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Do High-Speed Rails Improve the Allocation Level of Medical Resources?

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Transportation is an important factor that affects social public health and basic services. The opening of high-speed rails also has an impact on China's urban medical and other basic health services. Based on the panel data of 280 cities at the prefecture level and above in China from 2008 to 2018, this study uses a multi-period difference-in-difference model to explore the impact of opening high-speed rails on the level of urban medical resources, and uses the mediation effect model to analyze its path of influence. The empirical results show that opening high-speed rails has significantly increased the level of medical resources in the city, and the impact has a time lag of about 3 years. Second, government actions are one of the mechanisms by which the opening of high-speed rails affect the level of medical resources. Finally, there is regional heterogeneity in the impact of high-speed rails opening on medical resources. The opening of high-speed rails has a stronger role in promoting the level of medical resources in eastern cities and provincial capitals of China. The conclusion of this study has certain policy significance for improving the social and economic welfare of HSR and promoting the rational allocation of medical resources.

Keywords: high-speed railway, medical resources, difference-in-difference model, transportation, health

INTRODUCTION

After the medium and long-term railway network planning was released in 2004, China began to enter a period of large-scale construction of HSR. In August 2020, it was clearly pointed out in the "New Era Traffic Power Railway Advance Planning Outline" that it was necessary to build a HSR network with the main channel of HSR as the skeleton and regional HSR connection extension.

It is planned that, by 2035, the national HSR mileage plan will reach 70,000 km. Provincial capital cities and cities with a population of more than 500,000 will have HSR access, and adjacent areas will form a 3-h HSR circle. There are HSR projects in various countries (Belgium, Brazil, France, Germany, Portugal, and the USA). The HSRs cannot only save time and improve reliability for passengers (Hensher, 2011) but also allow jobs and labor force through the extension of accessibility range and expansion of the labor market brought about by the improvement of transportation level, bringing a wide range of regional economic benefits (Vickerman et al., 2013). With the continuous growth of the regional economy, people's demands for various infrastructure and basic services are also growing. In China, the difficulty and high cost of getting medical service is a long-standing problem that plagues doctors and patients. A large amount of high-quality medical care is concentrated in larger cities and hospitals, and people's demand for the medical and health resources has not been fully met. Since the problems of lack of and unreasonable allocation of medical resources still exist, the purpose of this study was to examine the relationship between the opening of China's HSR and the allocation level of medical resources in cities along the route, and to test whether the opening of high-speed railways can effectively improve the level of urban medical resources and optimize the spatial distribution of urban medical resources.

Rus and Nombela (2007) analyzed the actual construction; maintenance and rolling stock costs; potential time savings; and expected demand growth of European HSR lines, and proposed that HSR constructions have certain social benefits. Among the existing studies related to HSR, scholars pay most attention to the impact of the opening of HSR on economic growth. Vickerman and Ulied (2006) believe that in the short term, the time saved by passengers should lead to a direct increase in productivity. In the long run, the improvement in accessibility brought about by the creation of HSR links will expand the market area, improve the implicit competitiveness and productivity of enterprises in newly connected areas, and attract new economic activities. Guo et al. (2020) investigated the impact of the Beijing–Guangzhou HSR (BGHSR) on urban economic development by using night-time light data from 2002 to 2018 and found that the construction of HSR has had a considerable positive impact on the economy of first-tier cities (such as Beijing and Guangzhou) and new first-tier cities (such as Zhengzhou, Wuhan, and Changsha). Based on the perspective of regional heterogeneity, Zhang et al. (2020) evaluated the impact of HSR from the aspects of HSR existence, network coverage, service quality, and fairness. They argued with their analysis that HSR construction can directly or indirectly affect regional employment, wages, and economic growth space, so as to reshape the economic spatial layout.

From the perspective of medical treatment, the supply of medical resources is an important factor affecting public health. Existing studies show that the transportation infrastructure construction can increase the supply of urban medical resources, effectively reduce transportation costs, optimize the allocation of medical resources, and improve the geographical accessibility of medical and health infrastructure to improve people's health status (Airey, 2007; Bell, 2012). Levinson (2010) talks about how HSR lines can create a larger effective area, thus affecting the regional distribution of infrastructure. In China, Yuze et al. (2020) introduced HSR as a core explanatory variable. Based on the data of China's health and older adult care follow-up survey, it was found that the opening of HSR can improve the health level of residents along the line by reducing the access time between cities, improving the accessibility of medical resources, accelerating the flow and agglomeration of medical resources, and promoting the regional economic development. At present, there is still a large gap in the research on the impact mechanisms by which HSR affects public health, and there is still a lack of research on the impact of HSR opening on the allocation of urban medical resources. This study regards the opening of high-speed railways as a quasi-natural experiment, uses the multi-time point double difference method to explore the impact of the opening of high-speed railways on the allocation level of urban medical resources, and analyses the transmission mechanism of the impact of the opening of high-speed railways on the allocation level of urban medical resources by constructing an intermediary effect model.

The remainder of this study is structured as follows: The second part is theoretical analysis and research hypothesis, the third part is data and model setting, the fourth part presents the empirical results and analysis, the fifth part introduces the intermediary effect model for mechanism analysis, and the sixth part presents conclusions and policy recommendation.

THEORETICAL ANALYSIS AND RESEARCH HYPOTHESIS

Transportation development affects medical and health resources through its indirect effects. This study mainly analyses the impact of the opening of HSR on the level of medical resources from two angles, namely, government behavior, and resource agglomeration.

Government Behavior

It is the expectation of the people and the responsibility of the government to have a sense of security for the older adults and have medical care for the sick. The government's importance in social infrastructure and basic service activities is unique. At the same time, governmental investment and financing for high-speed railway projects play an important role (Guha et al., 2014). The opening of HSR will have an impact on government behavior in the opening area, and then improve the regional medical and health environments. Specifically, the opening of HSR will promote the economic growth of cities along the route, and economic growth will guarantee the level of regional medical resources. As a regional large-scale transportation infrastructure, HSR has a positive impact on the economic development of cities along the route by optimizing resource allocation and promoting industrial restructuring (Yang et al., 2019). Economic development will promote the increase in public health budget expenditure of local governments and provide a strong guarantee for the improvement of local medical and health environments; second, to seize the great opportunity brought by the opening of HSR, local governments will strengthen the location advantage of the opening area and improve the regional business environment through various actions. The medical and health environments is an important component of regional social security, and the government has stepped up efforts to improve local medical and health conditions based on strengthening regional advantages and retaining talent, including increasing policy support for medical and health undertakings and increasing financial expenditure, thus improving the medical and health conditions in the areas where HSR is opened. The government has effectively improved the allocation level of regional medical resources through fiscal expenditure, which directly affects the level of regional health human resources and health facilities resources.

Resource Agglomeration

The opening of high-speed railways promoted the flow and concentration of medical resources in the region, and the efficiency of resource allocation was significantly improved. On the one hand, the opening of high-speed railways improves the accessibility between regional cities, and on the other hand, the effect of medical treatment in different places will promote medical institutions to improve the level of medical allocation. Compared with other modes of travel, high-speed railways have advantages in cost performance, travel time, and comfort, and are the first choice for most people to travel long distances. According to the data of the Industry Information Network, the turnover of HSR passengers in the entire market has increased from 1% in 2008 to 20% in 2018, and there is room for further increase in the future. Therefore, the opening of HSR has created conditions for residents in areas with insufficient medical resources to go to medical institutions farther away for treatment, and with the increase in the number of people who come to see a doctor, the medical institutions will also increase the investment in medical human resources and support medical infrastructure. On the other hand, the opening and operation of HSR created conditions for the rapid flow of medical staff between regions and effectively improved the medical health level in the areas where the HSR was opened. For example, in the COVID-19 outbreak in 2020, HSR have played an important role in transporting prevention and control personnel, epidemic prevention, and living materials for severe epidemic areas such as Wuhan, Hubei Province. As a means of passenger transport, HSR promotes the redistribution of labor force among regions and is also accompanied by the phenomenon of service industry agglomeration (Delaplace, 2011). The agglomeration of both labor force and service industry in the cities where the HSR is opened will improve the local medical demand to a certain extent. To meet this demand, local medical institutions will increase their investments in medical and health resources.

Based on this analysis, this study argues that the opening of a HSR will improve the level of medical and health resources in cities along the route through government actions and resource agglomeration mechanisms. From a classification point of view, medical resources include soft and hard resources. Among them, medical and health soft resources refer to intangible resources that are difficult to quantify, such as medical science and technology, education, health information, and health regulations, while the hard resources of medical and health care are tangible resources, such as medical and health manpower and material resources. The HSR effect promotes the latter more directly. Therefore, this study proposes the following research hypotheses:

Hypothesis 1: The opening of HSR improves the density of human resources in urban health.

Hypothesis 2: The opening of HSR increases the resource density of urban sanitation facilities.

RESEARCH DESIGN

Model Setting

To investigate the impact of HSR construction on the allocation level of medical resources in China, this study takes the cities that opened HSR in a certain year from 2008 to 2018 as the treatment group and the cities that did not open HSR as the control group, and empirically analyzed the impact of HSR opening on the allocation level of urban medical resources by using the multi-point double difference method. To eliminate individual differences, individual effects are added to the multi-point dual-difference model. The model was set as follows:

$$HDRIdoctor_{it}=a_0+\alpha_1 D_{it}+\alpha \times \sum Z_{it}+\mu_i+\tau_t+\varepsilon_{it} \quad (1)$$

$$HDRIbed_{it}=\beta_0+\beta_1 D_{it}+\beta \times \sum Z_{it}+\mu_i+\tau_t+\varepsilon_{it} \quad (2)$$

where HDRIdoctor refers to the resource density index of doctors (practicing doctors and practicing assistant doctors), HDRIbed indicates the bed resource density index of hospitals, and α_0 and β_0 are constant terms; D_{it} is the virtual variable of the policy of opening HSR, which is 1 for cities with HSR and 0 for cities without HSR; Z_{it} represents the control variable; μ_i indicates the individual fixed effect, which controls individual differences in prefecture-level cities; and τ_i represents the effect of time fixation, which controls the maintenance of certain variables in a given time, where ε_{it} is the standard residual term.

Description of Data Sources and Variables

Data Sources

In this study, the panel data of prefecture-level and larger cities in China from 2008 to 2018 (excluding Hong Kong, Macao, and Taiwan) were used. To ensure robust empirical results, cities with missing data, such as Sansha, Danzhou, Lhasa, and Shigatse, were excluded. Finally, 280 cities were selected as the basic sample and the whole city data were used instead of the municipal district data, and the HSR opening city and HSR opening time data were obtained from the China Railway Yearbook and the website of the State Railway Administration. Other data were obtained from the China Urban Statistical Yearbook (2008–2018), China Statistical Yearbook (2008–2018), and the EPS database. To eliminate heteroscedasticity, the absolute value variables are treated as logarithms in this study, and the descriptive statistics of the main variables are shown in **Table 1**.

Description of Variables

Interpreted Variables

In this study, we refer to the research of Lee (2006); the health resources density index (HRDI) is selected as the evaluation index of health resources, and the medical resources level of each prefecture-level city is measured by the doctor resource density index (HDRIdoctor) and bed resource density index (HDRIbed). The HRDI value is the geometric mean of health resources per thousand population and per square kilometer, which reflects the comprehensive level of population distribution and geographical

TABLE 1 | Descriptive statistics of main variables.

Variable	Explain	Observed value	Mean value	Standard deviation	Minimum value	Maximum
HDRIdoctor	Doctor resource density index	3,080	1.362	1.134	0	12.049
HDRIbed	Bed resource density index	3,080	2.605	1.770	0	14.454
D_{it}	Whether to open HSR	3,080	0.400	0.490	0	1.000
ln*popu*	Population size	3,080	15.094	0.687	12.133	17.343
ln*gdp*$_p$	Per capita economic level	3,076	10.499	0.654	4.605	13.056
ln*sq*	Administrative division area	3,080	9.338	0.803	7.016	12.474
ln*FE*	Government financial expenditure	3,080	14.582	0.833	11.325	18.241

distribution of health resources. The specific calculation method is as follows:

$$HDRIdoctor = \sqrt{\frac{Number\ of\ Doctors}{Population/1000} \times \frac{Number\ of\ Doctors}{Square\ Kilometers}} \quad (3)$$

$$HDRIbed = \sqrt{\frac{Number\ of\ Beds}{Population/1000} \times \frac{Number\ of\ Beds}{Square\ Kilometers}} \quad (4)$$

Explanatory Variables

Opening of HSR (D_{it}) This study selects the policy dummy variable of the HSR opening as the explanatory variable and sets $D_{it} = di^* dt$, where di is the individual dummy variable, the cities with HSR are the treatment group ($di = 1$), and the cities without HSR are the control group ($di = 0$). Here, D_t is a time dummy variable, and the year after the HSR is opened is $dt = 1$, and the year without the HSR is $dt = 0$. The interactive term ($di \times dt$, i.e., D_{it}) represents the virtual variable of the city after the opening of the HSR, which is the core explanatory variable that this study focuses on, and its coefficient can reflect the differential influence of the opening of the HSR on the treatment and control groups. **Table 2** shows the opening of HSR in 280 sample cities from 2008 to 2018.

In this study, the policy dummy variable of the HSR opening is selected as the explanatory variable, and $D_{it} = di \times dt$ is set. Here, D_i is an individual virtual variable, the cities with HSR are the treatment group ($di = 1$), and the cities without HSR are the control group ($di = 0$); D_t is a time dummy variable, and the year after the HSR is opened is $dt = 1$, and the year without the HSR is $dt = 0$. The interactive term ($di \times \text{dt}$, that is, D_{it} represents the virtual variable of the city after the opening of the HSR, which is the core explanatory variable that this study focuses on, and its coefficient can reflect the differential influence of the opening of the HSR on the treatment and control groups. **Table 2** shows the opening of HSR in 280 sample cities from 2008 to 2018.

Control Variables

Population Size. Population size is an important factor that affects the allocation of medical resources. When studying the scaling relationship between medical resources and population in cities of different sizes in China, we found that doctor density and bed density index increased linearly in the same direction with the size of urban population. In this study, the logarithm of the city's total population at the end of the year (ln*popu*) is selected as a measure of population size.

Per Capita Economic Levels. Usually, the higher the level of economic development, the better is the infrastructure construction and the higher is the level of medical resource allocation. The per capita economic level of cities directly affects the level of urban medical resource allocation. In this study, the logarithm of the city's per capita GDP (lngdp_{p}) was selected to measure the per capita economic level.

Administrative Area. The area of urban administrative divisions is one factor that affects the level of urban medical allocation. The supply of medical resources is related to the size of urban areas, while the area of urban administrative divisions affects the density of medical and health resources. In this study, the administrative division area (ln*sq*) was obtained from the logarithm of the land area of the urban administrative divisions.

Government Behavior. In this study, government behavior is regarded as an intermediary variable, and the government promotes the rational allocation of urban medical and health resources by increasing policy support for medical and health undertakings and increasing fiscal expenditure. The different regions have different levels of economic development, and the government's financial expenditure on medical care is also affected; in this study, the fiscal expenditure of prefecture-level city government is taken as the concrete index to measure government behavior, and the logarithm of fiscal expenditure is taken and expressed by ln*FE*.

EMPIRICAL RESULTS

The Benchmark Regression

Table 3 shows the benchmark regression results of the impact of HSR opening on the allocation level of medical resources in prefecture-level cities across China. In the multi-time to (empirical test of the impact of HSR opening on health human resources, Models (1)–(4) explore the impact of HSR opening on

TABLE 2 | Opening of high-speed rail from 2008 to 2018.

Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Open quantity	15	32	53	68	88	108	145	169	178	185	191
Opening ratio (%)	5.36	11.43	18.93	24.29	31.43	38.57	51.79	60.36	63.57	66.07	68.21
Opening increase (%)	/	113.33	65.63	28.30	29.41	22.73	34.26	16.55	5.33	3.93	3.24

TABLE 3 | Estimation results of benchmark regression model.

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	HDRIdoc				HDRIbed			
D_{it}	0.331***		0.091***	0.084***	0.773***		0.262***	0.252***
	(19.23)		(4.87)	(4.51)	(28.97)		(9.92)	(9.53)
ln*popu*		2.224***	0.665***	2.137***		3.159***	1.133***	2.895***
		(13.33)	(11.04)	(12.76)		(13.14)	(13.30)	(12.15)
ln*gdpp*		0.410***	0.434***	0.365***		0.987***	0.929***	0.853***
		(23.58)	(22.56)	(18.32)		(39.43)	(34.20)	(30.08)
Ln*sq*		−1.947***	−0.747***	−1.919***		−2.647***	−1.151***	−2.562***
		(−12.35)	(−14.23)	(−12.20)		(−11.66)	(−15.49)	(−11.45)
_cons	1.229***	−18.33***	−6.290***	−16.84***	2.295***	−30.71***	−13.61***	−26.23***
	(133.65)	(−10.56)	(−7.11)	(−9.56)	(160.92)	(−12.29)	(−10.89)	(−10.48)
N	3,080	3,076	3,076	3,076	3,080	3,076	3,076	3,076
Fixed effect	YES	YES	NO	YES	YES	YES	NO	YES
R^2	0.117	0.283	0.268	0.288	0.231	0.462	0.468	0.480

****indicate significance at the 1% levels, respectively, and the value of T is in brackets.*

health human resources, and Models (5)–(8) explore the impact of HSR opening on healthcare resources.

Models (1), (3), and (4) contain the core explanatory variables to be investigated in this study. Model (3) is a mixed regression and model (4) is a bidirectional fixed-effect regression model which controls the year and individual effects. Model (2) is the regression result of the controlled and explained variables. It can be seen from **Table 3** that in columns (1)–(4), the coefficient sign of the core explanatory variable D_{it} is basically consistent with the significance level, and the control variables population size, per capita economic level, and the administrative division area are all significant at the 1% level. The coefficient sign of all variables in this study has not changed, indicating that the policy dummy variable of HSR opening and the variables such as population size and per capita economic level have passed the significance test, and the estimation result is relatively stable. Specifically, the regression coefficient of the core explanatory variable D_{it} is positive from Models (1)–(4), and it is significant at the 1% level, which indicates that the opening of the HSR can positively promote the doctor resource density in cities along the route, and the opening of HSR will increase the health of human resources in cities, which is consistent with hypothesis 1. In the model, the controlled variables, population size, and per capita economic level, have positive effects on doctor resource density; that is, the larger the urban population size and the higher the per capita economic level, the higher the doctor resource density; however, the area of administrative divisions has a negative impact on the doctor resource density of each prefecture-level city. The symbol of the coefficient of the control variables is consistent with the conclusions of previous studies; to some extent, it reflects the rationality of the model setting in this study.

In an empirical study on the impact of the opening of HSR on the bed resource density in various prefecture-level cities, the regression results are similar to the doctor resource density. The settings of Models (5)–(8) correspond to columns (1)–(4), respectively, and will not be repeated. There is no change in the sign of the coefficients of the core explanatory variable D_{it} and the control variable, it shows that the virtual variables of HSR opening policy, population size, per capital economic level, and other variables have passed the significance test. The regression results show that the coefficient of the core explanatory variable D_{it} is significantly positive at the 1% level from Models (5)–(8), which indicates that the opening of HSR is positively correlated with the bed resource density of the hospitals along the line, and the opening of the HSR will increase the resources of urban health facilities, which is in accordance with Hypothesis 2.

The Robustness Test

Parallel Trend Test

Using the traditional double difference method to analyze the policy assumes that the interpreted variables of the treatment group and the control group have a common trend; that is, the medical resource density of all cities has a parallel trend before the opening of the HSR. Otherwise, the double difference result is meaningless, and this condition is also applicable to the

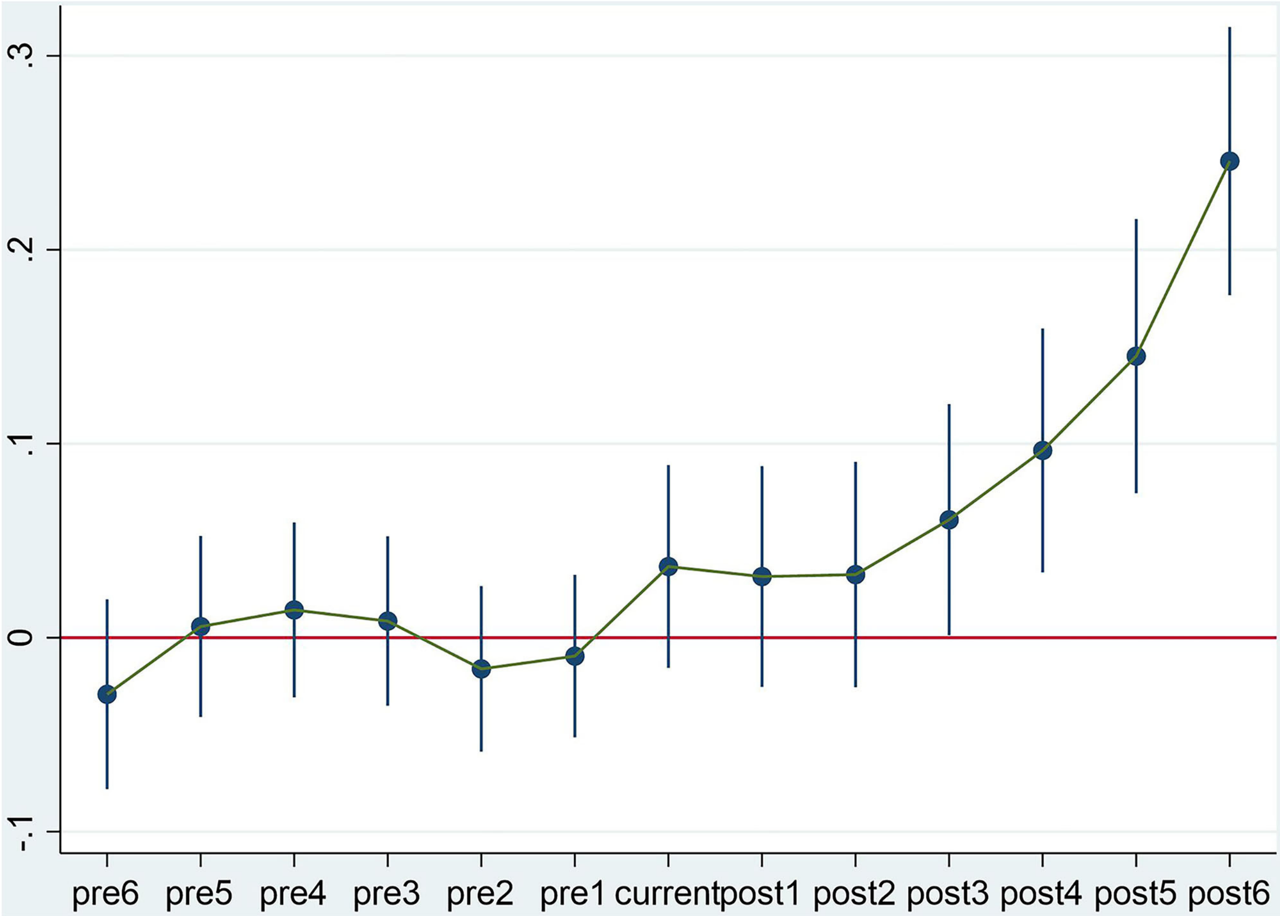

FIGURE 1 | Parallel trend and dynamic change of doctor resource density.

multi-point double difference method. To test the parallel trend hypothesis, in this study, an observation window period of 12 years before and after the opening of the HSR is selected, and the virtual variables of the first 6 years and the last 6 years after the opening of the HSR are included in the regression model.

Figures 1, **2** show the parallel trend and dynamic change of doctor resource density and bed resource density, respectively, and their overall trends are consistent. The figure shows the estimated coefficient and 95% confidence interval of the virtual variables in each year during the observation window. It can be seen that the correlation coefficient between carbon emissions and policies in the first 6 years of HSR opening is close to 0. This shows that the doctor resource density and bed resource density of the treatment and control groups have a common trend before the implementation of the HSR opening policy, which means that there is no pre-correlation between the opening of the HSR and the level of medical resources. In the 6 years after the HSR, the correlation coefficients are all positive, and the absolute value of the correlation coefficients increases with time, which shows that the opening of the HSR can obviously promote the doctor resource density and bed resource density, and the longer the opening of the HSR, the greater the promotion effect.

As shown in the figure, the doctor resource density and bed resource density began to increase significantly in the fourth year after the opening of the HSR, and the rising trend gradually expanded in the following 3 years, indicating that the effect of the opening of the HSR on improving the level of medical resources lags behind. The reason for this lag effect may be that the opening of HSR brings the economic growth effect of cities first, which will lead to the concentration of capital, labor, and other factors, and at the same time, it affects the fiscal expenditure behavior of the city government that opened the HSR. The rise in the level of medical resources caused by government actions requires a process. Therefore, it takes a long time for the opening of HSR to affect the medical resources level of HSR cities, and there is usually a time lag of 2–3 years.

Spatial DID

High-speed rail is a spatialized product. The traditional difference-in-difference model is prone to serious multicollinearity between dummy variables and cross terms. From the perspective of spatial measurement, the opening of high-speed rails will not only affect the medical resources of the city, but also affect the medical resources of surrounding areas

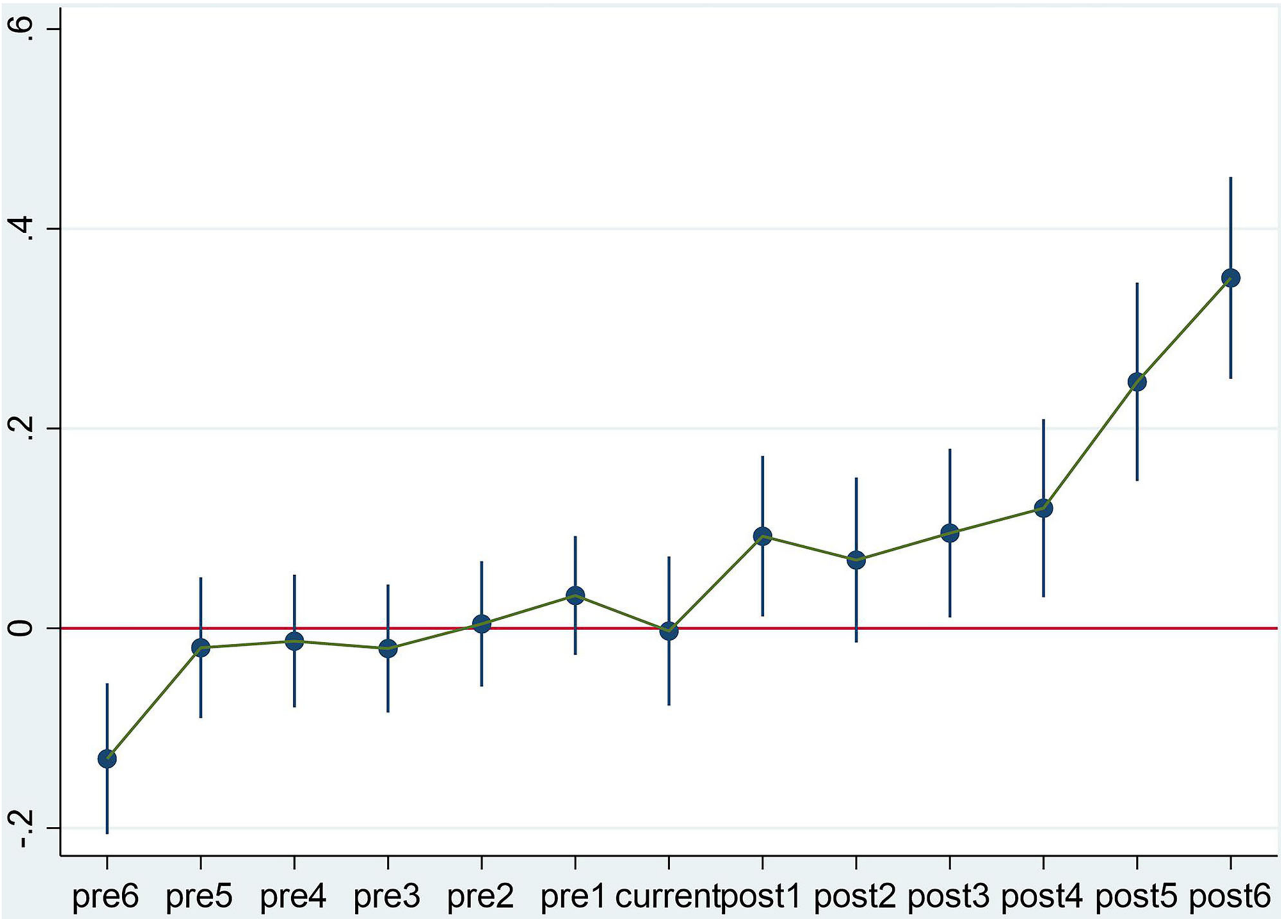

FIGURE 2 | Parallel trend and dynamic change of bed resource density.

through positive or negative external effects. In view of this, based on the traditional difference-in-difference model and fully considering the avoidance demand of spatial multicollinearity, this study constructs a spatial DID autoregressive model to more comprehensively, systematically and accurately measure the temporal and spatial differences in the allocation of medical resources after the opening of high-speed rails. The specific model is shown in Equation (5):

$$\begin{aligned} Inno_{it} &= \alpha_0 + \sum_{it=1}^{NT} \rho_{SAR}(\xi^{'} \otimes \pi^{'})_{it,it} Inno_{it} + \beta_1 D_{it} \\ &\quad + \beta_k \sum_{k=1}^{K} X_{it,k} + \varepsilon_{it} \end{aligned} \quad (5)$$

where, ρ_{SAR} is the spatial correlation coefficient of the model; π' is the spatial weight matrix after row random standardization, which is calculated by constructing the distance function based on the reciprocal of the spatial distance between provinces (straight line distance between the centers of two provinces); ξ' is the time weight matrix after row random standardization, which is calculated according to the ratio of Moran index in each year; π' and ξ'. The row random standardization processing method of is that each element is divided by the sum of all elements of the corresponding row; $\otimes$ is the Kronecker product sign of the matrix. This study mainly refers to the method of (Qiao and Hudson, 2018) in the setting of spatio–temporal weight matrix. The matrix formed by ξ'$\otimes\pi$' is an NT × NT order endogenous space–time weight matrix with variable time effect.

Tables 4, **5**, respectively, show the global Moran index test results of the number of doctors and the number of beds of the explained variables. It can be seen that the global Moran index of the number of doctors and the number of beds from 2008 to 2018 is >0, and both passed the significance test, indicating that there is a robust and significant positive spatial correlation between the level of medical resources among cities in China. Spatial geographical distance is an important factor affecting the spatial correlation of medical resources in China. There is spatial spillover between geographically adjacent cities, but with the shortening of time distance by means of transportation, the spatial correlation of medical resources is gradually weakening.

Table 6 reports the empirical results of spatial DID model. It can be seen from columns (2) and (4) that the spatial correlation coefficient of the impact of the opening of high-speed railway

TABLE 4 | Global Moran index of explained variable (HDRIdoctor).

Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Global Moranss I	0.017	0.015	0.014	0.008	0.013	0.019	0.017	0.020	0.021	0.020	0.022
SD (I)	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006
Z	3.511	3.076	2.970	1.863	2.824	3.832	3.559	3.999	4.074	4.000	4.256
p-value	0.000	0.001	0.001	0.031	0.002	0.000	0.000	0.000	0.000	0.000	0.000

TABLE 5 | Global Moran index of explained variable (HDRIbed).

Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Global Moran's I	0.015	0.012	0.011	0.009	0.008	0.009	0.007	0.006	0.006	0.004	0.004
SD(I)	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006
Z	3.101	2.655	2.487	2.165	1.94	2.232	1.713	1.629	1.669	1.378	1.315
p-value	0.001	0.004	0.006	0.015	0.026	0.013	0.043	0.052	0.048	0.087	0.094

TABLE 6 | Estimation results of spatial DID model.

Variable	(1)	(2)	(3)	(4)
	HDRIdoc	HDRIdoc	HDRIbed	HDRIbed
D_{it}	0.199**	0.141**	0.381***	0.309***
	(2.23)	(2.22)	(7.26)	(4.64)
ln*popu*	0.274***	0.170***		
		(3.57)	(3.34)	
ln*gdp*$_p$		0.470***	0.452**	
		(7.13) (5.09)		
ln*sq*		−0.523*** −0.601***		
		(−7.99) (−3.96)		
_cons	−4.106*	−4.119***	−5.302**	−4.241**
	(−1.86)	(−5.69)	(−2.42)	(−4.13)
N	3,069	3,069	3,069	3,069
Spatial correlation coefficient	0.468***	0.364***	0.463***	0.481***
	(6.65)	(4.51)	(4.98)	(7.04)
R^2	0.455	0.428	0.487	0.483

****, **, and *indicate significance at the 1, 5, and 10% levels, respectively, and the value of T is in brackets.*

TABLE 7 | Regression estimation results of robustness test.

Variable	(1)	(2)	(3)	(4)
	HDRIdoc	HDRIbed	HDRIdoc	HDRIbed
D_{it}	0.0446*	0.218***		
	(1.96)	(6.72)		
Lag_D_{it}			0.115***	0.257***
			(5.98)	(9.58)
ln*popu*	2.762***	3.913***	2.030***	2.472***
	(12.65)	(12.57)	(11.35)	(9.88)
ln*gdp*$_p$	0.409***	0.866***	0.368***	0.829***
	(13.98)	(20.78)	(16.20)	(26.09)
ln*hosp*	−2.452***	−3.428***	−1.866***	−2.345***
	(−12.34)	(−12.10)	(−11.12)	(−9.99)
_cons	−22.22***	−34.31***	−15.75***	−21.58***
	(−10.24)	(−11.09)	(−8.38)	(−8.21)
N	2,097	2,097	2,796	2,796
Fixed effect	YES	YES	YES	YES
R^2	0.311	0.483	0.262	0.419

**** and * indicate significance at the 1 and 10% levels, respectively, and the value of T is in brackets.*

on medical resources is significantly positive at the level of 1%, indicating that the opening of high-speed rails has a significant positive spatial spillover effect, which has a positive impact on the surrounding areas while improving the level of medical resources in the city. Under the spatial DID model, the empirical results of the opening of high-speed rails on the level of medical resources are still robust.

Reduce the Sample

In this section, the robustness of the basic regression is tested by changing the sample size. During the observation period from 2008 to 2018, some prefecture-level cities have opened HSR, but as of 2018, there are still cities that have not opened HSR. Therefore, this study removes the cities that have not opened HSR from the basic samples and reduce the number of samples. As shown in **Table 7**, Models (1) and (2) eliminate the regression results of cities without HSR, and the regression coefficient of the main explanatory variable D_{it} is still significant, which shows that the research results of this study are robust to some extent.

Add Lag Variables e the Sample

Considering that there is a certain time lag in the impact of the opening of the HSR on the level of medical resources, this study regresses the main explanatory variable that the opening of HSR lags by one stage. Models (3) and (4) in **Table 7** show the regression results of one-stage lag, and the regression coefficient of lag variable Lag_Dit is significant at the 1% level. This is consistent with the result of the basic regression, which shows that the result of the basic regression is robust and provides a robust test.

Regional Heterogeneity Test

To further study the difference in the impact of the opening of the HSR on the level of medical resources, this section also estimated such impact from the level of combining regions and whether they are provincial capitals and cities with separate plans (see **Table 8**).

From Models (1)–(3), 280 cities at the prefecture level and above were divided into three categories according to China's geographical location. The results show that the regression coefficient of the core explanatory variable D_{it} is positively significant at the 1% level in eastern cities and 10% in western cities, indicating that the opening of HSR has positively promoted the doctor density in eastern and western cities; however, the opening of HSR has a greater impact on the increase of doctor density in eastern cities than in western cities. In central cities, the regression coefficient of D_{it} is not significant, indicating that this study has not found that the opening of HSR can promote doctor density in central cities. Models (4) and (5) distinguish 280 cities at the prefecture level and above according to whether they are provincial capitals or cities with separate plans, which are divided into provincial capitals, cities with separate plans, and other cities. According to the regression results, the opening of HSR has a significant positive effect on the increase in health human resources in provincial capitals and cities with separate plans, and the regression coefficient of the core explanatory variable D_{it} is significant at the 1% level; for the other cities, the impact of the opening of HSR on their health human resources is not significant.

Combining the two classifications, the opening of the HSR has the most significant promotion effect on health human resources in the eastern provincial capitals and cities with separate plans. This result also confirms the hypothesis that the opening of HSR affects the level of medical resources in the opening cities through government actions and resource agglomeration. We generally believe that the economic level of eastern China, provincial capitals, and cities with separate plans is higher than that of central and western cities and non-provincial capitals and cities with separate plans. The economic growth effect of the opening of HSR on large cities in eastern China is greater than that of medium and small HSR cities in central and western China. Economically developed areas usually provide local residents with higher public goods and services with higher fiscal expenditure levels. Therefore, for provincial capitals and cities with separate plans in the east, the opening of the HSR will affect government fiscal expenditure behavior through economic growth, and the it will increase its fiscal expenditure on medical and health care, thereby significantly improving the level of medical resources in this area. At the same time, the eastern cities and provincial capitals attract various elements with their superior geographical locations. The resource agglomeration effect of the opening of the HSR on eastern and provincial capitals is greater than that of central and western cities, so the medical resource agglomeration effect of the opening of HSR on eastern and provincial capitals will be more obvious.

MECHANISM ANALYSIS

The opening of HSR mainly affects the level of medical resources in HSR cities through government actions. The economic growth effect caused by the opening of HSR will increase the fiscal revenue of HSR cities; accordingly, the fiscal expenditure on basic services such as medical care will also increase, and the government will influence the allocation of medical resources through its fiscal expenditure on medical care. Therefore, the opening of HSR will affect the level of medical resources in HSR cities.

In this study, referring to Wen et al. (2004), aiming at the mechanism of the impact of the opening of HSR on the level of urban medical resources, an intermediary effect model is set up, and the government behavior of the HSR city government (expressed by government financial expenditure) is used as an intermediary variable for analysis. The specific regression model is set as follows:

$$lnFE_{it} = a_0+\alpha_1 D_{it}+\alpha \times \sum Z_{it}+\mu_i+\tau_t+\epsilon_{it} \quad (6)$$

$$HDRIdoctor_{it} = a_0+\alpha_1 \ln FE_{it}+\alpha \times \sum Z_{it}+\mu_i+\tau_t+\varepsilon_{it} \quad (7)$$

$$HDRIdoctor_{it} = a_0+\alpha_1 \ln FE_{it}+\alpha_2 D_{it}+\alpha \times \sum Z_{it}+\mu_i+\tau_t+\varepsilon_{it} \quad (8)$$

Equation (6) studies the impact of HSR opening on the financial expenditure of HSR cities, and (7) represents the impact of government financial expenditure on the resource density of urban doctors. The meanings of the specific variables and indicators are the same as those of the basic regression model discussed here.

Table 9 shows the regression results of government behavior as an intermediary effect, and Models (1)–(3) are the regression results of these three formulas. The regression coefficient of D_{it}, the main explanatory variable of Model (1), is significant at the level of 1%, which shows that opening HSR has played a positive role in promoting government financial expenditure, and the opening of HSR has increased the financial expenditure of HSR city governments. In model (2),The regression coefficient of the main explanatory variable ln*FE* is very significant, which shows that the government financial expenditure is significantly related to the doctor resource density, and the more the government financial expenditure, the greater the doctor resource density in the city. In model (3), two explanatory variables, government financial expenditure, and the opening of HSR, exist concurrently. The results show that the regression coefficient of financial expenditure of the intermediary variable is significant at the 1% level. However, the regression coefficient of variable D_{it} of HSR opening is not significant, which indicates that government behavior can be used as an intermediary variable that affects the level of medical resources, and the opening of HSR affects the level of medical resources in cities with HSR opening through government behavior.

TABLE 8 | Regional heterogeneity evaluation results of the impact of HSR opening on doctor resource density based on multi–time double difference model.

Variable	Full sample	Comparison by city geographical location			According to whether it is a provincial capital or a city with separate plans	
		Eastern city (1)	Central city (2)	Western cities (3)	Provincial capitals and cities with separate plans (4)	Other cities (5)
D_{it}	0.0839***	0.0932***	0.0254	0.0820*	0.306***	0.0299
	(4.51)	(3.48)	(0.68)	(2.57)	(7.09)	(1.54)
Ln*popu*	2.137***	3.311***	−0.603	0.545	2.046***	2.211***
	(12.76)	(14.89)	(−1.33)	(1.89)	(12.22)	(13.23)
$\ln gdp_p$	0.365***	0.523***	0.483***	0.216***	0.392***	0.396***
	(18.32)	(16.10)	(11.61)	(7.62)	(22.52)	(20.14)
ln*sq*	−1.919***	−2.880***	−1.494*	−0.723*	−1.816***	−1.950***
	(−12.20)	(−14.71)	(−2.10)	(−2.08)	(−11.53)	(−12.37)
_cons	−16.84***	−27.73***	19.47*	−2.502	−16.71***	−17.96***
	(−9.56)	(−12.80)	(2.03)	(−0.63)	(−9.63)	(−10.25)
N	3,076	1,506	770	800	383	2,689
Fixed effect	YES	YES	YES	YES	YES	YES
R^2	0.288	0.423	0.249	0.165	0.296	0.284

**** and * indicate significance at the 1 and 10% levels, respectively, and the value of T is in brackets.*

TABLE 9 | Regression results of mediation effect.

Variable	(1)	(2)	(3)
	ln*FE*	HDRIdoc	HDRIdoc
ln*FE*		0.365***	0.357***
		(13.93)	(13.19)
D_{it}	0.175***		0.0215
	(13.83)		(1.15)
ln*popu*	1.153***	1.737***	1.725***
	(10.15)	(10.52)	(10.42)
$\ln gdp_p$	1.063***	−0.0123	−0.0145
	(78.66)	(−0.35)	(−0.42)
ln*sq*	−0.147	−1.872***	−1.867***
	(−1.37)	(−12.27)	(−12.22)
_cons	−12.68***	−12.57***	−12.31***
	(−10.62)	(−7.27)	(−7.06)
N	3,076	3,076	3,076
Fixed effect	YES	YES	YES
R^2	0.818	0.330	0.330

****indicate significance at the 1% levels, respectively, and the value of T is in brackets.*

CONCLUSION AND POLICY SUGGESTIONS

Transportation is an important factor affecting the level of regional medical resources. The opening and popularization of HSR affects social and economic development, acts on the government's behavior, and affects the level of regional medical resources. By analyzing the panel data of 280 cities at the prefecture level and above in China from 2008 to 2018, a multi-time double difference model was used to explore the impact of opening HSR on the level of urban medical resources, and its mechanism was further analyzed through the intermediary effect model.

The findings are as follows: (1) The opening of HSR will increase the doctor resource density and hospital bed resource density in cities, and improve the overall level of medical resources in cities, and this influence has a time lag of about 3 years; that is, the density of urban medical resources increased significantly in the fourth year after the opening of HSR, and the increasing trend expanded further after that. (2) Government behavior plays an intermediary role in the impact of the opening of the HSR on the level of medical resources, and the opening of HSR increases the fiscal expenditure of cities along the route. However, the increase in government financial expenditure will play a positive role in promoting the level of medical resources. At the same time, the resource agglomeration caused by the opening of HSR has promoted the level of urban medical resources to a certain extent. (3) The impact of opening HSR on the level of medical resources is different in eastern, central, and western regions. Among all the cities in China, its influence on the eastern cities is more remarkable. In provincial capitals and cities with separate plans, the opening of HSR has obviously improved the level of medical resources, while in other cities, the impact was relatively small. From the research conclusion of this study, we can obtain the following policy enlightenment: Pay attention to the role of the opening of HSR in influencing urban medical resources through government fiscal expenditure, continue to intensify the construction of HSR networks, improve the coverage rate of HSR networks, and further enhance the level of medical resources and basic health services in cities where HSR is opened.

Second, it is necessary to fully understand the diffusion effect of provincial capitals and other big cities, shorten the time distance between cities by using HSR, promote the linkage development of health industries in urban agglomerations and urban circles, provide people with better medical products and health services, and encourage health practitioners to spread to surrounding cities, so as to optimize the resource allocation effect of HSR.

Third, we can promote the rational regional allocation of medical resources with the help of the layout and opening of HSR. There is a problem of uneven distribution of medical resources in China, and the level of medical resources in central and western China is obviously weaker than that in eastern China. Therefore, the central and western cities should take advantage of the opening of HSR to strengthen the construction of transportation infrastructure and optimize the location conditions of cities along the route; promote the concentration of regional medical resources and attract the inflow of health human resources, so as to alleviate the problem of uneven distribution of medical resources.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

AUTHOR CONTRIBUTIONS

HW, XR, and MZ contributed to the research and writing of this article. HW focused on the theoretical mechanism of the impact of building high-speed rails on the reach of public health in China. XR and MZ focused on the empirical test of the article. All authors participated equally in writing of this manuscript. All authors contributed to the article and approved the submitted version.

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