

The impact of the opening of high-speed rail on the joint innovation of enterprises

- Evidence from listed companies

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Abstract. As a link for exchanges between cities, high-speed rail accelerates the flow of factors between different regions, obviously promotes joint innovation of enterprises. This paper uses the data of high-speed rail opening in various regions and the number of patents applied by listed companies from 2015 to 2019 to examine the impact of high-speed rail opening on the degree of joint innovation of enterprises through the least squares model (OLS), and it is found that the opening of high-speed rail has a significant role in promoting joint innovation of enterprises. At the same time, the mechanism analysis shows that the opening of high-speed rail mainly promotes the flow of highly educated talents and promotes joint innovation of enterprises. The heterogeneity test found that for different regions, different urban agglomerations, and enterprises with different innovation intensity, the impact of the opening of high-speed rail on joint innovation was different. This paper studies the relationship between specific forms of innovation and the opening of high-speed rail, pointing out that highly educated talents are an important production factor for joint innovation of enterprises, indicating that the rapid construction of high-speed rail has a significant role in promoting joint innovation of enterprises, and the promotion of high-speed rail for joint innovation is conducive to realizing the development strategy of ranking among the forefront of innovative countries in the 14th Five-Year Plan, and improving the efficiency of innovation and reform. Injected strong strength into the overall economic development.

Keywords: high-speed rail opening; joint innovation; talent mobility; Least squares; Innovation intensity.

1. Introduction and Literature Review

China's high-speed rail is gradually completing the transformation from four vertical and four horizontal to eight vertical and eight horizontal, and as of September 30, 2022, the operating mileage of China's high-speed rail has reached 410,000 km; The construction of high-speed rail has further weakened the barriers to resource flow between regions, reduced the communication costs between various industries and enterprises, increased the investment of enterprises in different places, and created faster and more convenient conditions for the flow of human capital. As an important production factor of innovation, the higher the circulation of human capital, the lower the cost of effective information transportation and dissemination, and the more conducive to local enterprise innovation and economic development. In particular, the 14th Five-Year Plan pointed out that science and technology and innovation are still China's development priorities, and China is expected to be among the top innovative countries in 2035. In China, industrial integration has become the current economic development trend; Interdisciplinary and compound talent training, the concept of government, industry, academia and research has also been continuously strengthened, which shows that the exchanges between industries are gradually deepening, the cooperation carried out is gradually increasing, and joint innovation is a part of various types of innovation that cannot be ignored. Chen Jing et al. (2019) [1] pointed out that enterprise innovation has strong externalities, and it is difficult for an enterprise to cover all the knowledge of an innovation at the same time, so external knowledge sharing and technology flow enterprise innovation are crucial. The opening of high-speed rail has accelerated the flow of factors in different regions, and the core element of enterprise innovation, human capital, has benefited from the opening of high-speed rail, and there are

more work choices and work opportunities under the profit-seeking nature, and the exchanges between parties in different industries have been deepened, which has gradually promoted the formation of industrial agglomeration. The number of joint innovations has increased significantly. As an important part of the national new development strategy plan, the impact of high-speed rail opening on joint innovation is a reference indicator to test the progress of the country becoming an innovative country in the 14th Five-Year Plan.

At present, most of the literature research on the impact between enterprise innovation and high-speed rail opening can be divided into the following aspects: First, the study of the impact of high-speed rail opening on enterprise innovation by affecting the flow of different innovation factors to elaborate, for the element of information, Ma Guangrong et al. (2020) pointed out that the opening of high-speed rail reduces enterprises and investment. Guo Jin and Bai Junhong (2019) pointed out that part of the knowledge needs to be better disseminated and understood through face-to-face communication, and the opening of high-speed rail makes this part of the information accelerate the spread with the flow of carriers, and this part of knowledge is just a necessary condition for enterprise innovation [2]; For the element of capital, Ma Guangrong et al. (2020) pointed out that because large cities have a larger market scale and industrial agglomeration, the opening of high-speed rail has reduced the obstacles to capital flow, reflecting the "siphon effect" [3]; For the labor force, Ji Yun and Yang Qing (2020) pointed out that the opening of high-speed rail promotes the circulation of employees with bachelor degree or above, and the circulation of technical employees to enterprises along the route is one of the important mechanisms for enhancing the innovation of enterprises along the route [4]; Second, from the perspective of research, the impact of the opening of high-speed rail on enterprise innovation can be divided into macro and micro; At the macro level, it mainly studies the economic impact of the opening of high-speed rail on the overall region of the region. Wang Yufei and other scholars (2021) pointed out that the opening of high-speed rail optimizes the allocation of resources between different regions, and non-central cities enjoy the convenience brought by knowledge spillover from central cities, and should strengthen collaborative innovation between cities and build an innovative spillover city system [5]. At the micro level, the research aspects include the number of enterprise innovations, capital market efficiency, corporate governance, corporate decision-making, etc., Yang Jinyu and Luo Yonggen (2019) pointed out that the opening of high-speed rail reduces the stickiness of enterprises' human capital units, and at the same time makes the flowing human capital achieve more significant self-improvement and innovation performance growth [6]. To sum up, on the relationship between high-speed rail opening and enterprise innovation, most of the current research focuses on the macro and micro economic, static and dynamic research of high-speed rail opening, but few articles have studied the way of innovation. To this end, this paper conducts research on the impact of high-speed rail opening on enterprise joint innovation.

The marginal contribution of this paper is mainly reflected in the discussion of innovation methods, whether joint innovation or independent innovation; In this context, joint innovation is defined as cooperation between companies, schools, institutes and institutes, and research institutes and institutes. After determining the specific definition of United Innovation, this paper collects more than 3,000 from 2015 to 2019 through the Smart Buds patent search platform. The patent applications of listed enterprises define two or more patent applications for inventors as joint innovation, and the impact of the opening of high-speed rail on joint innovation of enterprises is tested by ordinary least squares method. Based on the micro perspective of economic growth, it focuses on the growth of the number of joint innovation of enterprises, and enriches the literature on the specific innovation types of enterprise innovation caused by the opening of high-speed rail. At the same time, the opening of high-speed rail promotes enterprise innovation. There are also many transmission mechanisms, this paper mainly classifies the academic qualifications of employees in listed companies, and finds that the opening of high-speed rail promotes the proportion of talents with bachelor degree or above, thereby promoting the joint innovation of enterprises.

2. the theoretical mechanism and research hypothesis

Infrastructure construction has a vital role in economic growth, from China's first Beijing-Tianjin intercity opening, the construction of high-speed railway to the Central Plains as the core, carried out the strategic layout of the meter-shaped modern transportation network, with the Central Plains as the economic radiation center, and gradually provided rich capital and talents for tourism, manufacturing, high-tech industries, etc. in the surrounding areas, and promoted the local economic development. At the same time, Li Jianqiang and other scholars (2021) pointed out that the homogeneity of local products in industrial agglomeration is serious, and competition is becoming more and more fierce, so in order to study differentiated products, the company's sense of competition is enhanced, thereby promoting enterprise innovation [7]. Huang Kainan and Sun Guangzhao also pointed out that [8] the opening of high-speed rail has expanded the market space and sphere of influence, deepened exchanges with the industry in the areas where high-speed rail was opened, continuously learned advanced technology and management concepts, and improved their own innovation capabilities. Wang Guan (2020) [9] pointed out that the opening of high-speed rail reduces the cost of long-distance communication between enterprises, so that investment companies can inspect enterprises, and reduce the lack of information between the two sides. Reciprocity, so that investors are more willing to invest, thereby reducing the investment constraint of enterprises, capital as a key factor in enterprise innovation, after the reduction of financing constraints, the degree of innovation of enterprises has also been significantly improved. This article makes the following assumptions:

Hypothesis 1: The opening of high-speed rail has a promoting effect on joint innovation of enterprises.

Compared with other means of transportation, high-speed rail has the characteristics of speed, stability and punctuality. In Glaeser (1999) and Storper & Storper & Storper In the face-to-face theory proposed by Venables in 2004, research pointed out that knowledge can be divided into explicit knowledge and tacit knowledge, explicit knowledge has strong spillover, and is more accessible, generally speaking, knowledge and information that can be widely disseminated as a visible carrier. Tacit knowledge is non-coding knowledge that needs to be transmitted through human communication, and the new ideas and new ideas hidden behind are often the key elements of innovation, and high-frequency feedback between different ideas during face-to-face communication can be achieved, which plays a vital role in enterprise innovation. As the carrier of this non-encoded information, people have been more convenient and faster circulation through high-speed rail, which means that different knowledge has also been transmitted faster and communicated at a deeper level. Yang Jinyu, Luo Yonggen (2019) pointed out that the opening of high-speed rail has promoted the flow of human capital, especially inventors, to enterprises along the route, while increasing the quantity and quality of innovation. Human capital has a certain degree of profit-oriented, the opening of high-speed rail has broken the geographical barriers of high-tech talent flow, so that talents gather, industry agglomeration, further promote enterprise innovation, this paper puts forward the following hypothesis:

Hypothesis 2: The opening of high-speed rail is to promote joint innovation of enterprises by promoting the flow of highly educated talents.

Ma Guangrong, Cheng Xiaomeng, Yang Enyan (2020) pointed out that the opening of high-speed rail reduces the cost of capital flow, so that capital flows from small and medium-sized cities to large cities, and the phenomenon of agglomeration of large cities in eastern China is more obvious than in other regions. Through a series of institutional reforms such as the opening of household registration in major cities to other cities in recent years, the obstacles to the flow of human capital from institutional factors have been alleviated, and the opening of high-speed rail has broken the natural geographical factors, accelerating the development of large and medium-sized cities. At the same time, it brings about the loss of population in underdeveloped areas, central cities due to the overall market scale, industrial agglomeration phenomenon is obvious, production costs and other factors will be improved in such a large environment, and finally concluded that for large cities, the "siphon effect" is greater than the "spillover effect", and for small cities or underdeveloped areas, the

"spillover effect" is greater than the "siphon effect". Secondly, the opening of high-speed rail has also improved the imbalance between the eastern and western regions to a certain extent, and the eastern resources have a better circulation channel to the western region, and at the same time, the western region has also flowed to the eastern region to find more development opportunities, learn more advanced technologies and management methods, and promote the development of the region. This article makes the following assumptions:

Hypothesis 3: The opening of high-speed rail has different degrees of impact on the innovation of enterprises in different regions.

3. Data sources and econometric models

3.1 Data sources

The measure of enterprise innovation in this paper is the number of enterprise patent applications, and the number of patent applications comes from the smart bud patent search platform; The number of patent applications downloaded from 2015 to 2019 downloaded from the Wisdom Buds platform totaled 50661, and then the data was sorted and screened, the information of the inventor's location abroad or invalid was eliminated, and then the data was summed in groups. In order to ensure the matching of later data, duplicates were removed, and the data were shrunk to avoid the influence of outliers on subsequent further analysis. In further analysis, the collected variables are divided geographically, and the explanatory variables in this paper are whether the location of the patent-applied enterprise has high-speed rail access; The data on whether the company is located has opened high-speed rail comes from the national railway passenger train timetable disclosed by the Ministry of Railway Transport (12306 official website), and the data can be used to obtain the number of high-speed rail lines opened in each city. The control variables in this paper include return on total assets, high education of directors and supervisors, government subsidies, age of the enterprise, and shareholding ratio of the largest shareholder. These control variables are all from the Cathay Security Database (CSMAR).

3.2 Explanation of relevant data

Table1 Descriptive statistics

Variable	N	Mean	SD	Min	Max
Joint innovation	10223	7.82	138.50	0	7253
High-Speed Rail Opening (HSR).	10223	0.95	0.21	0	1
Return on Total Assets	10223	0.05	0.06	-1.39	0.39
Supervisor has a high degree of education	10223	3.23	1.72	0	7
Government subsidies (subsidy).	10223	2442	179	-91.14	5002
Enterprise age	10223	12.09	8.36	5	48.67
The largest shareholding ratio (RS).	10223	26.77	20.13	4.80	81.85

3.3 Econometric models

$$Y(\text{joint})=\gamma+\alpha\text{HSR}+\beta\text{cvit}+\varepsilon_{it} \quad (1)$$

Among them, γ , α , and β are all coefficients to be sought, HSR indicates whether the enterprise located city is open to high-speed rail, Y is the number of joint innovation of enterprises, and cvit represents the total return on assets of the company i in the t year, Directors and supervisors have high education, government subsidies, enterprise age, the shareholding ratio of the largest shareholder, and it ε indicates that the company i in t years of other disturbance items that may exist.

4. Empirical analysis

4.1 Basic regression

As can be seen from the second column of Table 2, the coefficient result between enterprise joint innovation and high-speed rail opening is 4.022, indicating that the number of enterprise joint innovation increased by 4.022 units from high-speed rail opening, and the result is significant. The opening of high-speed rail has promoted enterprise innovation. First of all, the opening of high-speed rail has improved the efficiency of cooperation between enterprises and reduced distance barriers. In the past, cooperation between enterprises was costly due to inconvenient transportation. The opening of high-speed rail can improve the efficiency of communication and cooperation between enterprises by reducing the distance. The materials and technologies required for joint innovation can be quickly exchanged and transported through high-speed rail, which can promote the interaction between enterprises, increase the opportunities for cooperation and collaborative innovation, and improve innovation efficiency and product quality. Secondly, the opening of high-speed rail has more advantages for innovative enterprises. Innovative enterprises need to continuously obtain new things and creative ideas in product innovation, and the opening of high-speed rail can provide enterprises with faster and more extensive access to global cutting-edge technology and market information, thereby providing better innovation conditions, accelerating the innovation process and improving innovation capabilities. Finally, the opening of high-speed rail can drive the coordinated development of regional economy. High-speed rail not only connects cities with surrounding areas. This can improve exchanges and cooperation in the region, promote interaction and technology transfer between enterprises in the region, form a greater innovation alliance, promote the adjustment and optimization of regional industrial structure, and promote regional economic development.

Table 2 Base regression results

variable	Joint innovation
High-speed rail opened	4.022*** (2.62)
Return on total assets	0.696 (0.10)
Supervisor has a high degree of education	1.151 (1.33)
Government subsidies	0.001*** (3.15)
Enterprise age	1.274*** (2.73)
The shareholding ratio of the largest shareholder	-0.444** (-2.21)
Constant	-6.829* (-1.90)
Observations	10,223
R-squared	0.039

Note: Standard error in parentheses below the coefficients, *, ** and represent significance levels of 10%, 5% and 1%, respectively, as shown in the table below.

4.2 Mechanism testing

Regarding the specific transmission through which the opening of high-speed rail promotes the joint innovation of enterprises, the following is a test of hypothesis 2, and it is also a mechanism test. Du Xingqiang and Peng Miaowei (2017) pointed out that the opening of high-speed rail has significantly promoted the flow of senior talents with doctoral degree or above in non-state-owned enterprises along the route [10], and the rapid flow of human capital has optimized the allocation of resources between different regions. Senior talents have broader choices and opportunities, and

information between industries is also disseminated and exchanged in the process of flow, which will also improve the efficiency of joint innovation and innovation of enterprises to a certain extent. Ji Yun and Yang Qing (2020) defined highly educated talents as bachelor degree or above, and the proportion of technical talents in the total number of employees is also one of the factors affecting enterprise innovation, the research results show that the opening of high-speed rail reduces the flow cost of highly educated talents and technical talents, and to a certain extent, it also increases the proportion of technical talents, making enterprises better innovation atmosphere and technical support. The above literature shows that the opening of high-speed rail has indeed promoted the increase of highly educated talents and technical talents of enterprises, Table 3 verifies the second part of mechanism transmission, and the innovation of enterprises is due to the increase of highly educated talents thereby increasing the joint innovation of enterprises. As can be seen from the second column of Table 3, the regression results are significant, and the increase in undergraduate degrees has increased the number of joint innovation of enterprises by 0.009 units, indicating that the flow of highly educated talents is indeed one of the reasons for the increase in joint innovation of enterprises.

Table3 Mechanism regression

variable	Bachelor's degree
Joint innovation	0.009* (1.77)
Return on total assets	-11.327** (-2.28)
Supervisor has a high degree of education	-0.006 (-0.03)
Government subsidies	-0.000*** (-5.38)
Enterprise age	-0.022 (-0.42)
The shareholding ratio of the largest shareholder	-0.017 (-0.85)
Constant	10.716*** (7.72)
Observations	5,437
R-squared	0.002

5. Further analysis

5.1 Testing for heterogeneity

In terms of heterogeneity analysis, we classify enterprises according to their regions, which are divided into north and south, east, central and western regions, and enterprises with high innovation intensity and low innovation according to the innovation intensity of enterprises. Strength enterprises were tested for heterogeneity for the above classifications. Among them, the strength of enterprise innovation intensity is specifically defined as: the number of innovation of enterprises and the number of quantiles above 75% of the sample number of innovations is defined as enterprises with high innovation intensity, and the following points of classification are explained

5.1.1 Impact on innovation between different regions

It can be seen from Table 4 that the opening of high-speed rail has a more significant effect on the promotion of enterprise innovation in the northern region. Here's why:

In recent years, the overall development speed of the north has slowed down, and the economic development rate is not as fast as that of the south, which has also prompted northern enterprises to improve their competitiveness through joint innovation. The economy of the southern region is relatively more developed, the competitive pressure between enterprises is greater, and at the same time, southern enterprises have more advantages in talents, capital and other aspects, and it is easier to achieve independent innovation; If northern enterprises want to achieve technological innovation, they must carry out joint innovation and share resources and talents.

The industrial structure of the northern region is relatively single, and most enterprises are concentrated in the traditional manufacturing field, which is difficult to carry out transformation and upgrading. The opening of high-speed rail has made the cities in the north form closer ties, which is conducive to exchanges and cooperation between different industries and promotes joint innovation between enterprises.

Table4 impact of the opening of high-speed rail on joint innovation in different regions

The variable name	Northern region Joint innovation	Southern region Joint innovation
High-speed rail opened	18.026*** (2.73)	-0.355 (-0.46)
Return on total assets	-13.458 (-0.92)	16.604*** (2.79)
Supervisor has a high degree of education	5.757** (2.26)	-0.881** (-2.40)
Government subsidies	0.002** (2.37)	0.001*** (3.36)
Enterprise age	3.852** (2.34)	0.274** (2.26)
The shareholding ratio of the largest shareholder	-1.387** (-1.98)	-0.067 (-1.39)
Constant	-33.714*** (-2.62)	3.000*** (3.10)
Observations	2,610	7,613
R-squared	0.047	0.117

5.1.2 Impact on the eastern, central and western regions

It can be seen from Table 5 that the opening of high-speed rail has the most significant impact on the joint innovation of enterprises in the eastern region, followed by the promotion of joint innovation of enterprises in the western region, and has no significant impact on the joint innovation of enterprises in the central region. First of all, the east has always been China's more economically developed area, compared with other regions, the eastern region is the first to start the construction of high-speed rail, so the eastern region is the first to obtain the convenience brought by the opening of high-speed rail, the continuous flow of human capital accelerates industrial agglomeration, in addition to its own economic development advantages, the opening of high-speed rail further promotes joint innovation of enterprises. The western region is mountainous, the construction of high-speed rail is more difficult, and the western region has a small population, so there are fewer high-speed rail lines opened, compared with the eastern and central regions, the western region is economically underdeveloped and the level of education is also there. After the implementation of the western development plan, after the opening of the high-speed rail, human capital in the eastern and central regions flowed to the west, and the economic development and education level of the western

region were improved, thus further promoting the joint innovation of local enterprises. As the center of China, the central region has unique development conditions, and in recent years, finance, logistics and tourism have become new highlights in the development of central China. The central region itself has a good development momentum and development conditions, and the terrain is flat, in the absence of high-speed rail, there are also complete road and railway infrastructure, the flow of personnel and capital on the opening of high-speed rail is not much dependent, so the impact of the opening of high-speed rail on the joint innovation of enterprises in the central region is not significant, but it is also an obvious positive effect, in the future, the central region will be better supported by the continuous improvement of high-speed rail lines.

Table 5 The impact of the opening of high-speed rail on the joint innovation of enterprises in different regions

The variable name	Eastern region Joint innovation	Central region Joint innovation	Western region Joint innovation
High-speed rail opened	4.512** (2.21)	2.349 (1.43)	2.030* (1.77)
Return on total assets	-2.812 (-0.33)	19.153 (1.30)	7.478 (0.47)
Supervisor has a high degree of education	1.683 (1.58)	-1.870 (-1.51)	-0.080 (-0.23)
Government subsidies	0.002*** (3.00)	0.001 (1.10)	0.000*** (3.60)
Enterprise age	1.502*** (2.63)	0.493 (1.15)	0.077 (0.42)
The shareholding ratio of the largest shareholder	-0.533** (-2.18)	-0.135 (-0.68)	0.088 (0.69)
Constant	-8.580* (-1.91)	2.914 (1.00)	-1.032 (-0.55)
Observations	8,286	1,201	746
R-squared	0.041	0.078	0.043

5.1.3 Impact on different urban agglomerations

As can be seen from Table 6, the impact of the opening of high-speed rail on the Yangtze River Delta is more obvious than that of the Pearl River Delta. First of all, Shanghai is an economic and financial center in the mainland, is the first choice for talent employment in related fields, and the financial industry in Shanghai is developing rapidly, a large amount of capital and a relatively open environment can promote the flow of talents, compared with the Yangtze River Delta, the talent attraction of the Pearl River Delta is slightly lower than that of the Yangtze River Delta; The point where the opening of high-speed rail has promoted the flow of talent is not very significant in the Pearl River Delta region. The main economic industry in the Pearl River Delta region is light industry and the production and assembly of high-tech products, since the establishment of the Shenzhen Special Economic Zone, a relatively complete industry cluster has been formed in the high-tech industry, and brands with a wide range of products like Midea have their own multi-faceted qualities and technologies for innovation, and in statistics, the number of independent innovation is greater than the number of joint innovation. Therefore, joint innovation is not obvious.

Table 6 The impact of the opening of high-speed rail on the joint innovation of enterprises in different urban agglomerations

	Yangtze River Delta region	Pearl River Delta region
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The variable name	Joint innovation	Joint innovation
High-speed rail opened	2.366*** (5.14)	0.546 (0.55)
Return on total assets	4.859 (1.20)	23.357* (1.89)
Supervisor has a high degree of education	-0.510*** (-3.44)	-1.533 (-1.33)
Government subsidies	0.000*** (2.73)	0.002*** (2.71)
Enterprise age	0.060* (1.68)	0.331 (1.30)
The shareholding ratio of the largest shareholder	0.029 (1.59)	-0.068 (-0.73)
Constant	0.148 (0.27)	2.738 (0.93)
Observations	3,428	2,466
R-squared	0.094	0.217

5.1.4 Impact on enterprises with different innovation intensity

It can be seen from Table 7 that the opening of high-speed rail has a more significant effect on the promotion of joint innovation of high-intensity innovative enterprises than that of low-innovation enterprises. First of all, the evaluation criterion of enterprise innovation intensity in this paper is defined as high-innovation enterprises in 75% of the number of joint innovation in the selected sample companies, such high-innovation intensity enterprises themselves have relatively strong capital, can support the development of innovation work, this type of innovation companies have a certain number of patents accumulated in the year of selecting the sample. In the patent research and development and related scientific research team quality and organization management experience is better than low innovation intensity enterprises, after the opening of high-speed rail is more conducive to such enterprises to find technical talents and reduce the information asymmetry between investors and enterprises, such high innovation intensity enterprises can receive more investment further investment in patent research and development, so the opening of high-speed rail is right Enterprises with high innovation intensity have a more significant role in promoting.

Table 7 The impact of high-speed rail opening on enterprises with different innovation intensity

The variable name	High innovation intensity enterprise	Low innovation intensity
	Joint innovation	Joint innovation
High-speed rail opened	21.211*** (2.76)	-0.041 (-1.16)
Return on total assets	-14.250 (-0.36)	0.076 (0.52)
Supervisor has a high	6.140* (1.78)	-0.025*** (-5.60)
Government subsidies	0.002*** (3.01)	0.000** (2.11)
Enterprise age	5.291*** (2.89)	-0.002** (-2.11)
The shareholding ratio of	-1.834**	0.002***

	(-2.42)	(3.66)
Constant	-29.541**	0.463***
	(-2.18)	(11.69)
Observations	2,333	7,890
R-squared	0.058	0.007

5.2 Robustness test

In the robustness test section, this article tests whether the experimental model is robust by replacing the host variables. This paper selects the number of patents of each company to measure the degree of joint innovation of enterprises, patents can be divided into three categories: new utility patents, invention patents and design patents, of which invention patents can be divided into application for invention and authorized invention, these two patentsThe application is difficult and has high requirements for the innovation ability of enterprises, so the invention patent is selected to replace the main variable, and the results show that the model is still robust, even if only the invention patent is examined, the opening of the high-speed rail still has a significant impact on the number of joint innovation invention patent applications of enterprises.

Table5 Robustness Check

The variable name	Invention application	Authorized inventions
	Joint innovation	Joint innovation
High-speed rail opened	10.573*** (3.17)	5.957*** (2.67)
Return on total assets	46.612** (2.57)	17.949** (2.03)
Supervisor has a high degree of	1.583 (0.96)	1.138 (1.26)
Government subsidies	0.004*** (3.60)	0.002*** (3.63)
Enterprise age	3.046*** (4.05)	1.836*** (3.88)
The shareholding ratio of the	-1.111*** (-3.50)	-0.635*** (-3.17)
Constant	-10.609* (-1.78)	-5.402 (-1.44)
Observations	1,994	1,460
R-squared	0.100	0.079

5.3 Endogenous testing

Considering that the opening of high-speed rail has a great relationship with the flatness of the region, in order to solve the endogenous problem of high-speed rail opening, this paper selects altitude as a tool variable, and obtains the following results. Whether the area opens high-speed rail depends on the geographical location and economic development of the region, the higher the terrain of the area, the higher the altitude, the greater the difficulty of opening high-speed rail, but the altitude has nothing to do with the innovation of enterprises, so this paper selects altitude as a tool variable, as can be seen from Table 9, whether high-speed rail is opened and altitude shows an obvious negative

correlation, altitude increase by 1 unit, The possibility of the opening of high-speed rail is reduced by 43.857 units.

Table6 Endogenous tests

The variable name	elevation	Joint innovation
High-speed rail opened	-43.857*** (-3.29)	109.370* (1.79)
Return on total assets	-109.064*** (-4.08)	0.907 (0.12)
Supervisor has a high degree of education	-1.699* (-1.69)	1.199 (1.35)
Government subsidies	-0.000 (-0.86)	0.001*** (3.15)
Enterprise age	0.299 (1.27)	1.283*** (2.72)
The shareholding ratio of the largest shareholder	-0.158 (-1.59)	-0.452** (-2.19)
Constant	131.609*** (9.14)	-108.796* (-1.79)
Observations	10,223	10,223
R-squared	0.005	0.021

6. Conclusions and Recommendations

Based on the research on the impact of high-speed rail opening on enterprise joint innovation, this paper uses the least squares method to explore the impact between the two, verifies that the opening of high-speed rail does promote joint innovation of enterprises, and the mechanism test part, through the number of enterprises with bachelor degree or above screened out by the employee details in the sample, concludes that the opening of high-speed rail promotes the flow of talents with bachelor's degree and thus promotes joint innovation of enterprises. In the heterogeneity analysis part, the impact of high-speed rail opening on different regions is analyzed, and it is pointed out that the impact of high-speed rail opening on enterprises with high innovation intensity in the northern, eastern regions, Yangtze River Delta regions and high innovation intensity is more significant. In the robustness test part, the robustness test was carried out with the number of invention applications and authorized invention patents by substituting with the core explanatory variables, and the robustness of the model was confirmed. Finally, the tool variables are used to solve the endogenous problems in the model. Based on the above conclusions, the following recommendations are made:

1. The construction of high-speed rail accelerates the flow of factors, optimizes the allocation of resources, and has an obvious role in joint innovation of enterprises, and China should continue to improve the construction of high-speed rail network to provide a strong guarantee for high-speed economic development in infrastructure construction.

2. High-skill, high-educated human capital is an important innovation element, the opening of high-speed rail optimizes the allocation of human capital, accelerates the flow of highly educated labor talents, reduces the cost of enterprise investment and exchange, and further promotes enterprise innovation. The cultivation of highly educated talents can also be carried out through policy support, school-enterprise cooperation, etc., and college students will be cultivated into high-quality comprehensive talents through school-enterprise cooperation and other exchange methods, so as to realize the docking with enterprises as soon as possible and promote innovation.

3. The opening of high-speed rail reduces the cost of long-distance communication between enterprises and the degree of information asymmetry between investors and parties, promotes the

increase of long-distance investment of enterprises, and according to knowledge spillover, enterprises with low innovation intensity can continue to conduct external exchanges, obtain information on all aspects of innovation, attract investment, integrate resources, and empower their own development.

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