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Research Article

Does High-Speed Rail Promote Enterprises Productivity? Evidence from China

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High-speed rail (HSR) is often claimed to bring different regions and cities closer together by shortening travel times, which can reduce the costs and increase enterprises productivity to promote a sustainable economy. However, another view argues that HSR transfers economic activities from peripheral cities to core cities, resulting in unbalanced regional economic development and damaging the sustainability of the economy. Based on microdata from China, this paper empirically investigates the impact of HSR on the enterprises productivity in both core cities and peripheral cities and explores the impact mechanism from the perspective of allocation effect and distribution effect caused by HSR. The results show that the connection of HSR positively affects the enterprises productivity in core cities, while it negatively affects the enterprises productivity in peripheral cities, with effect values of 1.38% and -8.45%, respectively. The conclusion still holds after endogenous treatment and multiple robustness tests are conducted. Additionally, the allocation effect analysis shows that the market access caused by HSR has an optimization effect on the resource allocation efficiency of both core cities and peripheral cities. The distribution effect analysis reveals that the distribution of enterprise productivity in peripheral cities has market heterogeneity, regional heterogeneity, and location heterogeneity. The important policy significance of this paper is that, in order to promote the sustainable development of enterprises and the economy, it should reduce policy restrictions and promote the effective flow of capital and talents, carry out the dislocation development of industry for peripheral cities, and "build a nest to attract the phoenix."

1. Introduction

The impact of high-speed rail (HSR) on economy and society is attracting more and more scholars' attention in the recent years [1–3]. In China, improving enterprise productivity and resource utilization efficiency is a major component of China's green and sustainable development strategy [4]. Since 2004, when the State Council of China approved the implementation of "Mid-to-Long Term Railway Network Plan," China's railways have achieved rapid development [5]. On April 18, 2007, China's first bullet train started operation (from Shanghai to Suzhou) [6]. Subsequently, in August 2008, China's first HSR line (Beijing-Tianjin intercity railway) operated, and, since then, China's HSR has developed rapidly [7]. As shown in Figure 1, since 2007 the number of prefecture-level cities with HSR increased from 57 to 215 in 2018. By the end of 2018, there were 92 lines/sections of HSR in operation, with a total mileage of nearly 30,000 km. According to the main targets of "13th Five-year Railway Development Plan" of China, by 2025, the length of HSR will reach 38,000 km, implementing that each provincial capital city is connected to other large and medium-sized cities with a population of more than 500,000. The overall goal of Chinese government is to achieve that the most provincial capitals are scheduled to arrive in Beijing within 2-8 hours and large and medium-sized cities that are close to each other are quickly contacted within 1-4 hours [8]. Therefore, China can be a very suitable research object to explore the economic benefits of HSR.

The rapid development of China's HSR has shortened the travel time of people, improved the travel efficiency, and increased the economic and personnel communication between different regions and cities. It is bound to have a profound impact on the flow of capital, technology, talents, and other enterprise factors and trigger the spatial reconfiguration of factors. Does the connection of HSR have

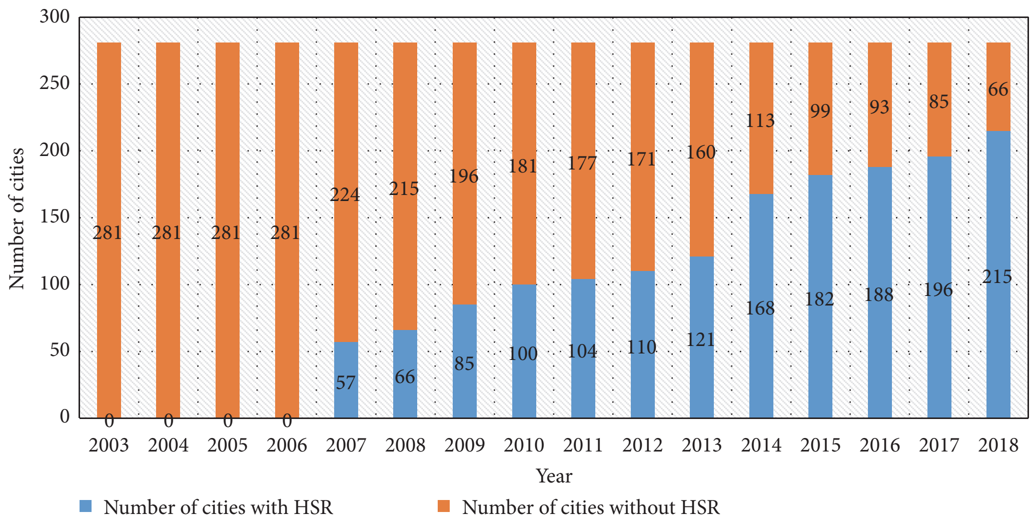

Figure 1: Number of prefecture-level cities with and without HSR.

an impact on the enterprises productivity in core cities and peripheral cities? Is there heterogeneity? What are the underlying mechanisms and channels of influence? These are the questions to be discussed in this article.

This paper mainly studies the impact of China's HSR on the enterprises productivity in different cities. The HSR in this paper consists of G-train, D-train, and C-train (D train is running on the original upgraded line; G train refers to the train using special railway lines. C train is the main body of intercity train. Their speed is above 200 or 250 km/ h. According to the definition of the International Union of Railways, the high-speed railway is defined as the railway whose existing lines are upgraded and speeded up to more than 200 km/h or whose new lines are designed to reach more than 250 km/h. So, we take these three types of trains as research objects, collectively known as "high-speed rail".). By matching China's HSR network data, cities data, and enterprise microdata from 2003 to 2013 (since the latest data of China's Industrial Enterprise Database is up to 2013, the last data matching is up to 2013), this paper empirically studies the impact of HSR on enterprise productivity in both core cities and peripheral cities and explored the mechanism from the perspective of resource allocation effect and distribution effect. The main contributions of this paper include the following. Above all, referring to the research of Song [9], Reggiani et al. [10], and Yi et al. [11], the empirical data of China are used to calculate the market access caused by HSR, which increases the reliability of market access index. Secondly, this paper enriches the research on HSR and enterprise productivity. Previous studies rarely involved the enterprise productivity of core cities and peripheral cities and lacked mechanism analysis between these two types of cities. Thirdly, we find that HSR has distribution effect and allocation effect and that productivity distribution effect shows market heterogeneity, regional heterogeneity, and location heterogeneity in peripheral cities. This paper further explores the influence channel of HSR on the enterprises productivity in core and peripheral cities. Finally, this study has important policy implications for promoting sustainable economic development through HSR.

The remainder of this article is as follows. Section 2 is a brief review of existing theories and literature. Section 3 is the description of data, methods, and indicators. Section 4 is basic regression analysis and endogenous treatment. Section 5 is mechanism analysis. Section 6 is the robustness test. Finally, the conclusion of the research is summarized.

2. Brief Review of the Literature

Through literature review, the literature that is closely related to this study mainly includes the following categories: the impact of transportation infrastructure on economy and enterprises, the study on transportation infrastructure, and market access.

2.1. The Impact of Transportation Infrastructure on Economy and Society. The economic and social impact of transport infrastructure such as high-speed rail remains a controversial issue. Aschauer held that "core" infrastructure such as roads, airports, public transportation, sewers, and water systems had the most explanatory power for productivity [12]. Button believes that, from the perspective of cost-effectiveness, high-speed railway has a huge investment, so whether it should be built or not is still a question that needs to be treated with caution [13]. Givoni and Banister believe that the direct effect of high-speed rail is to save travel time, but speed is not necessarily the most important factor in high-speed rail, which needs to be comprehensively considered from investment, passenger capacity, safety, and service frequency [14]. Guirao and Campa believe that the construction of high-speed railway requires multicriteria evaluation [15]. Although conclusions about the impact of transport infrastructure such as high-speed rail on economy and society are not consistent, there are two kinds of views in general, namely, positive promotion and accelerating regional unbalanced development.

There is positive impact of transportation infrastructure on economic growth, trade, resource flow, employment, and other aspects. Transportation promotes economic growth [16, 17], increases regional trade integration, and thereby improves the level of national income [18]. It has spillover effect [19]. It quickens the flow of products, capital, and labour between regions [20]. Transportation infrastructure facilitates labour migration [21]. Guirao and Casado-Sanz et al. found that the opening of high-speed railway would bring labor migration and help form a broader labor market [22]. However, Kanbur and Rapoport [23] as well as Haas and Osland [24] found labor migration was closely related to rent prices, house prices, income gap, unemployment rate, and location of enterprises/companies between different regions. In addition, Granato et al. found skill level was also important for the relationship between regional differences and labor migration [25]. Transportation infrastructure promotes the growth of urban employment and enhances the degree of specialization [26]. The development of HSR has narrowed the regional economic gap and promoted China's regional economic integration [27]. Bow-snow et al. found transportation infrastructure strengthens the economic "diffusion effect" of regional central cities on surrounding cities, thus promoting the economic growth of surrounding cities [28]. Carbo et al. assessed the economic impact of the introduction of high-speed rail between Madrid and Barcelona and found that high-speed rail improved labor productivity and economic output in the high-speed rail corridor and intermediate station area [29].

The possible adverse effect of transport infrastructure such as high-speed rail is to widen the development gap between different regions. Labour and economic activities in remote areas were promoted to gather in central cities. It restrains the economic growth of neighbouring regions [30]. Although HSR improves accessibility, it results in the unbalance of regional development [31, 32]. The connection of HSR transfers economic activities from marginal counties to urban core, resulting in unbalanced regional economic development and restraining the economic growth of noncentral cities along the HSR line [33]. Similarly, Holl and Mariotti studied the impact of the improvement of expressway on the productivity of urban logistics enterprises and rural logistics enterprises and found that the expressway promoted the productivity growth of urban logistics enterprises, while the productivity of rural logistics enterprises declined [34]. These studies provide inspiration for this paper to study the heterogeneity of enterprise productivity in core and peripheral cities.

In addition, there are a lot of references about the impact of transportation infrastructure on enterprises, including the following categories. One is to help enterprises save costs of inventory. Li et al. [35] found that China's highway investment led to inventory decline, although the efficiency was relatively low, and found that highway investment also had a significant spillover effect on enterprises in neighbouring provinces, accounting for about two-thirds of the total inventory decline. Second is the impact on enterprise location. Kim et al. [36] researched the impact of the opening of expressway in the west coast of South Korea on the site selection of new manufacturing enterprises near the highway and found that the accessibility of expressways had a significant impact on the site selection of new manufacturing enterprises. Third is the impact on productivity. Holl found that expressways would also attract economic activities and lead to the increase of local population density, thus affecting the enterprises productivity through agglomeration benefits [37]. Gibbons et al. found that the new road infrastructure has a positive impact on labour productivity (especially on total output and average wages) [38]. However, there are few researches on the relationship between HSR and enterprise productivity, especially on the productivity of microenterprises.

The above research provides analysis basis and research implications for this paper to explore the impact of HSR on enterprise productivity from the perspective of allocation effect and distribution effect.

2.2. Transport Infrastructure and Market Access

2.2.1. The Implications and Measurement of Market Access. Market access is a key analysis concept related to traffic network evaluation. It reflects the degree to which certain activities occur under different conditions. We can measure them by interactions such as population or GDP and the cost (such as time or distance). These indicators are considered as the standard methods to measure the market access of HSR and are often used in the literature [27, 39, 40]. Previous studies have shown that transportation infrastructure influences economic activities mainly through changes in market access.

Through literature review, it is found that there are many methods to measure market access. The common calculation formula of market access is $Acc_i = \sum_j M_j f(t_{ij})$ [11, 41–44]. M_j represents the characteristics of the destination, generally measured by the GDP or population; $f(t_{ij})$ represents the decay function of generalized travel cost from the starting point i to the destination j, and t_{ij} refers to the travel time, distance, or cost between i and j. Similar to market access is the "market potential" proposed by Harris, whose calculation formula is $mp_i = \sum_{j\neq i}^{R} GDP_j d_{ij}^{-1}$. GDP_j is the gross product of j and d is the distance between i and j, but the parameter value of decay function in this formula is actually fixed value "-1" [45]. Ingram examined the differences between four market access measures: average distance function, reciprocal function, negative exponential function, and Gaussian function [46]. Guy evaluated their accessibility seven different indicators: the shortest distance index, the index of cumulative opportunities, four gravity functions, and Gaussian functions, and pointed out that these methods are analytical and graphical and there is no statistical inspection, lack of empirical evidence to prove the effectiveness of the method to measure the market access [47]. Song summarized the accessibility functions, proposed 9 alternative models, and evaluated these models by using the criterion of explanatory power in ordinary least square (OLS) method regression analysis, i.e., R^2-values [9]. Reggiani et al. evaluated five decay functions in market access in a similar way and then used them to identify the homogeneity and heterogeneity characteristics of German commuter network [10].

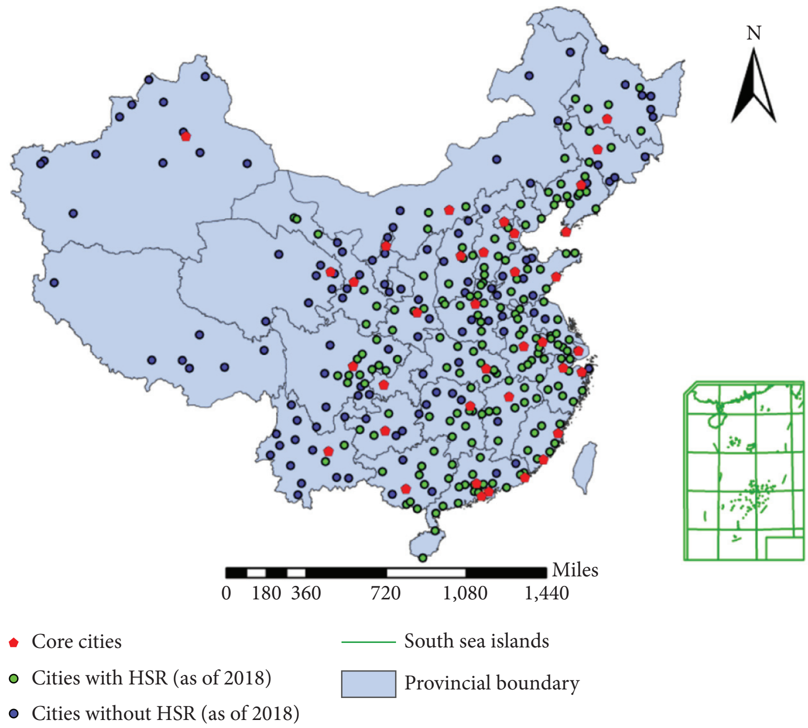

FIGURE 2: Distribution map of core cities and peripheral cities (as of 2018).

2.2.2. Possible Problems on Market Access. The key point to measure the market access index is to determine the parameters in the decay function. Through literature search, we found that few studies used empirical data to measure the decay parameters of market access induced by HSR. Lin measured the market access in the study of China's HSR traffic economy [26], but the parameter values they used were unrelated to China's traffic and the parameter values were fixed in the panel data, which maybe cause bias in the calculation of market access.

In this paper, we think that two points need to be emphasized. Firstly, these parameters should be dynamically changing. Because the transportation infrastructure changes, these parameter values are closely related to traffic, economic, and social development. In this paper, it is believed that, especially in the market access measurement involving traffic and economic development, if these parameters are considered to remain static, the measurement of market access may be biased or even inaccurate. Secondly, the values of these parameters should vary from country to country. Because the development of transportation varies greatly among different countries, the values of these parameters will also vary. Therefore, it is necessary to dynamically calculate the values of these parameters according to the actual traffic conditions of different countries. For example, Yi et al. used the form of exponential decay function to measure the market access of roads and railways in South Korea [11]. The parameters in their paper were measured by the traffic situation in South Korea. Therefore, we think it is necessary to dynamically calculate the parameters in the decay function according to the actual traffic condition of a country.

According to the above literature review, the influence of transportation infrastructure on economy has double sides. On the one hand, it promotes economic development, reduces regional differences, and produces "diffusion effect." On the other hand, it promotes the flow of economic factors in regional space and accelerates the imbalance of regional economic development. How does the connection of HSR affect the enterprises productivity in core cities and peripheral cities? Is there heterogeneity? Under the influence of market access induced by HSR, what is the impact of allocation effect and distribution effect on enterprise productivity? To begin with, this paper conducts empirical research on the impact of HSR on the enterprises productivity in core and peripheral cities. Secondly, the paper explores the allocation effect, distribution effect, and influence channel of HSR on the enterprises productivity in core and peripheral cities.

3. Data, Methods, and Index

3.1. Data Source. Due to the data limitation, our sample contains only 281 prefecture-level cities, including 36 core cities and 245 peripheral cities. The core cities studied in this paper refer to municipalities directly under the central government, provincial capital cities, deputy provincial cities, special economic zone cities, and cities under separate planning. Other prefecture-level cities are peripheral cities. The distribution of core cities and peripheral cities is shown in Figure 2. The data sources of this paper mainly include China City Statistical Yearbooks from 2003 to 2013, China Industrial Enterprise Database from 2003 to 2013, statistical yearbook of provinces and cities, statistical bulletin of provinces and cities, China Railway Yearbooks from 2003 to 2013, and Baidu Map Open Platform. According to the data content, it is further divided into the following three categories.

3.1.1. HSR Data. HSR data are mainly sourced from China City Statistical Yearbooks from 2003 to 2013, 12306.com (we have some data from 12306.com, the official website of China Railway Corporation, which publishes information about the opening time and cities of high-speed railway lines), the "Medium-Long-Term Railway Planning," the "13th Five-year Railway Development Plan" of China, China Railway, and other news reports or announcements. From there, we collect and sort out the information of HSR connection time and construction planning. Each city's annual HSR station operation frequency and other information is mainly from 12306.com, SMSK, JPSK (SMSK and JPSK are two railway travel information query software programs. We need to check high-speed railway flow information on these two software programs) and other applications. The distances from the location of each municipal government to the nearby HSR station, from the starting HSR station to HSR station of the destination, and from each peripheral city to the core city (all refer to the location of the municipal government) are calculated by ArcGIS.10.2 with the longitude and latitude of their location. Latitude and longitude data of stations and governments are from Baidu Map Open Platform.

3.1.2. Cities Data. The data of cities are mainly sourced from China City Statistical Yearbooks. Some missing values are supplemented by statistical yearbooks of provinces and cities, statistical bulletins of cities, or interpolation method. The data collected from China City Statistical Yearbooks mainly include GDP, population, China's actual use of foreign capital, the number of college students per 10,000 people, the number of education practitioners per 10,000 people, road, railway, air passenger volume, and other data. We also used elevation data, hydrological information, slope information, fluctuation information, and other data information of each city for the calculation and construction analysis of Instrumental Variable. Elevation data mainly came from Baidu Open Platform.

3.1.3. Enterprises Data. The microdata were mainly sourced from China Industrial Enterprise Database from 2003 to 2013. Before using, the database was processed as follows. According to the practice of Brandt et al. observation samples with fewer than 8 employees were deleted and new panel data is constructed with the enterprise name, corporate code, area code, year of establishment, industry code, and other information of the enterprises, and a new enterprise identification code is generated [48]. By referring to Feenstra et al. [49] and Yu [50], the observation samples lacking data information such as total assets, sales volume, industrial output value, establishment time of enterprise, export delivery value, and total liabilities were deleted. The samples that do not conform to Generally Accepted Accounting Principles (GAAP) are deleted, that is, the observation samples of current assets or total fixed assets greater than total assets. The observed samples with obvious anomalies in the establishment time and the survival time were deleted.

3.2. Model. In order to study the impact of HSR on enterprise productivity in core cities and peripheral cities, referring to the research model of Lin [26], the following model is constructed in this paper.

$$\ln\_persale_{cit} = \delta_0 + \delta_1 d\_hsr_{ct} + \delta_r X_{it} + \delta_m \Omega_{ct} + \delta_n \nu_{ct} + \lambda_c + year_t + \phi_i + \varepsilon_{cit}. \quad (1)$$

$\ln\_persale_{cit}$ represents the logarithm of enterprise productivity in city c in year t, and the per capita sales of enterprises are adopted as the proxy variable of enterprise productivity. d_hsr_{ct} is the main explanatory variable. If city c is connected to HSR in year t, d_hsr_{ct} is 1, otherwise, 0. X_{it} are some control variables for the enterprises, including the scale, the proportion of exports, the debt ratio, and the survival time of the enterprise i in year t. ν_{ct} are the control variables for the city. Ω_{ct} are the control variables from other means of transportation, including the cars and planes. λ_c is the unobserved area fixed effect. $year_t$ is the time fixed effect. ϕ_i is the fixed effect of enterprises. δ_0, δ_1, δ_r, δ_m, and δ_n are the coefficients to be estimated. ε_{cit} is error term. The specific definitions of control variables are shown in Table 1. The impacts of enterprise scale, proportion of export, debt ratio, and survival time on enterprise productivity are as follows.

The larger the enterprise scale, with more funds for risky innovation activities, the stronger the ability to purchase advanced equipment and more fully to employee of vocational training, thus being more conducive to the rapid growth of the productivity [51], and the larger the economies of scale and specialization, so as to reduce the production and management costs and improve production efficiency; thus expected enterprise scale coefficient is positive. According to the research of Gatti and Love [52], credit availability is positively associated with total factor productivity (TFP) of enterprise, so the expected coefficient of debt ratio is positive. According to Brandt et al., the productivity of new enterprises grows faster [48], so the expected coefficient is negative.

This paper also controls characteristic variables at urban level in the benchmark model, including population size, GDP, foreign investment, and education level. According to literature studies, population size, GDP [53], foreign investment [54], and education level [55] are correlated with productivity. The definitions and expected symbols of control variables are shown in Table 1.

In addition, the model in this article takes the roads and planes as the control variables. This is because, if there are allocative effects and distributional effects in core cities and peripheral cities, these effects may be caused by other means of transportation. It is difficult to identify that is caused by HSR. Therefore, we add the passenger volume of roads and planes into the model as the proxy variable of the impact of other major vehicles, but the expected symbol is still uncertain.

Table 1: Control variable definitions and expected symbols.

Control variables category	Variables	Definition	Expected symbols
enterprises level	ln_scale	Enterprises scale: the logarithm of the total assets of the enterprise (100,000 yuan)	+
	exportrate	The proportion of exports: the ratio of export delivery value to total industrial output value	-
	debtratio	Debt ratio: the ratio of a company's liabilities to its total assets	+/-
	age	Survival time: the duration of the enterprise as of the observation period (year)	-
cities level	ln_pop	Population size: logarithm of city population (10,000 persons)	+
	ln_gdp	GDP: logarithm of city GDP (10,000 yuan)	+
	ln_fdi	Foreign investment: the logarithm of actually used foreign investment (10,000 dollars)	+
	ln_peredu	Education level: the logarithm of the number of people engaged in education per 10,000 people	+/-
other transportation	ln_roadrship	Road passenger traffic of: the logarithm of the road passenger traffic (10,000 persons)	+/-
	ln_airrship	Air passenger traffic: the logarithm of the air passenger traffic (10,000 persons)	+/-

Table 2: Descriptive statistics of key variables.

Variables	Variable Definition	Obs.	Mean	SD	Min	Max
ln_persale	the logarithm of sales per capita	2885284	5.5744	1.1042	-8.1198	16.1162
d_hsr	Whether or not HSR in operation	2885284	0.3831	0.4861	0.0000	1.0000
ln_ACCxita	Market access	2885284	7.3269	5.2071	0.0000	11.4301
ln_scale	enterprises scale	2885284	9.9535	1.5286	0.0000	20.6717
exportrate	the proportion of exports	2885284	0.1878	23.8453	0.0000	1816.6250
debtratio	debt ratio	2885284	0.7334	3.1433	371.1333	4838.3333
age	survival time	2885284	8.7884	9.2935	1.0000	299.0000
ln_pop	population size	2885284	6.2484	0.6020	2.7955	8.1192
ln_gdp	GDP	2885284	16.7895	1.0791	12.6690	19.1909
ln_fdi	foreign investment	2885284	11.1769	1.8512	0.0000	14.3360
ln_peredu	education level	2885284	-4.3437	0.3098	-6.3973	-3.3298
ln_roadrship	road passenger traffic	2885284	9.2842	1.0029	4.4067	12.5657
ln_airrship	air passenger traffic	2885284	8.4989	7.2057	0.0000	19.4957

The per capita industrial output value is used to represent the enterprises productivity, and the methods of Olley and Pakes [56] (OP) and Levinsohn and Petrin [57] (LP) are used to calculate the TFP of enterprises, and in the robustness test they are used as the proxy variable of enterprise productivity. Descriptive statistics of key variables are shown in Table 2.

3.3. Market Access. In this paper, the market access induced by HSR is introduced to analyze the mechanism of enterprise productivity. The following is a brief introduction to the calculation method and process of market access and the calculation results of decay function parameters related to market access.

3.3.1. Calculation Method. Market access is widely used in academic circles [11, 41–44]; the common formula is

$$Acc_i = \sum_j M_j f\left(t_{ij}\right). \qquad (2)$$

The meanings of the indicators in the above equation are shown in Section 2.2.1. The main difference in the calculation method of market access is the decay function. There are various forms of decay function [10], such as the following:

(a) the power-decay function $f\left(t_{ij}\right) = t_{ij}^{-\theta}$, (3)

(b) the exponential decay function: $f\left(t_{ij}\right) = e^{-\beta_1 t_{ij}}$, (4)

(c) the exponential-normal decay function: $f\left(t_{ij}\right) = e^{-\beta_2 t_{ij}^2}$, (5)

(d) the exponential-square root decay function: $f\left(t_{ij}\right) = e^{-\beta_3 \sqrt{t_{ij}}}$, (6)

(e) the log-normal decay function: $f\left(t_{ij}\right) = e^{-\beta_4 (\log t_{ij})^2}$. (7)

3.3.2. Calculation Process. In this paper, we compare and select the decay function according to the method of Song [9], Reggiani et al. [10], and Yi et al. [11]. We then calculated

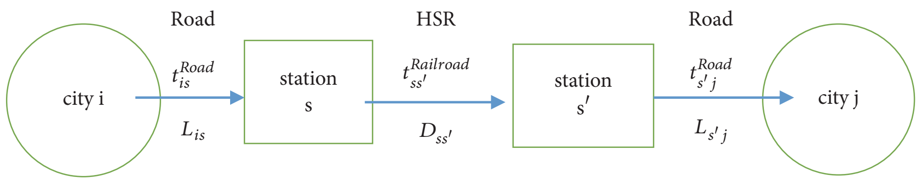

Figure 3: Travel diagram from city i to city j.

the annual parameters of the decay function and market access of China's HSR (from 2007 to 2013). The data used for the calculation is from passenger frequency between two HSR stations in China from 2007 to 2013, which is manually compiled.

The model is shown below:

$$OD_{ij} = KM_i^{\alpha_i} M_j^{\alpha_j} f\left(t_{ij}\right), \quad (8)$$

where OD_{ij} is the number of travellers between city i and city j by HSR. M_i, M_j refer to the population of cities i and j, respectively, and K is the scaling factor.

Take the logarithm of both sides of Eq. (8); namely,

$$\ln OD_{ij} = \ln K + \alpha_i \ln M_i + \alpha_j \ln M_j + \ln f\left(t_{ij}\right). \quad (9)$$

In Eqs. (8) and (9), the calculation method of time t_{ij} is as follows:

$$t_{ij} = \min\left(t_{is}^{Road} + t_{ss'}^{Railroad} + t_{s'j}^{Road}\right), \quad \left(s \neq s'\right), \quad (10)$$

$$t_{is}^{Road} = \frac{L_{is}}{RoadV_{is}}, \quad (11)$$

$$t_{ss'}^{Railroad} = \frac{D_{ss'}}{HsrV_{ss'}}, \quad (12)$$

$$t_{s'j}^{Road} = \frac{L_{s'j}}{RoadV_{s'j}}. \quad (13)$$

The travel diagram is shown in Figure 3, where t_{ij} is the minimum travel time using roads and HSR from city i to city j. t_{is}^{Road} is the shortest travel time through the roads network from city i to the nearest HSR station s. $t_{ss'}^{Railroad}$ refers to the shortest travel time using HSR from the nearest HSR station s to the station s'. $t_{s'j}^{Road}$ is the shortest travel time from the HSR station s' to the destination city j using the roads network.

L_{is} is the straight-line distance from city i (where the municipal government is located) to the nearest station s, which can be calculated by Arcgis.10.2 using the longitude and latitude coordinates of the city i and the station. $RoadV_{is}$ is the average speed on the road from the city i to the nearby HSR station s.

$D_{ss'}$ is the railway length between station s and station s' by HSR. According to Zheng and Kahn's method, the railway length between cities is equal to 1.2 times the linear length between stations [58]. The distance between cities is obtained by calculating the longitude and latitude coordinates of each city with Arcgis.10.2.

$HsrV_{ss'}$ is the average speed of HSR from the origin station s to the destination station s'.

3.3.3. Calculation Results. After using the ordinary least square (OLS) method regression, the results are sorted by the size of R^2, as shown in Table 3. According to the method of Reggiani et al., the larger the R^2 is, the better the fitting degree will be [10]. As can be seen from the annual R^2 value, the best fitting is the power-decay function and the least fitting is the exponential-normal decay function. The five parameters are all significant at the 1% confidence level.

According to the analysis results in Table 3, this paper selects the power-decay function method with the maximum R^2 to calculate the market access. In the robustness test later, the commonly used exponential decay function is used to calculate the market access. Since the mechanism analysis in this paper is mainly to investigate the resource allocation and resource distribution between core cities and peripheral cities, the spatial scope of market access measured in this paper is mainly between peripheral cities and 36 core cities.

The market access formula measured by the power-decay function is

$$ACCxita_i = \sum_j M_j f\left(t_{ij}\right) = \sum_{j=1}^{36} GDP_j t_{ij}^{-\theta}. \quad (14)$$

The market access formula measured by the exponential decay function is

$$ACCbeta_i = \sum_j M_j f\left(t_{ij}\right) = \sum_{j=1}^{36} GDP_j e^{-\beta t_{ij}}. \quad (15)$$

The definition of parameters in Eqs. (14) and (15) is the same as that in Eqs. (2), (3), and (4). The average logarithm of market access calculated by Eqs. (14) and (15) is shown in Table 4.

4. The Empirical Analysis

4.1. Base Regression Analysis. The regression results for the benchmark model about the impact of HSR on the enterprises productivity in core cities and peripheral cities are shown in Table 5. As discussed above, the dependent variable is the enterprise's per capita sales (ln_persale), and the core independent variable is the dummy variable of HSR connecting. Control variables include the logarithm of enterprise scale (ln_scale), export ratio (exportrate) and debt ratio (debtratio), enterprise surviving years (age), the logarithm of the city population scale (ln_pop), the logarithm of city GDP (ln_gdp), the logarithm of foreign direct investment (ln_fdi), the logarithm of education workers in every ten thousand people (ln_peredu), the logarithm of the road passenger

Table 3: Fitting degree and parameter values of decay function from 2007 to 2013.

	year	2007	2009	2011	2013	2007	2009	2011	2013
	decay function	R^2				parameters			
1	$f(t_{ij}) = t_{ij}^{-\theta}$	0.0114	0.0329	0.0680	0.0637	0.0877	0.2078	0.5202	0.5485
2	$f(t_{ij}) = e^{-\beta_4 (\log t_{ij})^2}$	0.0061	0.0182	0.0394	0.0422	0.0099	0.0251	0.0681	0.0749
3	$f(t_{ij}) = e^{-\beta_3 \sqrt{t_{ij}}}$	0.0055	0.0171	0.0366	0.0397	0.0229	0.0623	0.1696	0.1862
4	$f(t_{ij}) = e^{-\beta_1 t_{ij}}$	0.0032	0.0107	0.0217	0.0273	0.0011	0.0037	0.0109	0.0123
5	$f(t_{ij}) = e^{-\beta_2 t_{ij}^2}$	0.0025	0.0079	0.0140	0.0204	0.0000	0.0000	0.0001	0.0001

Note: due to space constraints, we have reported partial data.

Table 4: The average of the logarithms of market access each year.

market access	year						
	2007	2008	2009	2010	2011	2012	2013
ln_ACCxita	11.2811	10.6408	11.2325	10.7975	10.7784	10.5707	10.9386
ln_ACCbeta	11.5237	11.5653	11.7521	11.8464	11.9751	12.0202	12.1660

traffic (ln_roadrship), and the logarithm of air passenger traffic (ln_airrship).

Columns (1)-(4) of Table 5 are the regression of core cities, and columns (5)-(8) of Table 5 are the regression of peripheral cities. Both types of regression are the results of stepwise regression of control variables at the level of enterprises, cities, and other traffic levels on the basis of the model in column (1) and column (5). The results show that the connection of HSR has a significant, positive impact on the enterprises productivity in core cities, with an effect value of 1.38%. The connection of HSR has a significant, negative impact on the enterprises productivity in peripheral cities, with an effect value of -8.45%, indicating that the connection of HSR has an uneven impact on the enterprises productivity in different regions with the opposite results.

Are the opposite impacts of HSR on the enterprises productivity in core cities and peripheral cities due to the endogenous problems caused by differences in economic basis and location advantages? Then, we used instrumental variable method for endogenous treatment.

4.2. Endogenous Treatment

4.2.1. Selection of Instrumental Variables. Instrumental variable (IV) method is a common method to identify the impact of traffic infrastructure. Through literature research, it is found that the instrumental variables of transportation infrastructure have the following three strategies. Firstly, geographic information is used as an instrumental variable. For example, Duflo et al. used slope as the instrumental variable of modern transportation infrastructure construction in the study of highway construction and regional economic development [59]. Faber used the method of "Least Cost Path" [30]. The method connected the central city with a straight line and took it as the instrumental variable of "whether the city is located on the straight line or a certain distance from the straight line." The second is to look for instrumental variables from historical information. For example, Duranton and Turner used highway planning distribution map and early railway distribution map in American history as instrumental variables in predicting the distribution of modern highways [60, 61]. The third is to find instrumental variables from the planning. Michaels used highway planning information from 1944 to construct the instrumental variable in predicting the real road construction [62].

This paper mainly uses the second method and refers to the research of Faber [30] to construct the instrumental variable based on the principle of "Least Cost Path." We thank Zhang et al. [63] for sharing data from their research paper. Qualified instrumental variables need to meet the two conditions, relevance and exogeneity. One is correlation. According to the principle of "geographic development cost is the lowest," the dummy variable of whether a city has HSR connection is obtained by using the path network constructed by elevation data, hydrological information, slope information, fluctuation information, and other basic information. The instrumental variable is related to the construction cost of HSR and meets the correlation condition. The other is exogenous. The instrumental variables constructed by using geographical features are exogenous and generally do not directly affect the enterprises productivity. Therefore, the selection of instrumental variables is appropriate. Two-stage regression is carried out for the instrumental variables below for further verification.

4.2.2. Two-Stage Regression Analysis of Instrumental Variables. Since the constructed instrumental variables belong to geographical characteristics and generally do not change with time, this paper selects the data in the research sample close to the middle year (such as 2011) of HSR for two-stage regression of instrumental variables.

Table 6 shows the two-stage regression results of instrumental variables. Column (2) and column (4) of Table 6 report the first-stage regression results of core cities and peripheral cities. It can be seen that the dummy variable of "least cost path" is significantly positively correlated with HSR connection and is significant at 1% confidence level,

Table 5: The basic regression of enterprise productivity in core and peripheral cities.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Core cities				Peripheral cities			
	ln_persale				ln_persale			
d_hsr	0.0185***	0.0164***	0.0095**	0.0138***	-0.1215***	-0.1261***	-0.0814***	-0.0845***
	(0.0045)	(0.0042)	(0.0043)	(0.0043)	(0.0027)	(0.0026)	(0.0026)	(0.0026)
ln_scale		0.2514***	0.2512***	0.2512***		0.2039***	0.2032***	0.2035***
		(0.0007)	(0.0007)	(0.0007)		(0.0005)	(0.0005)	(0.0005)
exportrate		0.0000*	0.0000*	0.0000*		-0.0131***	-0.0133***	-0.0133***
		(0.0000)	(0.0000)	(0.0000)		(0.0005)	(0.0005)	(0.0005)
debtratio		0.0215***	0.0195***	0.0198***		0.0015***	0.0016***	0.0016***
		(0.0008)	(0.0008)	(0.0008)		(0.0002)	(0.0002)	(0.0002)
age		-0.0197***	-0.0195***	-0.0195***		-0.0178***	-0.0175***	-0.0175***
		(0.0001)	(0.0001)	(0.0001)		(0.0001)	(0.0001)	(0.0001)
ln_pop			-0.0105	0.0092			-0.2800***	-0.3208***
			(0.0201)	(0.0221)			(0.0152)	(0.0153)
ln_gdp			0.4980***	0.5090***			0.4730***	0.4403***
			(0.0147)	(0.0148)			(0.0089)	(0.0089)
ln_fdi			0.0598***	0.0585***			0.0551***	0.0560***
			(0.0034)	(0.0034)			(0.0014)	(0.0014)
ln_peredu			-0.4310***	-0.4551***			-0.3546***	-0.3916***
			(0.0188)	(0.0189)			(0.0119)	(0.0120)
ln_roadrship				-0.0102***				0.0994***
				(0.0024)				(0.0026)
ln_airrship				-0.0495***				0.0041***
				(0.0040)				(0.0004)
City fixed	Y	Y	Y	Y	Y	Y	Y	Y
Time fixed	Y	Y	Y	Y	Y	Y	Y	Y
Enterprise fixed	Y	Y	Y	Y	Y	Y	Y	Y
N	966411	966411	966411	966411	1918873	1918873	1918873	1918873
adj. R^2	0.111	0.231	0.233	0.233	0.166	0.237	0.240	0.240

Note: $*$, $**$, and $***$ represent 10%, 5%, and 1% levels of statistical significance, respectively. Standard errors are reported in parentheses. Due to space limitation, constant term coefficient and standard error are not reported.

Table 6: Regression results of instrumental variables.

	(1)	(2)	(3)	(4)
	Core cities		Peripheral cities	
	2SLS	First stage	2SLS	First stage
	ln_persale	d_hsr	ln_persale	d_hsr
d_hsr	0.4244*		-0.3623**	
	(0.2379)		(0.1628)	
Least Cost Path IV		0.6324***		0.3730***
		(0.0082)		(0.0030)
City fixed	Y	Y	Y	Y
Time fixed	Y	Y	Y	Y
Enterprise fixed	Y	Y	Y	Y
N	53117	53117	108090	108090
adj. R^2	0.228	0.539	0.162	0.323
F statistic		10.572		11.139

Note: $*$, $**$, and $***$ represent 10%, 5%, and 1% levels of statistical significance, respectively. Standard errors are reported in parentheses. Due to space limitation, constant term coefficient and standard error are not reported.

because the lower the cost is, the more favorable it is for the construction of HSR. Column (1) and column (3) in Table 6 report the two-stage regression results. Considering the endogeneity problem, the coefficients of HSR variable are significantly positive in the core cities and significantly negative in the peripheral cities, consisting with the base results (generally, the IV estimate value is larger than the OLS estimate value, and it is the same in our estimate, indicating that the original equation may indeed have the estimation error caused by endogeneity problem, so it is necessary to conduct endogeneity treatment).

Next, we discuss the problem of weak instrumental variables. When kleibergen-paap rank Wald F statistic was used to judge the weak instrumental variable, Baum et al. suggested that the F value should be more than 10 as the judgment standard [64]. As can be seen from the last line of Table 6, Kleibergen-paap rank Wald F statistic was more than 10 in the sample regression of both core cities and peripheral cities, indicating no weak instrumental variable problem.

5. Mechanism Analysis

Through the base regression analysis and endogenous processing mentioned above, it is found that HSR connection positively affects the enterprises productivity in core cities and negatively affects the enterprises productivity in peripheral cities, which is similar to the research conclusions of Chandra and Thompson [65], Faber [30], and Qin [33] on transportation infrastructure. Chandra and Thompson found that highways affected the spatial allocation of economic activities in the region, increasing the level of economic activities in the counties they pass through directly, but attracting activities away from neighboring counties, thus keeping the net level of economic activities in nonmetropolitan areas unchanged [65]. Faber believes that for cities that have no connection with the peripheral areas the connection of expressways is not conducive to the GDP growth. If a region is not included in the urban road network, the average economic growth rate is 18% lower than other surrounding cities, and the average growth rate of industrial output value is 26% lower [30]. Qin focused on the distribution effect between counties with HSR stations and counties without HSR stations and empirical results show that, with the reduction of transportation costs in core areas, the peripheral counties without HSR stations may see a decline in GDP due to insufficient investment [33]. These studies all focus on the fact that the improvement of interregional transport infrastructure will accelerate the transfer of factor resources from surrounding cities or regions to central cities, enhance the economic agglomeration of regional central cities, and inhibit the economic growth of neighboring regions. This is known as the "economic distributional effect" in new economic geography. Next, we focus on the analysis and verification of market access, allocation effect, and distribution effect by introducing the concept of market access.

5.1. Allocation Effect. Resource allocation mainly reflects the utilization efficiency of resources. Hsieh and Klenow believe that the more serious the resource misallocation is, the lower the utilization efficiency is and the more negative impact it has on the enterprises productivity [66]. The measurement method of resource allocation mostly adopts the resource misallocation coefficient. In addition, another type of literature uses the productivity dispersion to describe the degree of resource misallocation [67]. Compared with the method of Hsieh and Klenow [66] and Aoki [68], the method of TFP dispersion to measure resource mismatch is more simple, more vivid, and faster. Therefore, this paper adopts TFP dispersion as the proxy variable of resource allocation level. In this paper, referring to the research method of Lashitew [69], the resource allocation level is measured by the quartile distance of TFP, and the difference between the 90 and 10 points of TFP was used as the robustness test, so as to obtain a more robust conclusion.

Table 7 presents the regression analysis results of market access and resource mismatch. Columns (1)-(3) of Table 7 adopt the resource mismatch measured by the quartile distance (ln_persale7525). It can be seen that the market access caused by HSR significantly reduces the degree of resource mismatch of enterprises in the whole cities, core cities, and peripheral cities, or the market access promotes the improvement of enterprise productivity. Columns (4)-(6) of Table 7 are the resource mismatch measured by the difference between 90% and 10% points (ln_persale9010). Market access also reduces the degree of resource mismatch between the whole cities and the core cities, but the impact on the enterprise resource mismatch in peripheral cities is positive and not significant.

Using the quartile distance to measure the resource mismatch has the advantage of excluding the influence of outliers and can better reflect the sample dispersion degree near the median. Compared with the quartile distance, the difference between 90% and 10% reflects more the influence of outliers, so the quartile distance measure must be smaller than the difference between 90% and 10%. Therefore, it is inevitable that there will be a large deviation in the measurement of resource mismatch conducted by the difference between 90% and 10% and thus more likely to produce a situation that does not meet the theoretical expectation or is not significant.

The above analysis shows that although there are some differences between the above two methods in measuring the resource misallocation of enterprises in peripheral cities, the main conclusions tend to be the same; that is, the HSR optimizes the enterprise resource allocation, thus contributing to the improvement of enterprise productivity.

5.2. Resource Distributional Effect. In the following, we further investigate the resource distribution effect from three aspects, namely, the heterogeneity of market, regional heterogeneity, and location heterogeneity in peripheral cities.

5.2.1. Heterogeneity of Market. In order to explore the impact of HSR distribution effect on enterprises with different export intensity, this paper divides enterprises samples in peripheral cities into nonexport enterprises, low-export enterprises, high-export enterprises, and complete export enterprises according to their export shares. The specific method is to use the ratio of export delivery value to industrial output value.

Table 7: Regression analysis of market access and resource mismatch.

	(1)	(2)	(3)	(4)	(5)	(6)
	All cities	Core cities	Peripheral cities	All cities	Core cities	Peripheral cities
		ln_persale7525			ln_persale9010	
L1_ln_ACCxita	-0.0366***	-0.0485***	-0.0050***	-0.0416***	-0.0558***	0.0010
	(0.0007)	(0.0013)	(0.0009)	(0.0013)	(0.0027)	(0.0015)
Enterprises control	Y	Y	Y	Y	Y	Y
Cities control	Y	Y	Y	Y	Y	Y
Other traffic control	Y	Y	Y	Y	Y	Y
City fixed	Y	Y	Y	Y	Y	Y
Time fixed	Y	Y	Y	Y	Y	Y
Enterprise fixed	Y	Y	Y	Y	Y	Y
N	2885284	966411	1918873	2885284	966411	1918873
adj. R^2	0.765	0.813	0.756	0.774	0.796	0.773

Note: ∗, ∗∗, and ∗ ∗ ∗ represent 10%, 5%, and 1% levels of statistical significance, respectively. Standard errors are reported in parentheses. Due to space limitation, constant term coefficient and standard error are not reported.

Nonexport enterprises have a ratio of zero, low-export enterprises have a ratio of 0-50%, and high-export enterprises have a ratio of 50-100%. In addition, complete export enterprises are taken as separate samples for regression analysis. It can be seen from Table 8 that the market access induced by HSR has the largest negative impact on the productivity of nonexport enterprises in peripheral cities and the least impact on the productivity of complete export enterprises. This may be because the sales market of nonexport enterprises is mainly domestic, and the production and sales of enterprises are highly dependent on HSR, while export-oriented enterprises are on the contrary.

5.2.2. Regional Heterogeneity. Core cities are mostly distributed in the eastern and middle regions. In other words, the distance between peripheral cities and core cities is closer. So, it can be assumed that in the eastern region core cities should have a greater negative impact on the enterprises productivity in the eastern peripheral cities and a smaller negative impact on the enterprises productivity in the middle peripheral cities. According to the regression of enterprises in the eastern, middle, and western peripheral cities, it can be seen from columns (5)-(7) of Table 8 that in the eastern and middle regions the core cities have a significant negative impact on enterprises productivity of peripheral cities. However, in the west, the core cities have a significant positive impact on the enterprises in the peripheral cities. This is consistent with the conjecture, indicating that the farther the distance is, the less the negative effect is.

5.2.3. Location Heterogeneity. The location heterogeneity means that the influence of core cities on the enterprises productivity of peripheral cities varies with the distance between them. We need to calculate the linear distance between the peripheral cities and the core cities. This distance can be calculated using ArcGIS.10.2. We take 50 km as the distance unit stratified sample regression, as shown in Table 9. It can be seen within 20-40 km in column (1) of Table 9 market access has positive influence on the enterprise productivity of peripheral cities. After 40 km, with the increase of the distance, the negative influence gradually increases and then weakens, showing an inverted U shape. We find 300 km is the cut-off point in column (7) of Table 9. After 300 km, the negative influence disappears or is not significant. Therefore, in the range of 40 km, the market access coefficient is positive, which is shown as the "diffusion effect" of core cities, which is similar to the research of Baum-Snow et al. [28]. Therefore, the influence range of "distribution effect" between core cities and peripheral cities is about the straight-line distance of 40 km to 300 km.

5.3. Channel of Distribution Effect. Next, we analyze the relationship between market access and economic factor flow. The "distribution effect" of HSR should be reflected in the market access to accelerate the flow of economic factors between core cities and peripheral cities, in which investment and human capital are two basic elements with strong liquidity. We examine whether the market access facilitates the flow of people, leading to changes in investment and human capital flows, and thereby affecting the enterprises productivity in core and peripheral cities.

Firstly, we explore whether market access promotes the flow of personnel. The logarithm of railway passenger traffic (ln_railrship) was used as the dependent variable to investigate the flow of personnel. As can be seen from column (1) and column (2) of Table 10, the coefficients of market access are both significantly positive, indicating that HSR promotes the increase of frequency of rail passenger travel in core cities and peripheral cities and accelerates the flow of personnel, which is consistent with the research conclusion of Lin [26].

Then we examine the impact of market access on regional fixed asset investment and human capital. The weighted average of the total fixed assets of enterprises in the region was used as the proxy variable of the fixed assets investment (ln_invest). The logarithm of the number of college students per 10,000 in cities is used as the proxy variable for human capital (ln_perhum). As can be seen from columns (3)-(6) of Table 10, the coefficient of market access in core cities is

Table 8: Regression results of different export intensity and regional productivity in peripheral cities.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Non	Low	High	Complete	East	Middle	West
	ln_persale				ln_persale		
ln_ACCxita	-0.6511***	-0.6310***	-0.3997***	-0.2039***	-0.6244***	-0.0610**	0.0967***
	(0.0091)	(0.0237)	(0.0272)	(0.0445)	(0.0107)	(0.0275)	(0.0264)
Enterprises control	Y	Y	Y	Y	Y	Y	Y
Cities control	Y	Y	Y	Y	Y	Y	Y
Other traffic control	Y	Y	Y	Y	Y	Y	Y
City fixed	Y	Y	Y	Y	Y	Y	Y
Time fixed	Y	Y	Y	Y	Y	Y	Y
Enterprise fixed	Y	Y	Y	Y	Y	Y	Y
N	1447163	220803	161989	88908	1398317	375128	145428
adj. R^2	0.235	0.350	0.260	0.238	0.234	0.246	0.312

Note: ∗, ∗∗, and ∗ ∗ ∗ represent 10%, 5%, and 1% levels of statistical significance, respectively. Standard errors are reported in parentheses. Due to space limitation, constant term coefficient and standard error are not reported. Among the 281 cities studied, 98 are in the east, 99 in the middle, and 84 in the west.

Table 9: The boundary of the influence on the enterprises productivity of peripheral cities.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Distance to the core cities (km)	20-40	40-50	50-100	100-150	150-200	200-250	250-300	300-350	350-400	>400
	ln_persale									
ln_ACCxita	0.1116	-0.0913	-0.7005***	-0.6242***	-0.5773***	-0.6949***	-0.3351***	-0.0798	5.2735**	-0.1235
	(0.1370)	(0.0590)	(0.0157)	(0.0135)	(0.0335)	(0.0521)	(0.0507)	(0.0986)	(2.3680)	(0.4897)
Enterprises control	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Cities control	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Other traffic control	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
City fixed	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Time fixed	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Enterprise fixed	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
N	41628	114856	587290	563685	263948	183775	58849	33494	2442	7194
adj. R^2	0.275	0.279	0.227	0.240	0.246	0.265	0.273	0.242	0.221	0.268

Note: we also stratified regression by 20 km or 30 km and found the same conclusion. ∗, ∗∗, and ∗ ∗ ∗ represent 10%, 5%, and 1% levels of statistical significance, respectively. Standard errors are reported in parentheses. Due to space limitation, constant term coefficient and standard error are not reported.

Table 10: Influence of market access on personnel flow, fixed asset investment, and human capital.

	(1)	(2)	(3)	(4)	(5)	(6)
Regions	Core cities	Peripheral cities	Corecities	Peripheral cities	Core cities	Peripheral cities
	ln_railrship		ln_invest		ln_perhum	
ln_ACCxita	0.4849***	0.5387***	0.4521***	-0.2643***	0.2141***	-0.0968***
	(0.0053)	(0.0055)	(0.0099)	(0.0048)	(0.0044)	(0.0016)
Enterprises control	Y	Y	Y	Y	Y	Y
Cities control	Y	Y	Y	Y	Y	Y
Other traffic control	Y	Y	Y	Y	Y	Y
City fixed	Y	Y	Y	Y	Y	Y
Time fixed	Y	Y	Y	Y	Y	Y
Enterprise fixed	Y	Y	Y	Y	Y	Y
N	966411	1918873	901881	1799060	966411	1918873
adj. R^2	0.935	0.908	0.807	0.789	0.853	0.950

Note: ∗, ∗∗, and ∗ ∗ ∗ represent 10%, 5%, and 1% levels of statistical significance, respectively. Standard errors are reported in parentheses. Due to space limitation, constant term coefficient and standard error are not reported.

Table 11: Comprehensive analysis of allocation effect and distribution effect.

	Allocation effect	Distribution effect	Two effects	Results
Core cities	(+)	(+)	Both positive allocation effect and positive distribution effect act in the same direction	(+)
Peripheral cities	(+)	(-)	The negative distribution effect is greater than the positive allocation effect	(-)

Note: the positive sign in brackets indicates a positive impact on enterprise productivity; otherwise, it is the opposite.

significantly positive, while that in peripheral cities is significantly negative. This shows that market access promotes the increase of fixed asset investment and the inflow of human capital in core cities, inhibits the investment of fixed asset, and promotes the outflow of human capital in peripheral cities.

In conclusion, market access accelerates the flow of people and economic factors. Market access makes it easier for economic factors to flow from peripheral cities to core cities, thus promoting the improvement of enterprise productivity in core cities and inhibiting the improvement of enterprise productivity in peripheral cities. The flow of economic factors is the influence channel of "distribution effect" of HSR. This is similar to the research conclusions of Zhang et al. [63].

5.4. Comprehensive Analysis of Allocation Effect and Distribution Effect. Through the basic analysis and endogenous treatment, we find that HSR positively affects the enterprises productivity in core cities and negatively affects the enterprises productivity in peripheral cities. In the mechanism analysis, it is found that the market access caused by HSR has a significant optimization effect on the mismatching of enterprise resources in core cities and peripheral cities. In other words, HSR promotes the utilization efficiency of enterprise resources in core cities and peripheral cities, thus contributing to the improvement of productivity. The distribution effect analysis found that the HSR promoted personnel exchange and accelerated the flow of economic factors such as investment and talents from peripheral cities to core cities; that is, the distribution effect helped improve the enterprises productivity in core cities and inhibited the enterprises productivity in peripheral cities. Therefore, the final positive impact of HSR on the enterprise productivity of core cities is the result of both positive allocation effect and positive distribution effect. The negative impact of HSR on enterprise productivity in peripheral cities is caused by the fact that the negative distribution effect is greater than the positive allocation effect. Specific analysis and summary of allocation effect and distribution effect are shown in Table 11.

6. Robustness Test

Based on the above analysis, it can be seen that HSR positively affects the enterprises productivity in core cities and negatively affects the enterprises productivity in peripheral cities. Is this conclusion robust? Are there other nonobservable factors contributing to this conclusion? Are measures of market access effective? To this end, we test the robustness from the following aspects.

6.1. One Period Lag and Variable Substitution. The robustness tests are conducted from three aspects. Firstly, we carry out regression with a lag of one year for HSR. Because in some cities HSR connection is in the second half or the end of the year, HSR may not affect productivity in the years when the HSR is connected. The regression results in the columns (1) and (6) of Table 12 show that HSR still positively affects the enterprises productivity in core cities and negatively affects the enterprises productivity in peripheral cities. Secondly, per capita production value (ln_perprodv) and the TFP (TFP_LP, TFP_OP) calculated by OP method and LP method are used as the proxy variable of enterprise productivity in the columns (2)-(4) and (7)-(9) of Table 12, and the conclusion is still valid. The third is to consider the impact of ordinary passenger railways.

From the columns (1) to (4) and the columns (6) to (9) of Table 12, the test results support our main conclusions, although the coefficient of L1_d_hsr in the column (1) is not significant. The third test method is mainly analyzed as follows. Since HSR is mainly used to transport passengers, it may be questioned whether the impact of HSR on productivity is mainly caused by ordinary railway. To eliminate this doubt, we add the logarithm of railway passenger volume (ln_railrship) in the columns (5) and (10) of Table 12 as the proxy variable of ordinary railway, in order to control the influence of ordinary railway. The index ln_railrship includes passenger data of HSR. Compared with the base regression, the coefficient of d_hsr changes little and the sign remains unchanged in the columns (5) and (10) of Table 12. Therefore, if the influence of ordinary railway is not taken into account in the base regression, the conclusion that HSR affects enterprise productivity is still robust.

6.2. Placebo Test. In the previous empirical part of basic regression analysis, we controlled for the time fixed effect and cities fixed effect. We found that the HSR connection positively affected the enterprises productivity in core cities and negatively significantly affected the enterprises productivity in peripheral cities, but the influence of other unobservable systematic factors could not be completely excluded. In other words, the observed impact of HSR connections on the enterprises productivity in core and peripheral cities is caused by these unobservable systemic factors, rather than HSR.

Table 12: Regression results of various robustness tests.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Core cities					Peripheral cities				
	ln_persale	ln_perprodv	TFP_LP	TFP_OP	ln_persale	ln_persale	ln_perprodv	TFP_LP	TFP_OP	ln_persale
L1_d_hsr	0.0028					-0.0666***				
	(0.0043)					(0.0027)				
d_hsr		0.0332***	0.0294***	0.0279***	0.0134***		-0.0533***	-0.0550***	-0.0592***	-0.0834***
		(0.0042)	(0.0005)	(0.0005)	(0.0043)		(0.0026)	(0.0004)	(0.0004)	(0.0026)
ln_railrship					-0.0108***					-0.0263***
					(0.0030)					(0.0010)
Enterprises control	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Cities control	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Other traffic control	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
City fixed	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Time fixed	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Enterprise fixed	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
N	966411	966411	966411	966411	966411	1918873	1918873	1918873	1918873	1918873
adj. R^2	0.233	0.225	0.867	0.835	0.233	0.240	0.227	0.859	0.845	0.241

Note: ∗, ∗∗, and ∗ ∗ ∗ represent 10%, 5%, and 1% levels of statistical significance, respectively. Standard errors are reported in parentheses. Due to space limitation, constant term coefficient and standard error are not reported.

Therefore, a placebo test was conducted to try to dispel such fears.

Specifically, two years before the connection of HSR are considered as the "HSR pseudoconnection." Construct two sets of "HSR pseudoconnection" dummy variables: D_1 and D_2, and replace the *d_hsr* in Eq. (1) with these two sets of dummy variables for regression. If the constructed "pseudoopening of HSR" regression is consistent with the impact on enterprise productivity in the base regression analysis, then it indicates that there may be unobservable systematic factors that play a role in enterprise productivity when the HSR is connected. Otherwise, we would be more convinced that productivity changes occur during HSR connections and are caused by HSR rather than by other unobservable systemic factors. It can be seen from the columns (1)-(2) of Table 13 that the coefficient of the variable of "HSR pseudoconnection" in core cities is negative. This shows that HSR has a "negative impact" on the enterprises productivity in core cities, which is inconsistent with real connection time of HSR. At the same time, it can be seen from the columns (3)-(4) of Table 13 that the coefficient of "HSR pseudoconnection" of HSR in peripheral cities is positive, which is completely opposite to the conclusion of the real HSR connection time. The above placebo test has eliminated worries about the systematic influence of other unobservable factors and supported the conclusion of the base regress.

6.3. Effectiveness Test of Market Access Indicators. The mechanism of HSR connection lies in the improvement of market access caused by HSR. Market access is a very important measurement index, and the effectiveness of the constructed index will directly affect the reliability and effectiveness of the analysis results. Therefore, it is necessary to test the robustness of market access indicators. Specifically, we use the market access measured by the exponential decay function method commonly used in literature (Eq. (15)) instead of the power-decay function method (Eq. (14)) to conduct a regression analysis on the resource allocation effect and distribution effect mechanism. The analysis shows that, except for the change of the market access coefficient size, the sign and significance index of the coefficient have no substantial change, which from the side supports the reliability and effectiveness of the market access measured by the power-decay function method and also supports the reliability of the results of our mechanism analysis. Robustness tests of market access indicators are shown in Tables 14–16.

7. Conclusions and Discussions

This paper explores the impact of HSR on the enterprises productivity in both core cities and peripheral cities and analyzes the mechanism from the perspective of allocation effect and distribution effect. The main findings of this paper include the following aspects.

First of all, this paper calculates the market access induced by HSR through the empirical data of China's HSR, which enhances the reliability of market access indicators. Secondly, according to the research, the connection of HSR positively affects the enterprises productivity in core cities and negatively affects the enterprises productivity in peripheral cities, with effect values of 1.38% and -8.45%, respectively. The conclusion is still valid through endogenous treatment of instrumental variables constructed based on the principle of "Least Cost Path." Thirdly, after we conduct a serial robustness test with "explanatory variable lags for one period" and "various proxy variables of explained variables," the conclusions are relatively robust. Fourthly, the distribution effect of market access induced by HSR on enterprise productivity in peripheral cities is characterized by market, regional, and location heterogeneity. Market heterogeneity

Table 13: Influence of HSR connection on enterprise productivity: placebo test.

	(1)	(2)	(3)	(4)
	Core cities		Peripheral cities	
	ln_persale		ln_persale	
D_2	-0.0410***		0.0428***	
	(0.0041)		(0.0031)	
D_1		-0.0059		0.0132***
		(0.0039)		(0.0031)
Enterprises control	Y	Y	Y	Y
Cities control	Y	Y	Y	Y
Other traffic control	Y	Y	Y	Y
City fixed	Y	Y	Y	Y
Time fixed	Y	Y	Y	Y
Enterprise fixed	Y	Y	Y	Y
N	966411	966411	1918873	1918873
adj. R^2	0.233	0.233	0.240	0.240

Note: ∗, ∗∗, and ∗ ∗ ∗ represent 10%, 5%, and 1% levels of statistical significance, respectively. Standard errors are reported in parentheses. Due to space limitation, constant term coefficient and standard error are not reported.

Table 14: Regression analysis of market access and resource mismatch.

	(1)	(2)	(3)	(4)	(5)	(6)
	All cities	Core cities	Peripheral cities	All cities	Core cities	Peripheral cities
	ln_persale7525			ln_persale9010		
L1_ln_ACCbeta	-0.1420***	-0.1183***	-0.1072***	-0.2890***	-0.4676***	-0.2220***
	(0.0014)	(0.0037)	(0.0017)	(0.0025)	(0.0072)	(0.0028)
Enterprises control	Y	Y	Y	Y	Y	Y
Cities control	Y	Y	Y	Y	Y	Y
Other traffic control	Y	Y	Y	Y	Y	Y
City fixed	Y	Y	Y	Y	Y	Y
Time fixed	Y	Y	Y	Y	Y	Y
Enterprise fixed	Y	Y	Y	Y	Y	Y
N	2885284	966411	1918873	2885284	966411	1918873
adj. R^2	0.766	0.813	0.757	0.775	0.796	0.773

Note: ∗, ∗∗, and ∗ ∗ ∗ represent 10%, 5%, and 1% levels of statistical significance, respectively. Standard errors are reported in parentheses. Due to space limitation, constant term coefficient and standard error are not reported.

Table 15: Regression results of different export shares and regionals in peripheral cities.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Non	Low	High	Complete	East	Middle	West
	ln_persale				ln_persale		
L1_ln_ACCbeta	-0.5808***	-0.6252***	-0.8430***	-0.3642***	-0.6231***	-1.0471***	-0.0116
	(0.0167)	(0.0485)	(0.0713)	(0.1380)	(0.0188)	(0.1165)	(0.0318)
Enterprises control	Y	Y	Y	Y	Y	Y	Y
Cities control	Y	Y	Y	Y	Y	Y	Y
Other traffic control	Y	Y	Y	Y	Y	Y	Y
City fixed	Y	Y	Y	Y	Y	Y	Y
Time fixed	Y	Y	Y	Y	Y	Y	Y
Enterprise fixed	Y	Y	Y	Y	Y	Y	Y
N	1447163	220803	161989	88908	1398317	375128	145428
adj. R^2	0.233	0.349	0.260	0.238	0.233	0.246	0.312

Note: ∗, ∗∗, and ∗ ∗ ∗ represent 10%, 5%, and 1% levels of statistical significance, respectively. Standard errors are reported in parentheses. Due to space limitation, constant term coefficient and standard error are not reported.

Table 16: The boundary of the influence on the enterprises productivity in peripheral cities.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Distance to the core cities (km)	20-40	40-50	50-100	100-150	150-200	200-250	250-300	300-350	350-400	>400
	ln_persale									
L1_ln_ACCbeta	3.8901***	-0.4874*	-1.6501***	-0.4922***	-1.5088***	-0.4467**	0.7532***	-0.6112***	10.3547***	0.8215
	(0.5446)	(0.2569)	(0.0624)	(0.0168)	(0.1331)	(0.2229)	(0.1676)	(0.2051)	(2.7620)	(0.9464)
Enterprises control	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Cities control	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Other traffic control	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
City fixed	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Time fixed	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Enterprise fixed	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
N	41628	114856	587290	563685	263948	183775	58849	33494	2442	7194
adj. R^2	0.276	0.279	0.226	0.238	0.246	0.264	0.273	0.242	0.224	0.268

Note: we also stratified regression by 20 km or 30 km and found the same conclusion. ∗, ∗∗, and ∗ ∗ ∗ represent 10%, 5%, and 1% levels of statistical significance, respectively. Standard errors are reported in parentheses. Due to space limitation, constant term coefficient and standard error are not reported.

is that market access has the greatest impact on peripheral cities' enterprises mainly in domestic markets and the least impact on enterprises mainly in foreign markets. Regional heterogeneity has manifested that negative impact on the enterprises productivity in eastern and middle peripheral cities gradually weakens and positive spillover effect on enterprises in western peripheral cities. Location heterogeneity is that the range of negative influence on enterprise productivity in peripheral cities is from 40 km to 300 km away from core cities. Fifthly, according to the analysis of the influence channel of distribution effect, the market access induced by HSR can promote the agglomeration of economic factors such as fixed asset investment and human capital to core cities, thus helping to improve the enterprises productivity in core cities and restrain the enterprises productivity in peripheral cities. Finally, the positive impact of HSR on the enterprises productivity in core cities is the result of both positive allocation effect and positive distribution effect. The negative impact of HSR on enterprise productivity in peripheral cities is caused by the negative distribution effect that is greater than the positive allocation effect.

This paper has the following implications. First, from the perspective of national policies, the planning and construction of HSR should be oriented to surrounding cities and even remote cities to promote the coordinated and sustainable development of transportation and economy. Second, barriers to the flow of economic elements of labor and capital should be gradually removed. HSR network will accelerate the flow of economic factors such as capital and talent, promote market competition, and improve the utilization efficiency of factors. This requires policy makers to gradually weaken the restrictions on household registration, housing, and medical care systems and promote the rapid and effective flow of economic factors such as labor and capital, so as to improve the efficiency of resource utilization. Third, the threat of HSR should also be fully considered. Local governments should be fully aware that HSR connection presents both opportunities and threats. The "distribution effect" of HSR may also lead to the loss of capital and talents in peripheral cities. Therefore, the development strategy of "dislocation and complementarity" with the core cities should be adopted to give full play to the local comparative advantages, optimize the industrial layout, and "attract the phoenix with nesting."

Data Availability

The research data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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