

Fig. 2. Four levels of cities in our study (Source: *China City Statistical Yearbook 2017*).

$$\ln GDP_{it} = \rho \sum_{j=1}^{N} w_{ij} \ln GDP_{jt} + \alpha_0 + \alpha_1 \ln K_{it} + \alpha_2 \ln L_{it} + \alpha_3 HSR_{it} + \beta \ln X_{it} + \theta_1 \sum_{j=1}^{N} w_{ij} K_{jt} + \theta_2 \sum_{j=1}^{N} w_{ij} L_{jt} + \theta_3 \sum_{j=1}^{N} w_{ij} HSR_{jt} + \gamma_t + \eta_i + \varepsilon_{it}. \quad (9)$$

China's regional economy and transport infrastructure are characterized by unbalanced development, resulting in large gaps in the HSR development of different cities. Several studies reveal that the effects of HSRs on economic activities depend on a city's size (Givoni, 2006; Ureña et al., 2009). Thus, there is an urgent need to conduct a cross-city analysis of the relationship between HSRs and economic growth to better understand the role of HSRs in stimulating China's economy. Accordingly, as suggested by China's State Council, the sample is divided into small and medium-sized cities, each with a permanent urban population size of less than 1 million, and large and mega cities, each with a population size exceeding 1 million (China's State Council, 2014). To represent city size, this study uses a dummy variable (*CS*), which takes the value of 1 if a city is a large-mega city, and 0 otherwise. The interactions of HSRs and *CS* are included to test whether there is a difference in the impact of HSRs on economic growth among cities. Model III is the SDM based on the EW matrix with consideration of the interaction item of HSRs and *CS*, as follows:

$$\ln GDP_{it} = \rho \sum_{j=1}^{N} w_{ij} \ln GDP_{jt} + \alpha_0 + \alpha_1 \ln K_{it} + \alpha_2 \ln L_{it} + \alpha_3 HSR_{it} + \alpha_4 HSR_{it} {*} \mathrm{CS}_i + \beta \ln X_{it} + \theta_1 \sum_{j=1}^{N} w_{ij} K_{jt} + \theta_2 \sum_{j=1}^{N} w_{ij} L_{jt} + \theta_3 \sum_{j=1}^{N} w_{ij} HSR_{jt} + \gamma_t + \eta_i + \varepsilon_{it}. \quad (10)$$

Further, formula (9) is re-estimated for small-medium cities and large-mega cities, which is represented by Models IV and V, respectively. Table 2 reports the results.

Taking note of the feedback process among spatially correlated units in formula (9), the coefficient θ_3 cannot measure the accurate spatial spill-over effect of HSRs, as it contains feedback effects (i.e. those effects that pass through neighbouring cities and back to the city that instigated the change) (Arbués et al., 2015; Belotti et al., 2017; Shi et al., 2020; Yu et al., 2013). To accurately measure the spatial spill-over effects, the total spatial effects of independent variables can be divided into direct and indirect effects. The direct effects can be used to test the effect of a change in a particular independent variable on the dependent variable in a particular economy and include not only the estimated coefficient but also the spill-over feedback effects, and the indirect effects measure the effect of a change in an independent variable in a city on the dependent variable in all the other cities (Arbués et al., 2015; Golgher and Voss, 2016). Finally, total effects are computed as the sum of direct and indirect effects. The results are shown in Table 3.

According to the results in Table 2, the spatial autoregressive coefficients (ρ) are significantly positive in all models, indicating that there is significant spatial autocorrelation of economic activity among neighbouring cities. In other words, economic growth in a city is affected by its neighbouring cities, and this effect can be captured using the spatial econometric model. In all cities, the results of Models I and II show that HSRs have significant positive effects on economic growth, thereby confirming their positive role in promoting economic growth (Li et al., 2018a; Meng et al., 2018; Wu et al., 2014). However, the coefficient of HSRs in Model I is lower than that in the spatial econometric model, indicating that the effect of HSRs is underestimated if it does not consider the spatial spill-over effect. As proposed by Wu et al. (2014), the observed economic growth is mainly due to the advantages of HSRs in improving

Table 2
Results of the impacts of HSRs on economic growth (based on EW matrix).

Variable	All cities			Small-medium cities	Large-mega cities
	I	II	III	IV	V
lnK	0.174***	0.173**	0.177***	0.180***	0.212***
lnL	0.096***	0.096**	0.094***	0.067**	0.177***
lnSP	0.068***	0.063	0.078	0.112	–0.152**
lnTP	−0.290***	−0.285**	−0.270***	–0.243***	–0.410***
lnPFE	0.037***	0.038**	0.037**	0.032*	0.082***
lnFDI	0.011***	0.011***	0.010***	0.001***	0.018***
HSR	**0.008****	**0.010****	−0.023*	**−0.021**	**0.019*****
HSR*CS			**0.049*****		
W*K		−0.033	−0.047	–0.067	–0.067**
W*L		0.065	0.060	0.092**	0.003
W*HSR		−0.033	−0.047**	–0.082**	–0.003
ρ		0.090**	0.076**	0.082***	0.237***
Adj. R^2	0.660	0.691	0.687	0.678	0.832
Observations	285	285	285	197	88

Notes: *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

Table 3
Spatial direct, indirect, and total effects of independent variables (based on EW matrix).

Variable	All cities			Small-medium cities			Large-mega cities		
	Direct effects	Indirect effects	Total effects	Direct effects	Indirect effects	Total effects	Direct effects	Indirect effects	Total effects
lnK	0.174***	−0.023	0.151***	0.180***	–0.061	0.120**	0.211***	–0.020	0.192***
lnL	0.095***	0.082	0.177***	0.067**	0.107*	0.174***	0.178***	0.055	0.233***
HSR	0.011	**−0.033**	−0.022	–0.021	**–0.090****	–0.111**	0.020**	**0.002**	0.022

Note: *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

accessibility to existing and potential sources of labour, suppliers, and customers, which, in turn, increases specialisation, improves economies of scale, and raises productivity and output. When the effect of HSRs on economic growth across cities is further estimated, this study finds that the coefficient of the interaction item in Model III is significantly positive, indicating that the effect of HSRs on economic growth in small-medium cities is less than that in large-mega cities. As shown in Model IV, the aggregate growth effect is not significant in small-medium cities. The results of Model V for large-mega cities show that HSRs have a significant positive effect on local economic growth. Our results imply that HSRs aggravate economic disparities between small-medium cities and large-mega cities in China.

Turning to the spatial effects as shown in Table 3 and following the indirect effects interpretations presented, the spatial spill-over effects (indirect effects) of HSRs in all cities are not significant. It seems that HSRs in neighbouring cities do not have significant effects on local economic growth. The results across cities show that the spatial spill-over effect of HSRs is significantly negative in small-medium cities, whereas the spill-over effect is not significant in large-mega cities. The results of the direct effects are similar to the local effects of HSRs in Table 2. Both the local and spatial spill-over effects confirm the role of HSRs in enlarging economic disparity between small-medium and large-mega cities in China.

Regarding the results of the control variables in Table 2, capital stock and labour input contribute to economic growth in both small-medium and large-mega cities, which is consistent with the expected results. Turning to industrial structure, the proportion of the value-added of the secondary sector has a positive effect on economic growth in small-medium cities, whereas the effect is significantly negative in large-mega cities. This might be because large-mega cities are usually developed economies that seek the driving force of emerging industries, whereas economic growth in less-developed small-medium cities relies mainly on the traditional secondary sector. However, the proportion of the value-added of the tertiary sector has a significant negative effect on GDP in both small-medium cities and large-mega cities, which is in contrast with our expected findings. The PFE has a significant positive effect on the GDP in all models, indicating that the Chinese government plays a significant role in promoting economic growth (Gao et al., 2018). Meanwhile, significant growth effects of FDIs are observed in all models.

4.2. Impact of HSRs on economic disparity

To further examine the role of HSRs in economic disparity in China, the sample is reclassified into three sub-samples based on the ascending ranking of the GDP in 2016, including first-tier cities with a GDP ranking in the first tertile, second-tier cities with a GDP ranking in the middle tertile, and third-tier cities with a GDP ranking in the third tertile, called least-developed cities, developing cites, and developed cities, respectively. Accordingly, this study uses the variable *EL* to represent the level of economic development, taking the value of 1 for a least-developed city, 2 for a developing city, and 3 for a developed city. Then, the interaction item of HSRs

Table 4
Results of the impacts of HSRs on economic disparity.

Variable	All cities		Least-developed cities	Developing cities	Developed cities
lnK	0.173**	0.178***	0.182***	0.165***	0.209***
lnL	0.096**	0.089***	0.086**	0.056**	0.139***
lnSP	0.063	0.077	−0.016	0.394***	0.019
lnTP	−0.285**	−0.267***	−0.383**	−0.032	−0.166***
lnPFE	0.038**	0.035**	0.025	0.004	0.104***
lnFDI	0.011***	0.010***	0.008**	0.003	0.036***
HSR	**0.010****	**−0.125*****	**−0.019**	**−0.027**	**0.020*****
HSR*EL		**0.051*****			
W*K	−0.033	−0.040	−0.041	−0.050	−0.107***
W*L	0.065	0.055	0.056	0.085*	0.085**
W*HSR	−0.033	−0.054**	−0.101	−0.030	−0.014
ρ	0.090**	0.070**	0.062**	0.080***	0.271***
Adj. R^2	0.691	0.680	0.759	0.825	0.871
Observations	285	285	95	95	95

Note: ** and *** indicate statistical significance at the 5% and 1% levels, respectively.

with *EL* can be used to capture the heterogeneous effect of HSRs on economic growth in each city group. Thus, formula (9) is rewritten as formula (11) by considering the interaction item of HSRs and *EL*. The results of the estimation and spatial effects are reported in Tables 4 and 5, respectively.

$$\ln GDP_{it} = \rho\sum_{j=1}^{N} w_{ij}\ln GDP_{jt} + \alpha_0 + \alpha_1\ln K_{it} + \alpha_2\ln L_{it} + \alpha_3 HSR_{it} + \alpha_4 HSR_{it}{*}\mathrm{EL_i} + \beta\ln X_{it} + \theta_1\sum_{j=1}^{N} w_{ij}K_{jt} + \theta_2\sum_{j=1}^{N} w_{ij}L_{jt} + \theta_3\sum_{j=1}^{N} w_{ij}HSR_{jt} + \gamma_t + \eta_i + \varepsilon_{it}. \tag{11}$$

Table 4 shows that HSR networks have significant positive effects on economic growth in all cities. When further estimating the effects of HSRs on economic growth across cities with different levels of economic development, this study finds that the coefficients of the interaction item of HSRs with *EL* is significantly positive, indicating that the effect of HSRs on economic growth increases with higher levels of a city's economic development. Specifically, insignificant negative effects of HSRs on economic growth are found in least-developed and developing cities, whereas HSRs have a significant positive effect on economic growth in developed cities. The results suggest that HSR networks tend to benefit developed cities rather than least-developed and developing cities, which, in turn, aggravates economic disparity in China. These results are further supported by Wang and Duan (2018), who use a door-to-door approach to identify the "winner" and "loser" cities resulting from HSR network development in the Yangtze River Delta of China. According to their findings, type I winners of HSRs are mega cities with several rail stations and higher accessibility, such as Shanghai, Nanjing, and Hefei, whereas losers of HSRs are cities with remote locations and backward economies. Finally, focusing mainly on the spatial indirect effects in Table 5, the spatial spill-over effects of HSRs on economic growth are not significant in all city groups.

Regarding the results of the control variables in Table 4, significant growth effects of capital stock and labour input are observed in all city groups. Turning to the industrial structure, the proportions of the value-added of both secondary and tertiary sectors have a negative effect on economic growth in least-developed cities, which might be because the economic growth of these cities relies mainly on agriculture. In developing cities, the secondary sector plays a positive role in promoting economic growth. However, the proportion of the value-added of the tertiary sector has a significant negative effect on the GDP in developed cities. The PFE has a significant positive effect on the GDP in developed cities, whereas the effects are not significant in other cities, indicating that government expenditures are more effective in developed regions. FDIs have a significant positive effect on economic growth in least-developed cities and developed cities.

Table 5
Spatial direct, indirect, and total effects of independent variables.

Variable	Least-developed cities			Developing cities			Developed cities		
	Direct effects	Indirect effects	Total effects	Direct effects	Indirect effects	Total effects	Direct effects	Indirect effects	Total effects
lnK	0.184***	0.048	0.232***	0.166***	−0.042	0.124**	0.207***	−0.065*	0.141***
lnL	0.084*	0.068	0.152	0.056**	0.100*	0.156**	0.144***	0.159***	0.304***
HSR	−0.016	**−0.103**	−0.119	−0.025	**−0.032**	−0.057	0.020***	**−0.012**	0.008

Table 6
Labour increment before and after HSR operation.

Express line	City	Labour increment before operation of HSR (1,000 people)	Labour increment after operation of HSR (1,000 people)	Operation year
Beijing-Shanghai line	Shanghai	28.636	85.000	2011
	Nanjing	19.766	24.505	2011
Wuhan-Guangzhou line	Wuhan	21.510	60.299	2010
	Changsha	14.716	17.870	2010
	Guangzhou	16.043	93.993	2010
	Shenzhen	36.835	70.482	2010

Source: Author's elaboration based on various sources.

4.3. Influencing mechanism of HSRs on economic disparity

Our results suggest that HSRs tend to aggravate economic disparity in China. Considering that HSRs are almost exclusively for passenger transport, it seems that labour flows are an important mechanism of their role in enlarging economic disparities. Most large-mega cities and developed cities in our study are either developed cities located in China's eastern region or provincial cities in middle and western regions; these cities usually have the most advanced resources (e.g. sanitation, education, culture, and amusement/recreation) and have more development opportunities and high income levels, which attract the inflow of populations from surrounding small-medium cities and less developed cities (Gao et al., 2018). Furthermore, the operation of HSRs improves transport accessibility between cities, thereby reducing associated costs in accessing large-mega cities and developed cities. According to our results in Tables 2–5, local labour input and neighbouring labour input make positive contributions to economic growth in large-mega cities and developed cities. Therefore, the operation of HSRs can accelerate labour inflow to those cities and, in turn, promote their economic growth. However, the operation of HSRs does not promote economic growth in other cities.

Ke et al. (2017) indicate that more industrialised cities can gain substantial benefits from the operation of HSRs owing to their ability to absorb labour in the service sector and to provide a better supporting infrastructure. As shown in Table 6, a few key cities along the Shanghai-Nanjing and the Wuhan-Guangzhou express lines, for example, have shown high labour growth (total number of employed people) after the operation of an HSR. For Shanghai and Nanjing, this study uses the years 2010 and 2012 to represent the status before and after the operation of the HSR, respectively, given that the Shanghai-Nanjing express line started operating in 2011. Similarly, this study uses the years 2009 and 2011 to represent the status before and after the operation of the HSR, respectively, in Wuhan, Changsha, Guangzhou, and Shenzhen. The increments in labour supply in Shanghai (85,000 people) and Nanjing (24,505) in 2012 are higher than those found in 2010. The increments of labour in Wuhan (60,299), Changsha (17,870), Guangzhou (93,993), and Shenzhen (70,482) in 2011 are also higher than those in 2009. Our findings confirm the results of Sasaki et al. (1997), who reveal that the first HSR, the Shinkansen in Japan, has resulted in employment growth in Osaka and Tokyo but has led to an employment reduction in Nagoya. In addition, this study observes that HSRs in large-mega cities have significant negative spatial effects on neighbouring large-mega cities, suggesting that the HSR network in neighbouring large-mega cities may restrain the local economy of large-mega cities. This phenomenon may be because adjacent cities tend to compete for labour resources.

4.4. Robustness test

In this subsection, some robustness tests are conducted to verify the effectiveness of the results of spatial econometric models. The first concern is about the measure of economic growth. The GDP and GDP per capita (GDPPC) are the two most commonly used indicators of economic growth level; they measure economic growth from the aspects of scale and efficiency, respectively (Jia et al., 2017). In the models in Sub-sections 4.1 and 4.2, this study uses the GDP to represent economic growth; therefore, for the robustness test, this study uses the GDP per capita as the dependent variable to verify the impact of HSRs on economic growth from the perspective of efficiency. The model is as follows:

$$\ln GDPPC_{\mathrm{it}} = \rho \sum_{j=1}^{N} w_{ij} \ln GDPPC_{jt} + \alpha_0 + \alpha_1 \ln K_{it} + \alpha_2 \ln L_{it} + \alpha_3 HSR_{it} + \beta \ln X_{it} + \theta_1 \sum_{j=1}^{N} w_{ij} K_{jt} + \theta_2 \sum_{j=1}^{N} w_{ij} L_{jt} + \theta_3 \sum_{j=1}^{N} w_{ij} HSR_{jt} + \gamma_t + \eta_i + \varepsilon_{it}. \tag{12}$$

As this study is mainly interested in the spatial spill-over effects of HSRs, only the indirect effects of HSRs are reported in Table 7. As shown, HSRs have a significant negative impact on the GDP per capita in all cities, which differs from the significant positive effect of HSRs on the GDP. One explanation is that the GDP measures economic growth based on scale, which is different from the population and jurisdiction based on the GDP per capita (Gao et al., 2018). For example, four of the top ten cities[5] by GDP per capita

[5] The four cities are Erdos, Dongying, Karamay, and Baotou.

Table 7
Results of the models (dependent variable: GDP per capita).

Variable	All cities	Small-medium cities	Large-mega cities	Least-developed cities	Developing cities	Developed cities
lnK	0.192***	0.180***	0.229***	0.162***	0.199***	0.226***
lnL	0.012	0.018	0.010	0.016	0.004	0.002
lnSP	0.340***	0.293***	0.491***	0.252*	0.600***	0.542***
lnTP	–0.140*	–0.188**	0.060	−0.320***	0.102	0.142
lnPFE	0.023	0.009	0.075***	−0.021	0.005	0.099**
lnFDI	0.017***	0.016**	0.021***	0.015*	0.009	0.038***
HSR	**–0.029*** **	**–0.030** **	**−0.015**	**−0.073** **	**−0.010**	**−0.017**
HSR(Indirect)	**–0.029**	**–0.005**	**0.007**	**−0.015**	**0.034**	**0.009**
ρ	0.080**	0.069***	0.133**	−0.036	0.264***	0.204***
Adj. R^2	0.597	0.577	0.659	0.616	0.621	0.594

Note: *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

are resource-based cities with small populations and, as HSRs are mainly used for passenger transport, there may be no HSR operations in those cities. When this study further estimates the effects of HSRs on economic growth across cities, negative aggregate growth effects of HSRs are observed in small-medium cities and least-developed cities, whereas the aggregate effect and spatial spill-over effect of HSRs in other cities are not significant. Despite different effects of HSRs on the GDP per capita and GDP, the role of HSRs in aggravating economic disparity in China is empirically confirmed.

Second, this study uses the BW matrix to construct the spatial weight matrix as an alternative robustness check. For the BW matrix, w_{ij} is 1 if cities i and j share boundaries, and 0 otherwise. By replacing the EW matrix with the BW matrix in formulas (9–11), the results of Models VI, VII, and VIII for the effects of HSRs on economic growth in all cities are derived, as shown in Table 8. HSRs have significant and positive effects on economic growth, and the coefficients of the interaction item in Models VI and VIII are both positive and significant. These findings are consistent with the results based on the EW matrix, reconfirming the role of HSRs in promoting economic growth. The negative spatial spill-over effect of HSRs is significant in the BW matrix-based model, whereas the negative effect is not significant in the EW matrix-based model.

4.5. Placebo tests

Although this study introduces city fixed effects and year fixed effects in the proposed models, unobservable systematic errors cannot be captured yet, which may influence the effects of HSRs on economic growth. Therefore, mock HSR variables are used to construct placebo tests, indicating that significant GDP changes should not occur in the absence of HSRs. Following Gao et al. (2018) and Meng et al. (2018), this study moves the operation time of HSRs in cities forward by 4–6 years and constructs three mock HSR variables—HSR(T-4), HSR(T-5), and HSR(T-6)—which are used to represent the operation time of HSRs four, five, and six years earlier than T, respectively. This study then uses the three variables to replace the HSR in formula (9). As HSR networks did not yet exist, it is expected that the effects of HSRs on economic growth would not be significant in years (T-4), (T-5), and (T-6). The results of the placebo tests are shown in Table 9. As suggested by the insignificant local and spill-over effects of mock HSR variables in almost all regions, the effects of HSRs on economic growth are not a consequence of some unobservable systematic factors. This means the positive effects of HSRs on economic growth in large-mega cities and developed cities are due to the operation of HSRs in these cities, which further demonstrates the robustness of our results.

Table 8
Results of the models in all cities (based on BW matrix).

Variable	Model VI	Model VII	Model VIII
lnK	0.165***	0.168***	0.171***
lnL	0.079***	0.077***	0.073***
lnSP	0.005	0.015	0.0180
lnTP	–0.256***	−0.247***	−0.243***
lnPFE	0.023**	0.023**	0.021*
lnFDI	0.009***	0.009***	0.009***
HSR	**0.018** **	−0.005	−0.082**
HSR*CS		**0.028** **	
HSR*EL			**0.036*** **
HSR(Indirect)	−0.043*	0.021*	−0.100***
ρ	0.444***	0.443***	0.443***
Adj. R^2	0.648	0.654	0.707

Notes: *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively. Model VI is the SDM based on the BW matrix, Model VII is the SDM based on the BW matrix and the interaction item of HSRs and city size, and Model VIII is the SDM based on the BW matrix and the interaction item of HSRs and economic growth level.

Table 9
Results of placebo tests.

Variable	All cities	Small-medium cities	Large-mega cities	Least-developed cities	Developing cities	Developed cities
HSR(T-4)	−0.006	−0.027	0.013	−0.021	−0.025	0.012
WHSR(T-4)	0.004	−0.076	0.013	−0.020	0.020	0.020
HSR(T-5)	0.011	−0.026	0.013	−0.008	−0.025	0.010
WHSR(T-5)	0.014	0.084	0.015	−0.017	0.049	0.012
HSR(T-6)	0.011	−0.030*	0.012	−0.013	−0.29**	0.010
WHSR(T-6)	−0.009	0.038	0.007	−0.032	0.043	0.030

Note: * and ** indicate statistical significance at the 10% and 5% levels, respectively.

5. Conclusion and discussion

This study uses the spatial econometric model to investigate the effects of HSRs on economic growth and economic disparity in China, including both its aggregate growth effects and spatial spill-over effects. This study uses 285 cities as the sample. Our results confirm that HSRs drive economic growth but do not support the presence of significant spill-over effects of HSRs. The cross-city analysis indicates that HSRs can aggravate economic disparity in China. Specifically, the sample is first divided into small-medium cities and large-mega cities based on permanent urban population size. This study finds that HSRs make a significant positive contribution to economic growth in large-mega cities, whereas the spill-over effect is not significant. However, HSRs have insignificant effects on economic on economic growth in small-medium cities, whereas the spill-over effect is significantly negative. Then, the sample is divided into least-developed, developing, and developed cities based on an ascending ranking of the GDP. This study finds that HSRs make a significant positive contribution to economic growth in developed cities but have insignificant effects in other cities. The results suggest that HSRs tend to aggravate economic disparity in China. Our findings can help policy-makers understand the role of HSRs in promoting economic growth in China and can provide information for policy-makers to plan future HSR networks.

First, 'Looking for development, building the highway first' was China's successful development experience proposed in the initial stage of reform (Li et al., 2018b). Influenced by this concept, there is a general belief in China that once HSRs are built, development will follow with local economic growth in all regions. However, national conditions in China are different from those 40 years ago, especially in terms of accelerated population movement and urban agglomeration. Furthermore, HSRs are transport mode almost exclusive for passenger transport and play an important role in improving accessibility to sources of labour, suppliers, and customers. Our results show that the labour force is an important driver of economic growth and an important influencing mechanism of HSRs on economic disparity. Thus, in seeking economic growth, the governments of least-developed and developing cities should strive to attract enterprises to increase job opportunities rather than rely on HSR construction to promote economic growth.

Second, each city should fully consider local endowment conditions and reasonably plan HSR networks to take full advantage of HSRs to promote economic growth and reduce economic disparity (Jia et al., 2017). For example, once China's transport infrastructure is well developed, the construction of HSRs may have a crowding-out effect on other transport modes, especially the airline industry. Wang et al. (2017) show that in highly populated and developed corridors, HSR expansion is likely to leave low-cost carriers (LCCs) with little survival room. Conversely, in low-density corridors, especially in central and western China, LCCs may leave HSRs with little chance of survival in the long run. As a result, the construction plans of HSR networks should be coordinated with regional economic development and local endowment conditions, such as those related to geographic features and population.

Third, further coordination between HSRs and other transport modes is necessary to achieve a balanced and efficient transport system in China. In Europe, most HSR stations are incumbent and central stations, which are easily accessible; however, in China, the majority of HSR stations are located at the edge of cities, far from city centres (Zhang et al., 2017). An HSR station does not secure better regional accessibility improvements if the station is located far from the city centre and is less accessible for most people (Wang and Duan, 2018). In addition, least-developed and developing cities in China generally have poorer connectivity between different transport modes than that of developed cities. This makes it difficult for passengers to transfer between HSRs and other transport modes, thereby preventing the full exploitation of transport accessibility provided by HSRs. Thus, some measures can be taken to improve the exploitation of HSRs in less developed cities. For example, the results of Wang and Duan (2018) imply that it is more efficient to build a relatively cheap motorway to nearby HSR stations for some small cities in the Yangtze River Delta region than it is to build costly HSR stations.

Some limitations exist in this study. First, the endogeneity problem is not discussed owing to the unavailability of an effective instrumental variable for HSRs, which requires further research. Second, this study focuses only on the role of HSRs in economic growth and economic disparity in China but does not consider the impact of HSRs on income inequality and social welfare. These issues remain for future works.

CRediT authorship contribution statement

Mengjie Jin: Writing - original draft, Formal analysis, Data curation. **Kun-Chin Lin:** Funding acquisition, Writing - review & editing. **Wenming Shi:** Data curation, Writing - review & editing. **Paul T.W. Lee:** Writing - review & editing. **Kevin X. Li:** Supervision, Funding acquisition, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgement

This work is supported by Zhejiang University Education Foundation Global Partnership Fund and National Natural Science Foundation of China [Grant 71901116].

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