Impacts of High-Speed Rail Stations Opening on the Regional Innovation Level

—Analysis Based on Scoring Tendency Matching Model

Hongyu Fan

Jinan University, Guangzhou, China
Email: 15008677387@163.com

Abstract

In the background of the era of the "eight horizontal and eight vertical" high-speed rail (HSR), HSR has had a great impact on the location conditions of cities along the route, and the emergence of HSR compresses the "space-time" distance between regions, greatly promoting the flow of factors between regions. This paper analyzes the possible impact of HSR station opening on regional innovation level, tests the impact of HSR station opening on the level of urban innovation by combining the PSM model combined with panel data regression model, carries on the robustness test of the results with the tool variables, and further explores the impact of the influence on the heterogeneity of different characteristic cities. The study found that the opening of HSR stations has a significant positive impact on the improvement of regional innovation level in terms of average effect, but the cities with different locations have significant differences, and the level of urban innovation in the eastern and western regions where HSR stations are not set up is significantly higher than that of cities without HSR stations, while the impact on the eastern region is significantly greater than that of the western regions, but the opening of HSR stations has little impact on the level of urban innovation in the central and western regions, mainly because the eastern region has a good foundation for innovation, and the western region has a highly inclined support policy. This paper thinks that the government should further expand the construction of HSR network, and pay attention to the use of policy means to narrow the differences in the level of innovation between regions.

1. Introduction

HSR first emerged in Japan. In 1964, the world's first HSR line, the Japan Shinkansen, opened for operation. Since then, a new era of HSR development has begun. In the 1990s, China began to carry out research and exploration in the field of HSR, and made significant progress in a relatively short period of time. By the end of 2018, the operating mileage had reached 29,000 kilometers, accounting for more than two-thirds of the total mileage of the world's HSR. It is expected that by the end of 2019, the total operating mileage of China's HSR will reach 35,000 kilometers, ranking first in the world. China is currently the country with the longest operating mileage of HSR, the largest scale under construction, the highest commercial operation speed, the most comprehensive HSR technology, and the most experienced operation and management experience.

The current research on the relationship between HSR and regional development has got a lot of results, mainly focusing on regional accessibility, economic impact, spatial structure, micro-enterprise impact, and knowledge spillover. Some scholars believe that the opening of the HSR promotes the flow of regional factors. Wang & Li (2018) used the DID model to explore the impact of HSR construction on the economic agglomeration of urban agglomerations from the perspective of economic density and industrial agglomeration. The availability of factors has accelerated the flow of factors between regions, including funds and people. Du Xingqiang and Peng Miaowei (2017) examined the impact of the opening of HSR on the flow of senior talents in enterprises, and the study found that the region's attractiveness to senior talents has been significantly enhanced. This is reflected in the increase in the number of senior talents with a doctoral degree in enterprises. Some scholars believe that the opening of the HSR promotes regional information exchange, especially face-to-face exchanges. Okabe (1979) and Sands (1993) have investigated the commercial activities of cities along the Japan Shinkansen after opening, and found that business services, R&D, education, etc. face-to-face knowledge exchange activities have been significantly improved; Chen and Vickeman (2017) believe that regions with high-speed rail development have higher levels of knowledge and employment. This conclusion is verified by two cases in the Kent region of the United Kingdom and the PRD region of China. Dong et al. (2018) research found that authors who know between two cities with HSR will have more opportunities to interact face-to-face, and strange authors between two cities with HSR may establish new partnerships. More and more scholars have begun to pay attention to the effects of HSR opening. The focus is mainly on the relationship between HSR opening and economic growth, but the research conclusions have not reached consensus. Among them, studies by scholars such as Marie (2010), Wang & Nian (2014) found that in the short term, the opening of HSR did not play a role in leading local economic development; while studies by scholars such as Zhang and Tao (2016) found that HSR that was opened significantly re-

duced the economic growth rate of non-regional central cities along the way; some research conclusions support the promotion effect of the HSR opening on economic development, such as Wang and Ni (2016). The study found that after the HSR opened, the spillover effect of economic growth among regions in China was obvious. Ahlfeldt and Feddersen (2010) research based on the theory of new economic geography found that after the opening of the HSR, the economic growth rate of the station cities increased by 2.7%.

Su and Lin (2017) believe that for different regions, the improvement of innovation capabilities not only depends on their own innovation factors, but also depends on the flow of innovation factors in other regions. Some scholars have studied this from the perspective of transportation infrastructure. From the perspective of regional innovation systems, such as Andersson and Karlsson (2002), Fritsch and Slavtchev (2011), they believe that transportation infrastructure is an important part of regional innovation systems or innovation networks. It can promote the connection and exchange between the main bodies of the system, so the perfect transportation infrastructure is also conducive to the formation of a more complete and developed innovation network. Not only this, but also some studies by scholars suggest that the construction of transportation infrastructure can promote the flow of factors, which in turn can accelerate knowledge spillover between regions, such as Tsekouras et al. (2016).

Through the above research, it is found that the current research on the impact of the opening of HSR stations on regional innovation is relatively lacking. Some scholars use the accessibility to explore the problem of the flow of knowledge, technology and other factors brought by HSR stations from the perspective of knowledge spillovers. This article has very important reference and enlightenment significance, but these studies only focused on the phenomenon of knowledge spillovers that may arise from the opening of the HSR, and the discussion ended abruptly, ignoring whether the construction of HSR stations can contribute to regional innovation activities after knowledge spillover have further impact. In fact, knowledge spillover is only one of the conditions for regional innovation activities, which is not itself equal to regional innovation. After the opening of the HSR, the innovation factor flow and knowledge spillover effects can promote mutual learning, competition, and imitation of innovation activities between different regions, which will have an important impact on regional innovation activities. If this aspect is ignored, this study is bound to be detrimental to comprehensively examining the impact of HSR station construction, and it is not conducive to us to more scientifically explore the internal mechanism of the evolution of regional innovation patterns in China. Based on this, based on the current background of the rapid development of China's HSR, this article discusses the impact of the opening of HSR stations on regional innovation activities from the perspective of the flow of innovation elements, focusing on the question of whether the HSR opening promotes regional innovation.

2. Theoretical Analysis

The impact of HSR stations opening on regional innovation levels has certain objective inevitability, which is determined by the characteristics of HSR and the characteristics of innovation activities.

On the one hand, the HSR is mainly for passenger transportation, and its fast and large capacity meets the passenger communication between cities (especially long-distance cities). Passengers serve as carriers of knowledge and information, while innovative activities are based on manpower and knowledge, as the main input factor, the construction of HSR stations has an important impact on innovation activities. The HSR has facilitated the access of knowledge and information to the "depressions", in particularly, it has accelerated the effective transmission of tacit information that can be obtained through face-to-face communication, and innovation activities need to exchange information face-to-face.

On the other hand, it is determined by the characteristics of innovation activities. Innovation activities have characteristics that are not available in other investment activities, such as large investment quotas, long investment cycles, and high risk factors. Therefore, sufficient funds are the support for regional innovation and development; the nature lies in the higher requirements for information transmission and communication, and the need for face-to-face communication. Network information exchange alone is not enough to meet the needs of innovative activities. However, in the existing literature research, we found that the biggest feature of HSR is to reduce the space-time distance between regions and promote the flow of inter-regional factors. Therefore, we can preliminarily judge that the construction of HSR may have a positive effect on the innovative development of HSR station cities.

3. Model Design and Variable Selection

3.1. Model Design

In order to capture the net effect of increased venture capital investment in local cities after the opening of the HSR, we take cities that opened HSR during 2008-2015 as treatment groups and non-opened HSR cities as control groups, so we can get the impact of this quasi-natural experimental event on regional innovation levels is causal inference. Due to the differences in the years in which HSR are opened in each city, reference is made to the double-difference model used in studies such as Chen and Xiong (2015), Liu and Zhao (2016), Zhang and Tao (2016). Model (1) to test the impact of HSR station opening on regional innovation levels:

$$P_{it} = \alpha_i + \beta treat_{it} + \gamma Z_{it} + \delta_i + \rho_t + \varepsilon_{it} \tag{1}$$

P_{it} is an explanatory variable, in this article refers to the number of patent applications for the city i in year t, the number of utility model invention patents, $treat_{it}$ in this article refers to whether the city i is opened HSR station in year t, Z_{it} is a series of control variables; δ_i is the urban fixed effect, and ρ_t is the

time fixed effect.

In this paper, the propensity value matching method (PSM) is used to construct the control samples, and the 1:1 sampling is put back into the caliper matching to construct the control group. The selected matching variables include per capita GDP (pgdp), tertiary industry proportion (thi), local fiscal science education expenditure (secience), actual foreign capital used in that year (FC), and the number of college students (hstudent). Before applying the tendency value matching method (PSM), we need to estimate the "trend value" of the processing group and the control group, and use the Probit model to estimate. The dependent variable is whether the city has opened HSR station. The specific estimation model is shown in Formula (2). In the model, we control the fixed time effect (ρ)

$$\text{Logi}\left(perioda_i \right) = \gamma_0 + \beta Con_{it} + \rho_t + \varepsilon_{it} \tag{2}$$

3.2. Variable Description

The level of regional innovation in this article mainly refers to the level of technological innovation. Technological innovation output can directly measure the final technological innovation results of a region. This article also uses innovation output as an indicator to measure regional innovation. At present, the types of patent in China can be divided into three types: invention type, practical type, and design type. Since we study the level of innovation, we select invention type patents and practical type patents that are more closely related to regional innovation levels. Focus on the situation of invention patents. Patent application data and obtained data mainly come from the statistical data of the CRSN database.

The core explanatory variable of this article is "before and after the opening of the HSR station". Pay attention to the following points: First, the research on HSR mainly includes two aspects: "HSR construction" and "HSR opening". The flow of innovation factors and its impact on regional innovation activities, which in turn bring changes in regional innovation levels, so this article focuses on the "HSR opening". Secondly, for a certain city, the opening of HSR may include two states of "passing" and "stopping". This article focuses on "stopping". Therefore, this article focuses on whether to set up a station in the prefecture-level city after the opening of the HSR. Thirdly, as some prefecture-level cities have successively opened multiple HSRs, we will use the earliest year when the HSR station was established as the date when the city's HSR station was opened. The HSR station opening data mainly comes from the CRSN database's HSR station opening time database, and the auxiliary information comes from China's HSR operation map and the HSR network for related supplements.

In order to test the robustness of the results and further eliminate the endogenous nature, we borrowed from other scholars' studies to use the tool variables of whether the city passed by the railway in 1949 (Dong et al., 2018). The data come from the official website of the Ministry of Railways, Wikipedia, and "History of China Railway Development" books.

Existing studies have shown that differences in economic development level, industrial structure, and population density are the main reasons affecting the differences in urban economic transformation (Fang et al., 2016). This article selects the per capita GDP to control the level of regional economic development; the proportion of secondary and tertiary industries in the GDP to control the industrial structure differences between regions; the number of students in ordinary colleges and universities to control the regional human capital level differences; the using of foreign capital to control regional external Differences in the level of openness; the expenditure on scientific and technological by local finances to control policy support for innovation activities in different regions; and regional population density to control regional natural geographic population differences. The data are mainly from the "China City Statistical Yearbook" from 2001 to 2018 (Table 1).

Table 1. Main variables.

Variable category	Variable sits	Variable definition
Explained variables	ainva	The number of invention patents filed in the current year
	ginva	The number of invention patents granted in the current year
	aiu	The sum of the invention patents and utility patents filed in the year
	giu	The sum of the invention patents and utility patents obtained in the year
Explaining variables	treat	The year after the opening of the HSR station is treats 1, and the year before the opening of the HSR station is the year of the storts 0
Group variables	divide	Divided into East, Central, West
Tool variables	periodb	In 1949, if the city had set up a railway station, period b = 1;
	sitenum	The number of HSR station
Control variables	pgdp	per capita GDP
	secience	Expenditure on local financial science and business expenses
	sec	Secondary sector as a share of GDP
	thi	Tertiary industry as a share of GDP
	pd	Region Population Density
	Fc	Amount of foreign capital actually used in the current year
	hstudent	The number of students enrolled in general higher education institutions
Mediation variables	inv	Total fixed asset investment
	telephone	The number of mobile phone ownerships

4. Analysis of Empirical Results

4.1. Descriptive Statistical Results

As shown in Table 2, it can be seen that the standard error of the number of invention patent applications and acquisitions as explained variables is large, indicating that there are large differences between regions, and the necessity of investigating problems. At the same time, there is a large difference between the number of patent applications and the number of patent acquisitions. The number of applications is about 2 - 3 times the number of acquisitions, indicating that some patent applications cannot be converted into innovative output, so the number of patent acquisitions is also representative. There are large differences between the control variables, mainly due to the effects of time and regional differences. On the one hand, the selected control variables are representative, and on the other hand, the effects of time effects need to be strictly controlled in our model.

4.2. PSM Results

The estimated propensity score in this paper is mainly through the Logitech model. By comparing the matching results of several close matching methods, the kernel matching that is more suitable for the characteristics of this data is selected.

As can be seen from Figure 1, the feature variables have large deviations before matching, which are generally in the range of 20 - 50, and the standard error after matching is greatly reduced, which is generally near 0.

The reliability of the propensity matching score (PSM) mainly depends on whether the "independence conditions" of the samples can be met (Table 3). There is no significant difference in the observable variables between the

Table 2. Variable descriptive statistics.

Variable	Mean	Min	Max	Sd
ainva	1150	0	95,527	4610
ginva	321.8	0	46,061	1601
aiu	2507	0	149,525	8555
giu	1488	0	92,001	4926
pgdp	29,589	13	215,488	26,156
secience	44,916	0	4,035,240	201,064
sec	47.80	5.55	90.97	11.30
thi	36.94	8.50	583	13.38
Pd	474.4	4.70	45,385	774.3
Fc	61,021	0	3,082,563	162,802
hstudent	68,906	0	1,067,335	134,845

Data from *China City Statistical Yearbook* and CRSN database.
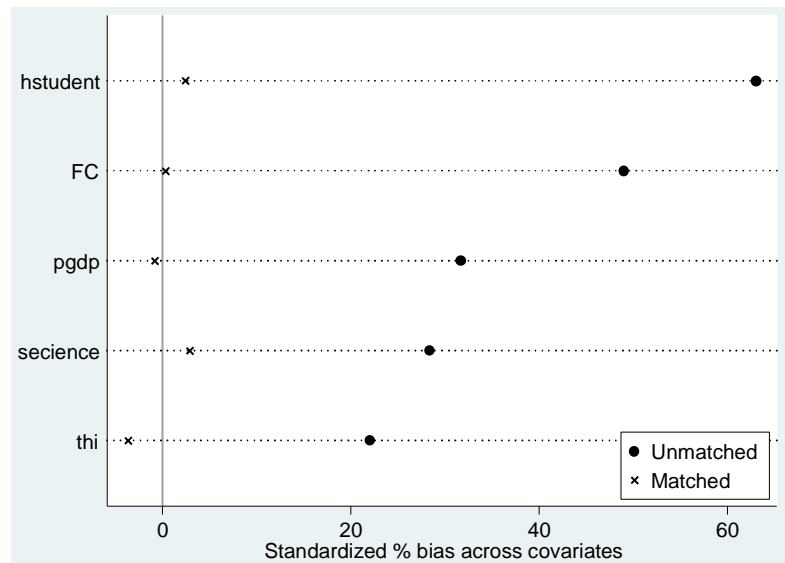
Figure 1. Standardized deviation chart of variables before and after matching.

Table 3. Variable balance table.

Variable	Unmatched matched	Average		Standard error	
		Experimental group	Control group	Standard deviation	Standard deviation reduced
pgdp	U	33,089	24,985	31.7	
	M	29,819	30,032	−0.8	97.4
secience	U	62,922	14,538	28.4	
	M	31,425	26,494	2.9	89.8
Thi	U	38.269	35.431	22.0	
	M	37.175	37.648	−3.7	83.3
FC	U	90,462	19,381	49.0	
	M	48,848	48,359	0.3	99.3
hstudent	U	10,005	26,183	63.0	
	M	62,376	59,410	3.4	96.2

Data from China City Statistical Yearbook.

experimental group and the control group after matching. Compared with before matching, the differences of the matched experimental group and control group has been greatly reduced，in per capita GDP (pgdp), the proportion of tertiary industry (thi), local fiscal science and education expenditure (secience), the actual amount of foreign capital used (FC), and the number of students in the college school (hstudent). The absolute values of the standard deviations of the matching variables are significantly less than 10. According to Rosenbaum & Rubin (1983), when the absolute value of the standard deviation of the matching variables is greater than 20, the matching effect is not ideal, so it can be seen that the matching effect of this article is more ideal.

4.3. Regression Results

As can be seen from Table 4, columns (1) and (2) use the number of patent applications as explained variables. In order to verify the robustness of the preliminary test results, columns (3) and (4) list the number of invention and utility model patent applications as Explained variables. The number of invention patent applications in the columns (5) and (6) of the table is used as the explained variables. From the significance of the regression results, they are all related at a significant level of 5%, indicating that the opening of HSR stations has a significant impact on the development of patent activities; from the sign of the coefficients, they all show positive effects and have certain stability. From this, it can be concluded that the opening of the HSR station has a significant impact on the level of regional innovation, and has a positive promoting effect.

Table 4. Impact of HSR station opening on regional innovation levels after PSM.

	(1)	(2)	(3)	(4)	(5)	(6)
	Aiud	aiud	aiu	aiu	ainva	ainva
the treat	2989.136	1327.960	2264.639	967.677	1011.141	374.303
	(4.08)	(3.23)	(4.47)	(3.65)	(3.96)	(2.70)
	(8.56)	(−0.57)	(8.65)	(−0.41)	(8.01)	(−0.87)
pgdp		0.056		0.042		0.021
		(2.24)		(2.28)		(2.17)
secience		0.035		0.028		0.014
		(4.16)		(4.11)		(4.38)
Thi		1.007		0.201		−0.284
		(0.79)		(0.22)		(-0.52)
Sec		−71.587		−46.688		−14.627
		(−3.39)		(−3.04)		(−1.74)
Pd		−0.004		−0.002		0.004
		(−0.16)		(−0.16)		(0.40)
Fc		0.017		0.011		0.005
		(2.42)		(2.11)		(2.02)
hstudent		0.006		0.007		0.004
		(1.63)		(2.67)		(2.30)
_cons	141.862	2504.861	54.001	1526.846	−19.528	354.563
	(0.55)	(3.32)	(0.28)	(2.80)	(−0.19)	(1.27)
FIX	YES	YES	YES	YES	YES	YES
N	3997	3896	3997	3896	3997	3896
r2_a	0.213	0.676	0.218	0.695	0.182	0.671
F	8.028	21.354	8.025	26.800	6.930	32.714

t statistics in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Data from *China City Statistical Yearbook* and CRSN database.

4.4. Heterogeneity Analysis

Due to the significant differences in the characteristics of cities in different regions, the basic environment for innovation activities is also quite different, and the utilization efficiency of factor agglomeration is also different. Therefore, testing by region can better deviate from the deviation caused by the average effect, and recognize the HSR stations opening has specific effects on regional innovation activities with different characteristics. Many scholars have used Chinese examples to find that transport infrastructure has different effects on the economy of different regions in China，and some scholars have directly studied the heterogeneous impact of regional innovation activities, such as Couture et al. (2018), Chen & Hayne (2017), and Bian Yuanchao et al. (2019). In this paper, we choose the traditional economic geography classification method, and divide all prefecture-level cities into three groups: eastern, central, and western, and perform double-difference within the group, which is representative. In view of the fact that there was a certain bias in the impact that year, the first-order lag variable of this variable was selected as our main explanatory variable.

As shown in Table 5, columns (1) and (4) are the regression estimation results for the eastern region, columns (2) and (5) are the estimation results for the central region, and columns (3) and (6) are listed as estimated results for western

Table 5. The impact of HSR station opening in different cities.

	ainva			aiu		
	Eastern	Central	Western	Eastern	Central	Western
L.treat	643.891	−25.325	849.797	1955.806	92.547	950.372
	(2.42)	(−0.26)	(2.43)	(3.61)	(0.62)	(2.44)
Pgdp	0.054	−0.006	0.006	0.099	−0.008	0.006
	(2.64)	(−2.27)	(1.05)	(2.69)	(−1.92)	(0.85)
secience	0.013	0.020	0.012	0.024	0.031	0.027
	(4.30)	(4.31)	(2.39)	(4.04)	(5.18)	(3.81)
Thi	−0.734	−10.819	−1.787	−0.707	−18.346	−3.315
	(−1.46)	(−1.34)	(−0.22)	(−0.61)	(−1.57)	(−0.31)
Sec	−40.236	−3.078	4.203	−75.544	−7.263	0.940
	(−1.91)	(−0.54)	(0.56)	(−1.97)	(−0.82)	(0.09)
Pd	−0.058	−0.824	0.002	−0.160	−1.787	−0.001
	(−0.64)	(−1.67)	(0.66)	(−1.07)	(−2.03)	(−0.33)
Fc	0.005	0.007	−0.006	0.013	0.012	−0.006
	(2.01)	(2.52)	(−1.39)	(2.25)	(3.17)	(−1.29)
hstudent	0.005	−0.001	0.008	0.013	0.001	0.012
	(1.44)	(−0.41)	(2.67)	(1.74)	(0.83)	(4.14)
_cons	966.526	836.264	−185.465	1932.392	1661.752	−5.247
	(1.35)	(1.66)	(−0.36)	(1.26)	(2.07)	(−0.01)
FIX	YES	YES	YES	YES	YES	YES
N	1443	1603	850	1443	1603	850
r2_a	0.721	0.635	0.534	0.740	0.752	0.708
F	34.844	30.010	15.818	27.426	34.904	51.386

t statistics in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Data from *China City Statistical Yearbook* and CRSN database.

regions. According to the estimation results by region, for the eastern and western regions, the opening of HSR stations has significantly promoted their regional innovation activities. That is, compared with those cities that do not have HSR stations, cities with HSR stations have higher The level of technological innovation; for the central region, the opening of HSR stations has no obvious impact on the level of regional innovation, and even a slight negative effect appears from the number of invention patent applications. The eastern region has a more favorable environment for innovation. The opening of the HSR has further strengthened the region's innovation advantages, attracting a large number of high-quality innovation resources, and it has also promoted the flow of internal production factors, which are conducive to promoting scientific and technological innovation in the region carry out. For the western region, the impact of HSR stations opening on the number of regional patents is significant at the level of 10%. The opening of HSR stations can help to further optimize its regional innovation environment and promote exchanges and interactions among innovation subjects. The innovation environment is weak, and the factor flow brought by the opening of HSR stations cannot be used to the maximum. For the central region, it lacks the excellent innovation environment in the eastern region and the strong policy support in the western region. On the contrary, the opening of the HSR has further enhanced the possibility of losing its innovative talents and capital. Later, it was able to more conveniently flow to developed areas, triggering "peacock flying southeast", which led to the continuous deterioration of the innovation environment and the reduction of innovation production levels in these areas.

4.5. Robustness Analysis

In order to further reduce the bias of endogenous estimation caused by this two-way causality, we will use the following three methods to further test the robustness of the results:

1) Using new explanatory variables. In this paper, we select the number of HSR stations in each country as the new explanatory variable for regression estimation. The estimation results are shown in Table 6.

2) Using new interpreted variable. In this article, we select the number of patents obtained by a prefecture-level city in year t as the new explanatory variable for regression estimation. Because there is a time difference of about one year from the patent application to the acquisition, so we choose the third order of the HSR station opening. The estimated results are shown in Table 6.

3) Using instrument variables. Regarding the selection of instrumental variables, this paper chooses whether or not the prefecture-level cities are railway instrument cities in 1949 as the instrumental variables (periodb). The basis is as follows: First, there were railways near the city in 1949, indicating that the region is suitable for geographical setting Railway stations can indirectly reflect the cost of setting up HSR station. Therefore, whether a city along the railway line is related to the establishment of HSR station in 1949. Second, whether or not a city

Table 6. Impact robustness test.

	(1)	(2)	(3)	(4)	(5)
	ainva	aiu	aiud	ginva	giu
Sitenum	182.452	454.116	578.930		
	(4.35)	(4.25)	(3.87)		
Pgdp	0.050	0.088	0.115	0.012	0.057
	(2.53)	(2.49)	(2.43)	(2.07)	(2.53)
secience	0.012	0.024	0.030	0.004	0.013
	(4.50)	(4.25)	(4.25)	(6.38)	(3.70)
Thi	−0.555	−0.304	−0.092	−0.275	−0.428
	(−1.14)	(−0.28)	(−0.06)	(−2.11)	(−0.60)
Sec	−45.940	−92.692	−126.936	−13.830	−56.085
	(−2.08)	(−2.29)	(−2.33)	(−1.56)	(−1.93)
Pd	−0.048	−0.139	−0.237	0.273	−0.063
	(−0.53)	(−0.96)	(−1.15)	(0.88)	(−0.09)
Fc	0.006	0.014	0.023	0.002	0.008
	(2.06)	(2.31)	(2.85)	(1.21)	(1.81)
hstudent	0.004	0.012	0.010	0.002	0.011
	(1.35)	(1.73)	(1.13)	(2.06)	(1.79)
L3.treat				241.539	2224.575
				(3.35)	(3.97)
_cons	1275.833	2826.926	4143.844	232.461	1484.530
	(1.66)	(1.72)	(1.81)	(0.96)	(1.16)
FIX	YES	YES	YES	YES	YES
N	1443	1443	1443	1250	1250
r2_a	0.729	0.748	0.732	0.724	0.705
F	40.644	30.191	23.114	187.686	40.447

t statistics in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Data from *China City Statistical Yearbook* and CRSN database.

along the railway line in 1949 is similar to the natural geographical conditions formed in the long history of the region. It exists objectively, is not directly related to the current regional innovation activities and meets exogenous requirements. The estimated results are shown in Table 6.

As shown in Table 6: columns (1), (2), and (3) are the estimated results after the replacement of the new explanatory variable. From the regression coefficient of the new explanatory variable, the number of HSR stations and regional innovation level is significantly related, which play a positive role in promoting regional innovation activities. Columns (4) and (5) are the estimated results after changing the explanatory variables. The number of patents obtained actually reflects the situation of regional innovation output compared to the number of

patent applications, and it is more representative of the level of regional innovation. The regression coefficient is significantly correlated at the 5% level. The opening of HSR stations has a significant positive effect on the acquisition of regional inventions and practical patents. From the test results, the robustness of the foregoing conclusions is proved.

As shown in Table 7, column (1) is a regression of instrumental variables with the number of invention patent applications as the explanatory variable, and column (2) is a regression of the instrumental variables with the number of invention and practical patent applications as the explanatory variable. Column (3) is instrumental variable regression with the number of patent applications as the explanatory variable. This paper uses a two-step GMM estimation. From the regression coefficient, it is significantly correlated at the 5% level, and the results are robust.

Table 7. Tool variable robustness test.

	(1)	(2)	(3)
	ainva	aiu	aiud
the treat	7274.701	1.9e−04	3.5e$^{s.04}$
	(3.09)	(3.61)	(3.68)
pgdp	−0.025	−0.070	−0.136
	(−1.74)	(−2.10)	(−2.31)
secience	0.016	0.026	0.027
	(8.31)	(9.66)	(8.84)
thi	0.773	2.865	8.760
	(0.48)	(0.76)	(1.23)
sec	0.010	22.819	65.534
	(0.00)	(1.17)	(1.89)
Pd	−0.094	−0.190	−0.234
	(−1.02)	(−0.99)	(−0.87)
Fc	0.002	0.007	0.012
	(1.82)	(3.66)	(3.78)
hstudent	0.000	−0.002	−0.010
	(0.35)	(−0.78)	(−2.13)
_cons	−343.117	−1.6e−03	−3.8e−03
	(−1.06)	(−2.18)	(−2.82)
N	4109	4109	4109
r2_a	0.539	0.271	
F			

t statistics in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Instrumented: treat. Instruments: pgdp secience thi sec pd FC hstudent period.

5. Conclusion and Recommendation

5.1. Analysis of Conclusion

Based on the establishment of "HSR stations", this paper uses the collected panel data of 287 prefecture-level cities in China from 2000 to 2017, and uses the score tendency matching method to explore the effect of HSR station opening on regional innovation levels. Through the analysis and research of empirical results, we draw the following conclusions:

The opening of high-speed rail stations has a significant role in promoting regional innovation. At the same time, due to the special nature of innovation activities, the cycle is long and the output is slow. Therefore, it can be found that the impact of the opening of high-speed rail stations on innovation output has a certain lag. Through the robustness test, it has been further confirmed that it can promote the development of regional innovation activities.

Through the heterogeneity analysis of regional, the impact of the opening of HSR stations on regions with different geographical and economic locations is significantly different. For the eastern and western regions, cities with high-speed rail stations have higher levels of innovation than cities without high-speed rail; for the central region; the opening of HSR stations has little effect on regional innovation levels, that is, for the central region, the opening and operation of HSR stations cannot effectively promote the development of innovative activities. According to a simple analysis, the central region does not have the long-established innovation environment in the eastern region, nor the effective policy support environment in the western region. The construction of HSR stations not only did not bring in the innovation elements, but accelerated the outflow of innovation elements.

5.2. Policy Recommendation

For government departments, we should see the positive impact of HSR in promoting regional economic development, especially the level of regional innovation, and constantly improve the construction and development of HSR transportation networks. The construction of transportation infrastructure opens the door of non-HSR cities to the outside world, gains more regional innovation and development elements, and creates a good regional innovation and development environment. At the same time, based on the different impact of HSR on innovation development in different regions, the government should properly provide support policy to vulnerable regions that avoid the lack of innovative elements in the less developed regions such as the central region, thereby forming a pattern of coordinated regional innovation development.

For the eastern and western regions where HSR stations have been set up and opened that have a significant impact on themselves, the opportunity of HSR opening should be fully grasped to guide the development of cities, create market potential, provide an environment for innovation and entrepreneurship, and accelerate the implementation of talent introduction projects. Entering the city

enhances the overall innovation vitality and even economic vitality of the city, and at the same time effectively expands the radiation of the surrounding knowledge spillovers to drive the surrounding economic development. At the same time, the eastern region should guard against the excessive "siphon effect" of large cities.

For the central region, which has set up HSR stations but has not benefited greatly, it is necessary to constantly improve the conditions of its economic and social development, and strive to speed up the deep integration of HSR construction with the economic and social development environment of the region, and the opening of HSR may increase the risk of losing its high-quality resources, so these areas should continuously improve their comprehensive advantages. Creating a better innovation environment and increasing factor compensation to attract higher quality innovation elements. It should also be noted that attracting factor inflow is the main path of HSR site opening affecting regional innovation level, so we should also pay attention to the construction of a more robust factor flow mechanism, through tax incentives, policy support and other means to encourage high-quality innovation factor inflow.

For cities that have not yet opened HSR, on the one hand, it should continuously improve their comprehensive competitiveness of economic and social development, access to HSR investment. On the other hand, we need to further speed up its interconnection with HSR cities, through the creation of various forms of connectivity channels, such as highway passenger lines, to achieve seamless docking with HSR cities, accelerate integration into the HSR "innovation circle", promote the flow of talent, capital elements and knowledge overflow, so as to enhance the level of innovation.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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