Analysis of the Impact of the Opening of Wuhan-Guangzhou High-speed Rail on the Innovation Ability of Cities Along the Line based on Empirical Test

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Abstract

By the end of 2020, China's high-speed rail mileage ranked first in the world. Many studies have shown that transportation development plays an important role in urban economic growth, and innovation ability is one of the key factors for urban economic growth. This paper uses the number of patents to represent the innovation ability. Based on the panel data of the three cities along the line from 2000 to 2009, this paper uses multiple regression models to make predictions, and explores the impact of the opening of Wuhan-Guangzhou high-speed rail on the innovation abilities of cities along the line by comparing the difference between the actual value and the predicted value from 2010 to 2018. The main conclusion is that the opening of the Wuhan-Guangzhou high-speed rail has improved the innovation abilities of cities along the line to a certain extent, and this positive impact has a certain time lag.

Keywords-*high-speed rail; innovation ability; patent*

1. INTRODUCTION

At present, China's economy has entered a stage of steady development, and innovation is one of the most important factors to promote technological progress and economic development. At the same time, many studies have shown that traffic development is positively affecting the economic growth of cities.

The construction of transportation infrastructure plays an important role in promoting regional economic growth, rebuilding the internal structure of the region and strengthening the connections between cities in the region. In particular, the construction of transportation infrastructure can promote the diffusion of technologies, talents, and resources in big cities to smaller neighboring cities, and drive the development of small cities with their own economic development, thereby narrowing the development gap between cities in the region. The opening of the Beijing-Tianjin Intercity Railway in 2008 marked the rapid development of China's high-speed railways. Large-scale high-speed railway construction has provided relevant data and information for studying the relationship between transportation infrastructure and regional spatial structure. As of the end of 2020, China's high-speed rail operating mileage has reached 38,000 kilometers, becoming the country with the longest high-speed rail operating mileage, the largest network scale, and the highest transportation density in the world. The rapid development of high-speed railways has not only greatly changed people's values and travel methods, but will also change the traditional transportation structure, promote the development of other transportation industries, and reconstruct China's urban and regional spatial pattern.

In recent years, China has actively encouraged the development of high-tech industries, and national development needs to rely more on innovation and technological progress. In terms of investment in innovation, China's R&D expenditure in 2018 was 19,957 billion yuan, an increase of 11.6% over 2017, which has exceeded the level of many developed countries. The huge investment has paid off. In terms of innovation output, China’s number of invention patent applications in 2017 was 1.382 million, ranking first in the world for 7 consecutive years, and the number of PCT patent applications received was 51,000, ranking second in the world. The number of patents represents the level of innovation to some extent. These patents have greatly promoted the development of related industries and promoted the stable and orderly development of China's economy.

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Technological innovation has high requirements for the construction of urban infrastructure. Cities with a high level of innovation in China are also cities with convenient transportation and relatively complete infrastructure. As an important link in China's strengthening of inter-city infrastructure construction, the opening of high-speed rail had a profound impact on urban innovation, but how big is the impact and what is the specific impact process? These issues have gradually attracted the attention of domestic scholars in recent years. This article has also studied and discussed these issues. By studying the impact of the opening of Wuhan-Guangzhou high-speed railway on the innovation ability of cities along the route, we can better understand the impact of high-speed rail on urban innovation, and help decision makers to choose high-speed railway lines and make better policies to promote the further development of cities based on the opening of high-speed railway.

2. LITERATURE REVIEW

In recent years, with the rapid development of high-speed rail, there have been more and more researches on high-speed rail. Since innovation ability determines the future development potential of a region, many domestic scholars have done relevant research on the impact of high-speed rail on regional innovation ability. This paper divides the relevant research into the following three categories.

Some scholars mainly explore the impact of the opening of high-speed rail on the city's innovation abilities. He, L.Y., and Tao, D.J. based on the theory of "face-to-face communication" of knowledge production, constructed an empirical model, and used the panel data of prefecture-level cities from 2003 to 2016 and the DID method for regression analysis [1]. Based on the panel data of 255 prefecture-level cities from 2002 to 2015, Guo, L.H., and Feng, T. used the DID model to study the impact of the opening of high-speed rail on regional technological innovation, and analyzed the heterogeneity from the perspectives of population size and marketization [2]. Lin, X.Y., and Li, M.Z. used the DID model to test the impact of high-speed rail on urban technological innovation based on the panel data of 27 prefecture-level and above cities in Guangdong-Guangxi region from 2007 to 2017 [3].

In addition to the impact of the opening of high-speed rail on urban innovation ability, the impact of the opening of high-speed rail on regional technological innovation spillover has also attracted the attention of many scholars. Bian, Y.C., Wu, L.H., and Bai, J.H. used data from 287 prefecture-level cities in China from 2004 to 2015 to empirically analyze the impact of high-speed rail on regional innovation and its gap. The study found that during the inspection period, the high-speed rail has significantly improved the level of regional innovation. The mechanism is mainly due to the flow of innovation factors triggered by the opening of the high-speed rail; the high-speed rail can have an important impact on the regional innovation gap. Compared with cities that have not yet opened high-speed rail, the continuous improvement of the innovation ability and innovation speed of high-speed rail cities can further widen the innovation gap between regions; and high-speed rail also has a significant time dynamic effect in the process of promoting regional innovation [4]. Yang, S.Y., and Li, Z. empirically analyzed the impact of the opening of high-speed rail on the spatial pattern of regional innovation and its mechanism. The study found that the opening of high-speed rail improves urban accessibility, strengthens the internal knowledge and technology spillovers of high-speed rail cities, drives the concentration of urban innovation elements, and has a profound impact on the spatial pattern of regional innovation [5].

Different cities have different resources, technologies, etc. Some scholars mainly study the impact of high-speed rail on the innovative abilities of different types of cities. Zheng, C.L., and Zhang, J.T. based on the panel data of 285 cities in China from 2007 to 2018, used invention patent applications and practical design patent applications to represent high-quality innovation and low-quality innovation. The PSM-DID method is used to study the impact of high-speed rail opening on the quality of urban innovation. Research has found that high-speed rail can accelerate the flow of innovation factors and optimize the innovation environment, thereby promoting the improvement of the quantity and quality of urban innovation; and this effect is based on city scale as the main factor, showing heterogeneity between cities. High-speed rail can significantly improve the overall innovation abilities of cities and enhance the innovation abilities of large and small cities [6]. Wang, C.Y., Meng, W.D., and Ling X.Y. used the PSM-DID method to investigate the changes in urban innovation output before and after the opening of the high-speed rail, and to identify the evolution characteristics of the regional innovation spatial pattern under the high-speed rail network [7].

3. RESEARCH DESIGN

3.1. Sample description

Considering the availability of data, this paper takes the relevant data of Wuhan, Changsha and Guangzhou from 2000 to 2018 as research samples to test the impact of Wuhan-Guangzhou high-speed railway on scientific and technological innovation in the three major cities. The relevant data come from the Statistical Yearbook of Chinese Cities over the years, the database of China Knowledge Network and the statistical bulletin of economic and social development of each city.

3.2. Variable definition

3.2.1. Interpreted variable

It is reliable to use patents to measure innovation. Although patents cannot represent all innovations, nor can they measure the importance of different technological innovations, patents are still an important measure commonly used by scholars to measure the level of innovation due to their consistency, objectivity, and availability. In China, the legal system related to patents is the same all over the country, and the patent data in different regions are comparable, so patents can represent the level of innovation to a certain extent. This paper measures the level of regional technological innovation by the number of patents granted by cities over the years.

3.2.2. Explanatory variable

The level of economic development, industrial structure, human capital environment, and government support will all have an impact on regional technological innovation. Based on the availability of data, this paper selects the following control variables: economic development level, measured by the value of per capita GDP of each city; Industrial structure is measured by the proportion of tertiary industry output value to regional GDP. The human capital environment is expressed by the number of college students per 10,000 people. The degree of government support is expressed by the proportion of science and technology expenditure to local general public budget expenditure.

3.3. Model design

In this paper, the impact of the opening of Wuhan-Guangzhou high-speed railway on the innovation ability of cities along the route is transformed into the difference between the predicted value and the actual value, which is taken as the main index of the influence degree, mainly because it is difficult to obtain the relevant data reflecting the innovation ability. Assuming that the high-speed railway in the city is not opened, the predicted value is obtained according to previous years' data. The multiple regression model is selected as the prediction model, and the *Innovation* in the model is set as the number of patents granted under the assumption that the high-speed railway is not opened. The prediction model is as follows:

$$Innovation_t = \alpha_0 + \alpha_1 X_1 + \alpha_2 X_2 + \alpha_3 X_3 + \alpha_4 X_4 + \varepsilon_t \quad (1)$$

Innovation represents the amount of urban patent grants; variable X represents explanatory variables, X_1, X_2, X_3, and X_4 represent factors such as economic development level, industrial structure, human capital environment, government support etc. α represents the impact of explanatory variables on urban technological innovation, and the larger the α, the greater the influence of this explanatory variable on the city's innovation ability. ε_t is a random error term, including other factors that affect the city's technological innovation ability.

Since the high-speed railway was opened at the end of 2009, it has little impact on the data of 2009. This paper selects the patent data from 2000 to 2009 to forecast.

4. EMPIRICAL TEST

4.1. Variable description

The actual number of patents granted in the three major cities from 2010 to 2018 is shown in Table 1. It can be seen that the number of patents granted in the three major cities has increased rapidly in recent years, reflecting the continuous improvement of the innovation abilities of the three major cities. The number of patents granted in Guangzhou in 2018 is much higher than that in Wuhan and Changsha. The number of patents granted in Guangzhou is about three times that of Wuhan and four times that of Changsha, reflecting the strong innovation ability of Guangzhou.

TABLE 1. THE ACTUAL NUMBER OF PATENTS GRANTED IN THE THREE MAJOR CITIES FROM 2010 TO 2018

years \ city	Wuhan	Changsha	Guangzhou
2010	10165	6209	15091
2011	11588	6692	18346
2012	13698	10382	21997
2013	15901	10362	26156
2014	16335	11448	28137
2015	21740	14633	39834
2016	22967	14960	48313
2017	25528	17170	60201
2018	32397	21188	89826

The per capita GDP of a region can reflect the local economic development level. The per capita GDP of Wuhan and Changsha has a similar trend in recent 20 years, while the economic level of Guangzhou is

relatively high in 2000, with per capita GDP more than twice that of Wuhan and Guangzhou, and it has been continuously improved since then. In 2018, the per capita GDP of Guangzhou reached nearly 230,000 yuan, which exceeded the per capita GDP of Wuhan and Changsha by nearly half.

4.2. Regression result analysis

Regression is carried out through Eviews software, and the relevant data is substituted. The final construction results of the three city prediction models are:

Wuhan: $Innovation_1 = 0.16X_1 - 11762.05X_2 - 0.85X_3 + 12618.77X_4 + 4270.43$ (2)

Changsha: $Innovation_2 = 0.12X_1 + 5109.63X_2 - 3.64X_3 - 48603.61X_4 - 642.30$ (3)

Guangzhou: $Innovation_3 = 0.04X_1 - 846.80X_2 + 5.60X_3 + 113921.9X_4 - 1657.94$ (4)

According to the test, the R^2 of the final regression results of the three models are all greater than 0.9, and the goodness of fit meets the requirements, so the result is valid.

Table 2 shows the forecast of the amount of patents granted in the three major cities without being affected by the opening of the high-speed rail.

TABLE 2. THE FORECASTED AMOUNT OF PATENTS GRANTED IN THE THREE MAJOR CITIES FROM 2010 TO 2018 WITHOUT BEING AFFECTED BY THE OPENING OF HIGH-SPEED RAIL

years \ city	Wuhan	Changsha	Guangzhou
2010	8130	5112	12770
2011	10892	6730	12251
2012	13524	8118	15210
2013	15633	8986	16312
2014	17604	10258	16966
2015	18975	11431	18938
2016	20934	12358	19708
2017	17784	13343	22175
2018	19421	15408	20788

4.3. Result analysis

The predicted value and actual value of the amount of patents granted in Wuhan are shown in Figure 1. It can be seen that from the opening of the Wuhan-Guangzhou high-speed rail at the end of 2009 to 2015, there was no significant gap between the actual number of patents granted in Wuhan and the predicted value. From 2016, there was a significant gap between the actual value and the predicted value. The actual value was about 67% higher than the predicted value in 2018.

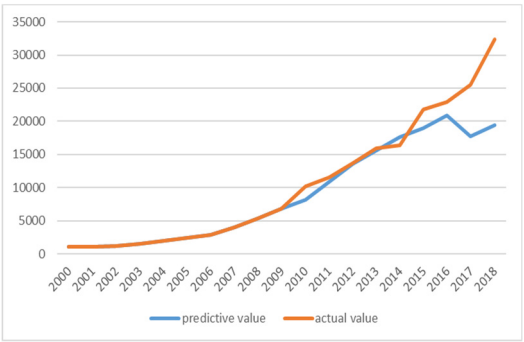

Figure 1. The predicted and actual values of the number of patents granted in Wuhan from 2000 to 2018

Figure 2 shows the predicted and actual values of patent grants in Changsha. It can be seen that after the opening of the Wuhan-Guangzhou high-speed rail at the end of 2009, the actual value was slightly higher than the predicted value. After 2012, the gap gradually increased, and the actual value in 2018 was about 38% higher than the predicted value.

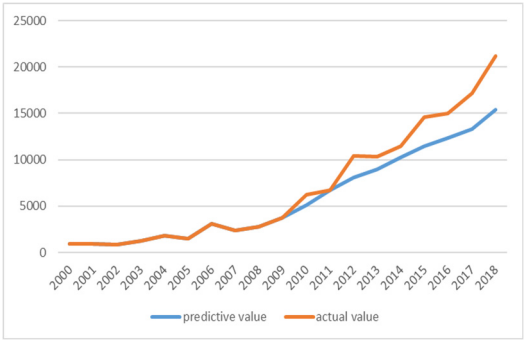

Figure 2. The predicted and actual values of the number of patents granted in Changsha from 2000 to 2018

The actual number of patents granted in Guangzhou and the predicted value are shown in Figure 3. It can be seen that after the opening of the Wuhan-Guangzhou high-speed rail at the end of 2009, the predicted value in 2010 was similar to the actual value. The actual value in 2011 was slightly higher than the predicted value. Since then, the actual value has continued to rise and the gap has gradually increased. The actual value in 2018 was much higher than the predicted value.

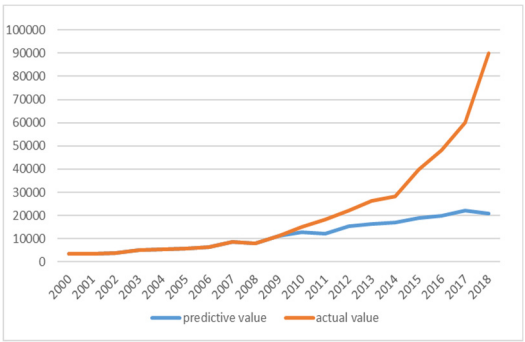

Figure 3. The predicted and actual values of the number of patents granted in Guangzhou from 2000 to 2018

5. CONCLUSION AND SUGGESTION

5.1. Conclusion

The opening of the Wuhan-Guangzhou high-speed rail has affected the innovation abilities of Wuhan, Changsha, and Guangzhou, and this impact is positive. Among the three cities, the high-speed rail has the greatest impact on Guangzhou's innovation ability. This article believes that it may be related to Guangzhou's relatively developed economy and more import and export trade. The empirical results in the fourth part show that there may be a certain time lag in the impact of high-speed rail on the city's innovation ability, that is, it takes a certain amount of time from the opening of the high-speed rail to the improvement of the city's innovation ability.

This article selects three economically developed capital cities, so the results may not be applicable to other small and medium-sized cities. When predicting innovation ability, in addition to considering factors such as economic development level, industrial structure, human capital environment, and government support, other influencing factors are not considered, which may have a greater impact on the results. In real life, factors such as the urban environment, related policies, and degree of openness may have a large impact on the city's innovation ability.

5.2. Suggestion

5.2.1. Promote market-oriented construction

Cities that have opened high-speed rail should actively promote market-oriented construction, improve the protection system for technological innovation achievements, encourage innovation entities (enterprises, individuals) to actively participate in innovation activities, and attract more innovation resources.

5.2.2. Promote the construction of high-speed rail

Let more cities enter the high-speed rail network, and use transportation location advantages to promote the exchange of scientific and technological human capital in the region. The flow of innovation-related knowledge can realize the effective allocation of innovative production factors, thereby reducing the risk of innovative activities in the city, improving the city's internal technological innovation environment, and increasing the city's technological innovation level through a reasonable increase in innovation input. Make full use of the spatial location advantages and talent accumulation dividends brought about by the opening of the high-speed rail, accelerate the integration of high-speed rail construction and regional economic development, promote the flow of resources and results sharing between various internal regions, and realize the cooperation between the corporate value chain and regional resources.

5.2.3. Promote the development of industries related to high-speed rail

According to the economic development level and resource endowment characteristics of different cities, the government should formulate differentiated policies. Focusing on the cultivation of characteristic industries and new growth points for the service industry in cities along the high-speed rail, through the development of high value-added service industries, the upgrading of the industrial structure will be promoted to achieve high-quality and coordinated economic development among regions.

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