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A GIS-based Study of The Impact of HSR Network Distribution on Firms' Total Factor Productivity: Evidence from Listed Manufacturing Firms in China

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Abstract: - With the rapid development of the economy, enterprises are increasingly pursuing efficient division of labor and communication, and in order to achieve high-quality economic growth and sustainable development, high speed rail (HSR) has been born. Therefore, the study of the impact of HSR accessibility on the total factor productivity (TFP) of enterprises has become a hot topic of research in today's academia. In this paper, firstly, based on GIS network analysis, the routes and stations after opening are matched with the locations of enterprises to describe the spatial correlation between HSR and the locations of enterprises as well as the distribution of HSR among enterprises; secondly, a multi-period difference-in-difference model (DID) is utilized to study the impact of HSR opening on TFP of enterprises on the basis of the data of China's listed manufacturing enterprises in the period of 2000-2017; and The PSM-DID model to test the robustness of the empirical results; finally, the path of the impact of HSR on the TFP is explored. The empirical results are as follows: (1) The distribution of HSR and the location of listed enterprises are highly correlated in terms of geographic distribution information; (2) HSR has a significant impact on the TFP, and the impact effect is different in different periods; (3) HSR mainly affects the TFP of enterprises by using the innovative behavior of enterprises and industrial agglomeration as the mediating variables.

Keywords: HSR, TFP, Industrial Agglomeration, Enterprise Innovation, GIS.

I. INTRODUCTION

Since the reform and opening up, China's economy has achieved high economic growth for more than 40 years, with a high savings rate, a high return on capital, and an adequate supply of labor as the main window of opportunity. However, since 2010, the population of working age has turned to a negative growth rate, the population dependency ratio has increased, the traditional labor-population dividend has disappeared, the crude economic development model driven by production factors is unsustainable, and the economic growth rate is starting to slow. In this regard, when the economy can no longer rely on cheap labor or natural endowments of resources and energy to achieve economic growth, China's economy will inevitably have to improve TFP as the main path to medium-to-high growth and the next stage of development [1]. The essence of TFP is a way to help allocate resources [2]. At the same time, New Geographic Economics points out that good transportation infrastructure helps the flow of labor and other production factors, which can not only promote the development of related industries through the multiplier effect of "fixed asset investment", but also promote economic growth [3-4]. Compared with the traditional railway mode, the emergence HSR is undoubtedly a transformation of transportation. Its advantage lies in the more efficient circulation of factors. Although the advantages of HSR are obvious, there are not many countries that actually build it, which is mainly limited by the high technicality, high construction cost and operation and maintenance cost of HSR. By the end of 2019, China's HSR mileage has reached 35,000 kilometers, both ranked first in the world. Therefore, China has become the best research object to study the relationship between HSR and TFP. If production factors, such as labor and capital, can be rapidly transferred within different economic regions of China, and if the dynamic transfer process is accompanied by the emergence of knowledge and technological innovation, TFP can grow on the basis of the opening of HSR, thereby realizing high-quality economic development.

Based on the above reasons, the main questions that this paper tries to clarify are: (1) in the critical period of economic development transformation, from the dual perspectives of theory and empirical evidence, can we test whether HSR can improve TFP? (2) With the gradual improvement of the HSR network, will the influential relationship between HSR and TFP change? If the answer is yes, how does it evolve? (3) Is there an intermediate variable that promotes the high-quality development of China's economy in the process of changing the path of HSR and TFP? The main innovation of this paper is that, with the theoretical support of regional economics and

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new geographic economics, we shift the perspective of from the macroeconomic field to the micro enterprise field, focusing on TFP, and combining it with the reality of the gradual improvement of high-speed railroad network, based on the computerized analytical software--GIS (Geographic Information System), we find that the development of high-speed railroads and the total factor productivity of enterprises have become more and more important in China. GIS to explore the geospatial distribution characteristics, correlation and influence mechanism analysis of high-speed railway stations and enterprises. In the propositional argumentation, this paper chooses the data of listed companies in the manufacturing industry during the period of 2000-2017 as the analysis sample, which is due to the fact that the manufacturing industry is more efficient in productivity compared with other industries, and is in the primary position in economic growth and employment creation, and is more susceptible to the influence of the flow of factors of production [5-6]. Based on this, using multiple difference model to empirically analyze the possibility of HSR on TFP, in order to coordinate the economy of HSR and promote the transformation of enterprises under the new normal conditions to provide a scientific and powerful reference basis.

II. Literature Review and Research Hypotheses

Under the condition that the economic system and policies are not changed, except for the interregional differences in factor input cost, the only intermediate condition affecting factor mobility is the interregional intermediate condition: basic transportation facilities [7]. The regional effect of TGV network and interregional accessibility in France, and the results show that TGV network is not the main factor affecting economic growth, but it promotes economic growth to a certain extent [8]. The HSR in Spain, France and the United Kingdom as the empirical evidence, and the result confirms that HSR can promote the development of regional economic integration within 200 kilometers of the central city and establish good connections with other central cities [9]. The internal mechanism between HSR and economic growth, and believes that the opening of HSR mainly leads to the rapid flow of labor production factors, which is the main reason for the rapid development of HSR, mainly leads to the rapid flow of labor production factors, which also generates consumer demand, and these demands will improve the development of related industries and economy [10]. With the opening of HSR, the population size of cities in stations along the route increased by 35.2%, which in turn promoted economic growth [11].

Hypothesis 1: There is a high spatial correlation between the distribution of HSR and the location of firms.

Labor always moves to the place with high income and low transportation cost, which makes the core city appear agglomeration phenomenon, but at the expense of smaller urban economic downturn, i.e. siphon effect [12]. The opening of HSR has a certain inhibiting effect on the TFP level of enterprises in the western region, but it hinders the process of economic integration [13]. This effect causes some factors of production to flow from underdeveloped cities to developed cities. From the empirical analysis that the effect of HSR opening on the TFP of cities in the one-hour HSR circle around the central city and its surroundings is positive, but the effect of enterprises in remote and small cities is negative [14]. The selection of HSR stations and the spatial distance between enterprises affect the TFP of enterprises, which exacerbates regional imbalances [15]. In the process of opening up HSR, when production costs in developed regions exceed the maximum value that manufacturing can afford, most companies will choose to move their factories to the outskirts of central cities as an effective way to reduce costs[16]. This compensates for the negative impact of the "siphon effect" on less developed cities, a mechanism known as the "polarization-trickle-down effect", which is used to explain how the economies of developed and less developed regions interact with each other and even promote each other's development. The impact of HSR on the TFP of enterprises using the data of Chinese manufacturing enterprises from 2007 to 2013 as a sample, and the results of the study show that every dollar invested in HSR reduces the inventory stock invested by enterprises by 12 cents, thus increasing the TFP of enterprises, and it is pointed out that this is a much larger impact than the previous highway or road-based investment, and it is also pointed out that the positive benefits are much larger than the negative effects[17]. The positive benefits far outweigh the negative effects. The impact of HSR on TFP from the perspective of regional economic disparities, and empirically finds that since the opening of HSR, regional economic disparities have been narrowed, i.e., The HSR has promoted the integration of China's regional economies [18].

Hypothesis 2: The HSR shows an inverted U-shaped effect on TFP;

The construction of HSR compresses the spatial and temporal distance between cities, expands the radius of urban spatial agglomeration, gradually breaks down the barriers between cities, and becomes an important "variable" in realizing the rapid development of cities [19]. The economic distribution effect of basic transportation facilities, and concluded that the construction of interregional transportation infrastructure can improve economic growth, and affirmed its positive effect, but also believed that there is a negative effect - "siphon effect", which

makes some factors of production flow from underdeveloped cities to developed cities [20]. According to the mechanism analysis above, it can be seen that HSR affects TFP from both positive and negative perspectives, and the positive effect should be the use of labor mobility, which brings about the flow of high-skilled talents and increases the innovation of enterprises, thus improving TFP; the negative effect arises from the fact that HSR reduces the accessibility of the region, and the inter-region has become more close to each other, and it also increases the industrial concentration.

Hypothesis 3: The opening of HSR affects firms' total factor productivity mainly through firm innovation and industrial agglomeration.

III. GIS Spatial Analysis

GIS (Geographic Information Science, GIS for short) was proposed by Goodchild in 1992, GIS and geographic information systems, compared to its more focused on geographic information as a science, rather than just a technical realization, the main research in the application of computer technology to geographic information acquisition, storage, management, as well as a series of fundamental issues raised during the application of computer technology to the acquisition, storage, management, and processing and analysis of geographic information [21]. In this paper, based on the spatial maps of high-speed rail lines, stations and locations of enterprises of listed manufacturing companies in 2011, 2016 and 2011, the specific results are shown in Figure 1, Figure 2 and Figure 3.

From Figure 1, it can be seen that most enterprises gather near high-speed rail stations, which reflects a certain correlation between high-speed rail stations and enterprise locations. Enterprise gathering points are mainly distributed near Beijing, Shanghai, and Shenzhen. Compared to Figure 1, it can be seen in Figure 2 that there is a significant increase in the number of high-speed rail stations and enterprise spatial aggregation points, and the range of aggregation points has also significantly expanded. Compared to Figure 2, there is no significant change in the concentration points of enterprises in Figure 3, but the concentration density has actually decreased.

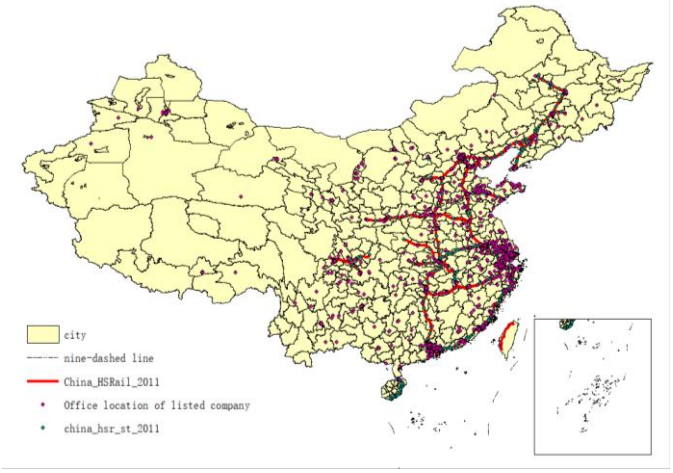

Figure 1: Distribution Map of Chinese Manufacturing Enterprises in 2011

Figure 2: Distribution Map of Chinese Manufacturing Enterprises in 2016

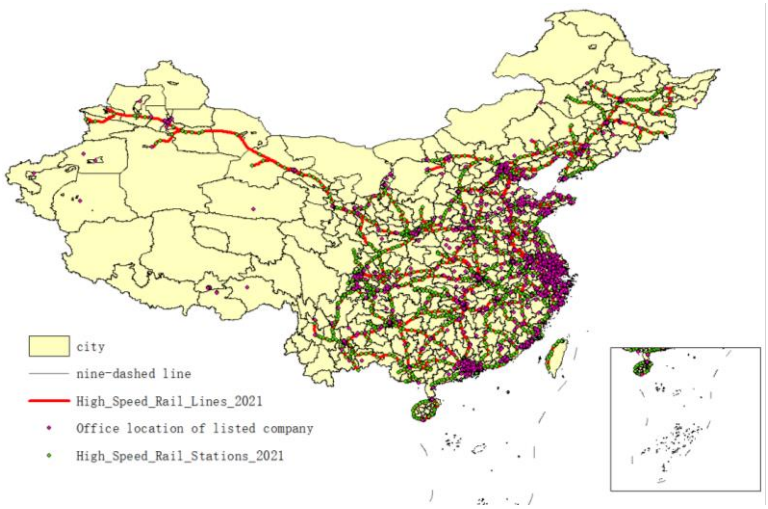

Figure 3: Distribution Map of Chinese Manufacturing Enterprises in 2021

IV. RESEARCH DESIGN AND EMPIRICAL ANALYSIS

A. Research Design

1) Data sources

After obtaining the initial data, this paper selects the data of listed companies in the manufacturing industry from 2000 to 2017 as the research and analysis sample, which also needs to be pre-processed: 1. Listed companies that issue both A shares and B shares are excluded; 2. Listed companies after 2000 are excluded; 3. To ensure data integrity and consistency, cities with changes in administrative region are excluded; 4. To prevent the abnormal financial data of enterprises, the data of listed companies of ST and *ST are excluded; 5. The data of enterprises with abnormal data and serious missing data are excluded; 6. To ensure that the regression results of the model are not affected by outliers, the method of winsorization is adopted to shrink the tail of abnormal values by 1% and 99%. All variables are taken from the annual data of consolidated financial statements published by general listed companies, as well as the database of expenditure details, in the unit of ten thousand yuan. All data are obtained from China Industrial Enterprises Database, Cathay Pacific Database and Wind Database.

2) Model design and variable selection

Combined with the empirical hypotheses presented above, the econometric model used to test the impact of the opening of the HSR on firms' TFP is as follows:

$$TFP\_LP_{it} = \beta_0 + \beta_1 Hsr_{it} + \beta_2 Control_{it} + \sum Year_t + \sum Firm_i + \varepsilon_{i,t} \quad (1)$$

Where i represents the firm and t represents time. The explanatory variable TFP_LP_{it} is the TFP of the firm. The explanatory variable Hsr_{it} denotes whether the HSR is opened or not. $Control_{it}$ denotes the control variables, the $Year_t$ and $Firm_i$ denote yearly time effects and individual firm effects.

The explanatory variables ($\boldsymbol{TFP\_LP_{it}}$): refer to Levinsohn and Petrin [22] for the measure: using the firm's annual operating income, net fixed assets, number of employees, and cash paid for purchases of goods and services as indicators.

Core explanatory variables ($\boldsymbol{Hsr_{it}}$): whether or not the HSR opens as a quasi-natural experiment. The before and after periods are divided according to the opening time, and the control group and experimental group are divided according to whether the city where the enterprise is located opens HSR. Due to the inconsistency of the opening time nodes of HSR, a multi-period DID method is adopted. Although there are multiple HSR lines and multiple HSR stations in many prefecture-level cities, especially large cities, this does not affect the division of the control group and the experimental group. Therefore, the time of the first opening of HSR is used as the basis for the division.

Control variables ($\boldsymbol{Control_{it}}$): control variables are screened from various perspectives such as capital, debt and income of the firm. The selected control variables are financial leverage (Em_{it}), which is the rate of change in earnings per common share/rate of change in EBITDA; the size of listed companies ($Size_{it}$), which is expressed by utilizing the average asset level of enterprises; operating results of listed enterprises (Mer_{it}), i.e. expressed using the profit from main business of the enterprise; return on total assets (Roa_{it}), i.e. net profit as a percentage of average total assets; gearing (Lev_{it}), i.e. the proportional relationship between total liabilities and total assets; categorical variables of ownership nature (Soe_{it}), which contain central state-owned enterprises, local state-owned

enterprises, private enterprises, collective enterprises, foreign-funded enterprises and other enterprises, respectively, are categorized into two main groups in this paper: first, state-owned enterprises, including local state-owned and central state-owned enterprises, which makes them$Soe_{it} = 0$ The first is, state-owned enterprises, including local state-owned and central state-owned enterprises, making itSoe_{it} is set to 1.

3) Statistical analysis

Table 1: Descriptive Statistics of Variables

Variable	Sample	Standard deviation	25% quartile	Median	75% quartile	Mean	Min	Max
TFP_LP_{it}	6210	1.226	6.857	7.598	8.394	7.622	-1.723	12.063
Hsr_{it}	6210	0.458	0	0	1	0.3	0	1
Em_{it}	6210	1.088	0.95	1.11	1.48	1.304	-2.22	6.19
$Size_{it}$	6210	1.474	10.086	10.985	11.983	11.0623	7.091	14.880
Mer_{it}	6210	73.307	0.310	5.300	22	24.101	-120	490
Roa_{it}	6210	7.675	2.05	4.52	8.04	4.614	-25.68	27.1
Lev_{it}	6210	23.289	36.6	50.99	64.62	52.062	9.45	166.17
Own_{it}	6210	0.489	0	0	1	0.397	0	1

Table 1 shows the descriptive statistics of the variable indicators. Table 2 is a test of the difference between the group means of TFP and financial characteristics of enterprises in the experimental and control groups for the opening of HSR, as can be seen in the table: either or , there are significant differences in the indicators of each variable after the opening of HSR. Specifically, there are: the TFP of enterprises after the opening of HSR is significantly higher than before the opening of HSR, the return on total assets of enterprises after the opening of HSR is also significantly higher than before the opening of HSR, while the asset-liability ratio is significantly lower than before the opening of HSR, while the size of enterprises is also significantly enlarged after the opening of HSR, which first verifies the research hypothesis of this paper, ie, The opening of HSR not only improves the TFP of enterprises along the route, but also significantly improves the business performance of enterprises.

Table 2: Analysis of Variance

Variable	$Hsr_{it} = 0$	$Hsr_{it} = 1$	p
TFP_LP_{it}	8.0223	8.7790	-0.7567***
Em_{it}	1.2971	1.3533	-0.0562*
$Size_{it}$	21.6882	22.2776	-0.5894***
Mer_{it}	9.3900	17.8846	-8.4945***
Roa_{it}	4.5134	4.8993	-0.3858*
Lev_{it}	53.2553	51.1662	2.0891***
Own_{it}	0.3634	0.3252	0.0382***

Note: *** significance at the level of 1%, ** significance at the level of 5%, * significance at the level of 10%.The same goes for the following table.

B. Full-sample Regression Analysis

Table 3 shows reference analysis of multi-period differential analysis. Columns (1) and (2) in Table 3 are simple OLS regression, which does not control time effect, province effect and individual effect. Columns (3) and (4) are fixed effect regression, using methods and again based on the control of the time effect; Columns (5) and (6) control the time effect and province effect. According to the regression coefficient of the HSR, the following conclusions can be drawn: First, the differences of the provinces where the enterprises are located will affect the size of the regression parameters, In other words, the opening of HSR has regional heterogeneity on TFP of enterprises. Second, the coefficients of all regression equations are significantly positive, and the opening of HSR will promote the improvement of enterprises' TFP, and also to stability. Third, it can be seen from the regression coefficient of control variables that Em_{it} has little impact on the TFP of enterprises. However, the increase of $Size_{it}$ and Roa_{it} will promote the increase of TFP of enterprises, while the Lev_{it} is contrary to it.

After multi period DID regression, it can not only judge the causal relationship between HSR and the TFP of enterprises, but also conclude that the influence coefficient of HSR is 6.34%. However, there is an important premise of the DID model, that is, the experimental group and the control group involved in the research must be comparable before the opening of HSR, which is also known as the "parallel trend hypothesis". In other words, before the opening of HSR, the change trend of TFP of enterprises in the experimental group and the control group was basically the same. Therefore, based on the theory proposed by Rao et al. [23]. The "parallel trend hypothesis" is tested by using the dynamic effect of the impact of HSR opening on enterprises' TFP. The inspection results are as follows:

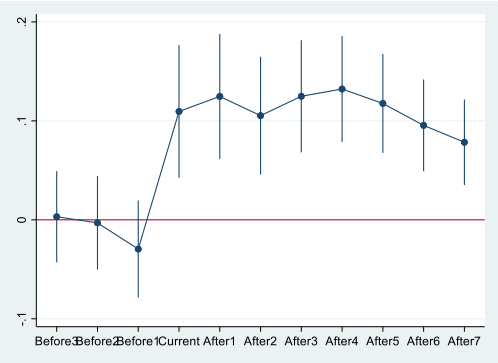

Figure 4: Parallel Trend Hypothesis

Table 3: Full-sample Regression Analysis of the Effect of HSR Opening on Enterprises' TFP

	TFP_LP_{it}					
	(1)	(2)	(3)	(4)	(5)	(6)
Hsr_{it}	0.692*** (0.0337)	0.419*** (0.0254)	0.0832*** (0.0302)	0.0634** (0.0275)	0.112** (0.0491)	0.0789** (0.0376)
Em_{it}		-0.00192 (0.0110)		0.0113 (0.00752)		0.00137 (0.0107)
$Size_{it}$		0.369*** (0.00911)		0.275*** (0.0114)		0.379*** (0.00874)
Mer_{it}		0.00322*** (0.000186)		0.00113*** (0.000155)		0.00299*** (0.000182)
Roa_{it}		0.0263*** (0.00178)		0.0168*** (0.00132)		0.0217*** (0.00176)
Lev_{it}		0.00146*** (0.000532)		-0.00251*** (0.000506)		0.00102* (0.000532)
$\_cons$	7.482*** (0.0196)	3.296*** (0.104)	6.850*** (0.0447)	3.994*** (0.129)	7.258*** (0.0759)	2.999*** (0.110)
Time	No	No	Yes	Yes	Yes	Yes
Individual	No	No	Yes	Yes	No	No
Province	No	No	No	No	Yes	Yes
N	6210	6210	6210	6210	6210	6210
R^2	0.071	0.489	0.327	0.443	0.3790	0.198

From Figure 4, it can be seen that the vertical line before the opening of HSR intersects with the x-axis, while the vertical line after the opening does not intersect with the x-axis and is significant. Therefore, it can be considered that the DID method is effective.

In order to further understand the dynamic impact mechanism of HSR opening on TFP of enterprises, the following dynamic testing model was constructed:

$$TFP\_LP_{it} = \beta_0 + \sum_{-2}^{8} \beta_t \, Hsr_{it} + \beta_2 Control_{i,t} + \sum Year_t + \sum Firm_i + \varepsilon_{i,t} \quad (2)$$

Table 4: Parallel Trend Hypothesis

	TFP_LP_{it}	
	(1)	(2)
Before2(Hsr − 2)	0.0358(0.0378)	0.0337(0.0416)
Before1(Hsr − 1)	-0.00378(0.0400)	-0.000767(0.0440)
Current(Hsr)	0.183**(0.0917)	0.212**(0.101)
After1(Hsr + 1)	0.220**(0.0911)	0.226**(0.100)
After2(Hsr + 2)	0.225**(0.0904)	0.234**(0.0994)
After3(Hsr + 3)	0.219**(0.0900)	0.235**(0.0990)
After4(Hsr + 4)	0.217**(0.0920)	0.223**(0.101)
After5(Hsr + 5)	0.237**(0.0923)	0.232**(0.102)
After6(Hsr + 6)	0.167*(0.0931)	0.181*(0.102)
After7(Hsr + 7)	0.119(0.0969)	0.117(0.107)
After8_(Hsr + 8)	0.0626(0.0508)	0.0672(0.0557)
cons	3.684***(0.146)	4.879***(0.138)
$Control_{it}$	Yes	No
Time	Yes	Yes
Individual	Yes	Yes
N	6,210	6,210
R^2	0.490	0.380

Before2, Before1, Current, After1, After2, After3, After4, After5, After6, After7, and After8_ in Table 4 are the estimates in the model, It represents the first 2 years, 1 year, the current year and 1 year, 2 years, 7 years and 8 years after the opening of HSR. As can be seen from the table, the coefficients before Before2 and Before1 are positive but not significant, while the coefficients before After1, After2, After3, After4, After5, and After6 in the current year of the opening of HSR are significant. After7 and After8_ are not significant, so it shows that they basically satisfy the "parallel trend hypothesis".

C. Model Heterogeneity Test

1) Tests of regional variability

According to the conclusions drawn from Table 3, as an example to study the provincial effect of the impact of the opening of HSR on the TFP of enterprises, the HSR stations are therefore divided into tests according to their geographical location. It is divided into east, center and west. The specific results are shown in Table 5. it can be found that the east Hsr_{it} The coefficient before is not only insignificant but also negative. The coefficient of the former is not only insignificant but also negative.Hsr_{it} The highest coefficient is 0.197, while the western region is slightly lower at 0.16. This is consistent with the theoretical hypothesis. It is analyzed that there are several reasons, firstly, although the eastern cities are more developed and the competition in the market is more intense, but also, therefore, in the cities with developed transportation facilities, the opening of HSR has little effect on the improvement of their accessibility, after all, the transportation facilities in their cities have been perfected for a long time, and the economic effect brought by HSR has been replaced by other transportation facilities for a long time, therefore, the opening of HSR can't have an impact on the eastern cities. Secondly, in the eastern region, the cities are generally developed, but high income is often accompanied by high cost, so the cost of living in the region is much higher than other regions, which for small and medium-sized enterprises, this leads to high production cost, and because of the development of transportation, the enterprises will choose to leave the region, and most of them will choose the cities in the central part of the country, which is also the reason why the impact effect coefficient of the central city is the highest.

Table 5: Regional Difference Test

	TFP_LP_{it}		
	East	Middle	West
Hsr_{it}	-0.0361(0.0361)	0.197***(0.0572)	0.160**(0.0752)
Em_{it}	0.0184**(0.00883)	0.0181(0.0148)	-0.0145(0.0173)
$Size_{it}$	0.199***(0.0139)	0.339***(0.0210)	0.316***(0.0249)
Mer_{it}	0.00127***(0.000184)	0.000563*(0.000321)	0.00201***(0.000381)
Roa_{it}	0.0227***(0.00170)	0.0153***(0.00249)	0.0142***(0.00273)
Lev_{it}	0.00228***(0.000653)	-0.00518***(0.000991)	-0.00220**(0.000984)
$\_cons$	4.718***(0.156)	3.070***(0.240)	3.222***(0.278)
Time	Yes	Yes	Yes
Individual	Yes	Yes	Yes
N	3,258	1,674	1,278
R^2	0.510	0.527	0.454

2) Industry heterogeneity test

Table 6: Industry Heterogeneity Test

	TFP_LP_{it}			
	Idu = 0		Idu = 1	
	(1)	(2)	(3)	(4)
Hsr_{it}	0.0832***(0.0302)	0.0634**(0.0275)	0.0423(0.0441)	0.0407(0.0440)
Em_{it}		0.0113(0.00752)		0.000380(0.00135)
$Size_{it}$		0.275***(0.0114)		0.0625***(0.0004)
Mer_{it}		0.00113***(0.000155)		0.000284***(8.43e-05)
Roa_{it}		0.0168***(0.00132)		0.000372***(8.77e-05)
Lev_{it}		-0.00251***(0.000506)		-1.79e-05**(8.28e-06)
_cons	6.850***(0.0447)	3.994***(0.129)	7.161***(0.0443)	7.159***(0.0442)
Time	Yes	Yes	Yes	Yes
Individual	Yes	Yes	Yes	Yes
N	6210	6210	6,372	6,372
R^2	0.327	0.443	0.332	0.335

In the study of the impact of the opening of HSR on the TFP of enterprises, this paper selects the manufacturing enterprises as the research sample, this is due to the manufacturing industry belongs to the labor-intensive industry,

the production link than the more complex, the purchase of raw materials, semi-finished products on behalf of the processing, finished goods into the warehouse, etc., the requirements of transportation and logistics, inventory turnover of goods and inventory management are more stringent, but also compared with the capital investment, more need to labor power It is also an industry that needs more labor power than capital investment, so the manufacturing industry is more sensitive to the population flow and transportation convenience brought by the opening of HSR. Therefore, it is not difficult to make a hypothesis: compared with other industries, the impact of the opening of HSR on the all-important productivity of enterprises is deeper and more significant in the manufacturing industry. Where $Idu = 0$ represents manufacturing enterprises, while $Idu = 1$ represents non-manufacturing enterprises (Table 6). From the table, it can be seen that the coefficients of the impact of the opening of HSR on the total factor production of manufacturing enterprises are 0.0832 and 0.0634, and they are significant. While the non-manufacturing enterprises are also positive, but the coefficient before it is not significant, which also verifies the expected hypothesis of this paper.

V. Expanded Analysis

A. Mediation Effect Test

After exhaustively analyzing the stage-by-stage impact of HSR on enterprise TFP, it is necessary to further consider how the opening of HSR affects enterprise TFP. According to the analysis of theoretical impact mechanism, it can be seen that the opening of HSR affects the TFP of enterprises from two competitive perspectives: the positive effect is the use of labor mobility, which brings about the mobility of high-skilled personnel, making the increase of enterprise innovation, and thus increasing the TFP of enterprises; the negative effect is produced because HSR makes the inter-regional accessibility decrease, and the inter-region becomes closer, and it also increases the industrial agglomeration. According to Baron and Kenny [24], the following mediation effect model is constructed:

$$TFP\_LP_{it} = \beta_0 + \beta_1 Hsr_{it} + \beta_2 Control_{i,t} + \sum Year_t + \sum Firm_i + \varepsilon_{i,t} \quad (3)$$

$$R\&D_{it} = \beta_0 + \beta_1 Hsr_{it} + \beta_2 Control_{i,t} + \sum Year_t + \sum Firm_i + \varepsilon_{i,t} \quad (4)$$

$$AGG_{it} = \beta_0 + \beta_1 Hsr_{it} + \beta_2 Control_{i,t} + \sum Year_t + \sum Firm_i + \varepsilon_{i,t} \quad (5)$$

$$TFP\_LP_{it} = \beta_0 + \beta_1 R\&D_{it} + \beta_2 Control_{i,t} + \sum Year_t + \sum Firm_i + \varepsilon_{i,t} \quad (6)$$

$$TFP\_LP_{it} = \beta_0 + \beta_1 AGG_{it} + \beta_2 Control_{i,t} + \sum Year_t + \sum Firm_i + \varepsilon_{i,t} \quad (7)$$

$$TFP\_LP_{it} = \beta_0 + \beta_1 R\&D_{it} + \beta_2 AGG_{it} + \beta_3 Control_{i,t} + \sum Year_t + \sum Firm_i + \varepsilon_{i,t} \quad (8)$$

Where $R\&D_{it}$ denotes the enterprise innovation, due to the lack of data on R&D investment of most enterprises, the number of patent applications, which includes invention patent applications, appearance patent applications, and utility model applications, is used as a proxy indicator. On the other hand, AGG_{it} denotes the enterprise innovation, and since industrial agglomeration is a macro-level influence, it can only be expressed by using the industrial agglomeration of the city in which the company is located, and in order to reduce the existence of errors, this paper adopts the two industrial agglomeration measures and takes the average of them to indicate the level of agglomeration.

Table 7: Test of Mediating Effect

	TFP_LP_{it}	$R\&D_{it}$	AGG_{it}	TFP_LP_{it}	TFP_LP_{it}	TFP_LP_{it}
	(1)	(2)	(3)	(4)	(5)	(6)
Hsr_{it}	0.0875* (0.0469)	0.582*** (0.143)	0.0148* (0.00895)	0.103** (0.0470)	0.109** (0.0451)	0.116** (0.0453)
$R\&D_{it}$				0.0262*** (0.00751)		0.0132* (0.00731)
AGG_{it}					-1.449*** (0.115)	-1.418*** (0.117)
$\_cons$	3.543*** (0.197)	-6.167*** (0.590)	1.027*** (0.0375)	3.689*** (0.201)	5.031*** (0.223)	5.073*** (0.224)
$Control_{i,t}$	Yes	Yes	Yes	Yes	Yes	Yes
Time	Yes	Yes	Yes	Yes	Yes	Yes
Individual	Yes	Yes	Yes	Yes	Yes	Yes
N	2,272	2,272	2,272	2,272	2,272	2,272
R^2	0.512	0.873	0.516	0.094	0.550	0.550

Table 7 shows that the model (2) and (3) are used to test the impact of HSR on enterprise innovation and industrial agglomeration. The coefficient of HSR in model (2) is significantly 0.582, and that of HSR in model (3)

is significantly 0.0148. Models (4) and (5) respectively test the impact of firm innovation and industry on TFP of enterprises. The coefficient of $R\&D_{it}$ is significantly 0.0262 in model (4). The coefficient of AGG_{it} is significantly -1.449 in model (5), model (6) is the comprehensive impact of the opening of Hsr_{it}, $R\&D_{it}$ and AGG_{it} on the TFP. It can be seen that the Hsr_{it} coefficient is significantly 0.116, the $R\&D_{it}$ coefficient is significantly 0.0132, and the AGG_{it} coefficient is significantly -1.418.

B. Robustness Check

The opening of HSR was conducted as a natural experiment. And the division of experimental group and control group is affected by the national macro policy and economic development, so there will be selection bias in the grouping results. Selection bias refers to the difference in the initial state of the participants, so the participants should choose whether to participate in the project according to their own status, rather than randomly grouping. Therefore, in order to test the robustness of the DID model, this paper uses PSM-DID method to re-test the relationship between the opening of HSR and the TFP of enterprises. PSM-DID is to find individuals with similar values of other variables except the processing variable (whether HSR is open or not) and combine them into a new control group, which is equivalent to re-randomization and solves the problem of selectivity bias.

Table 8: Balance Test of PSM-DID

$Control_{i,t}$		Mean		Deviation of standardization	T-test	
		Experimental	Control		T-value	p
Em_{it}	Before	1.355	1.283	-7.0	2.28	0.023
	After	1.3516	1.4249		-1.96	0.049
$Size_{it}$	Before	11.452	10.894	97.2	13.86	0.000
	After	11.45	11.465		-0.30	0.761
Mer_{it}	Before	38.786	17.798	97.1	10.43	0.000
	After	38.544	39.161		-0.19	0.846
Roa_{it}	Before	4.9042	4.4892	16.2	1.95	0.051
	After	4.9028	5.2504		-1.49	0.137
Lev_{it}	Before	51.121	52.466	53.5	-2.09	0.037
	After	51.126	51.751		-0.90	0.369

Table 9: PSM-DID Test Results

	TFP_LP_{it}	
	(1)	(2)
Hsr_{it}	0.0694**	0.0503*
	(0.0298)	(0.0271)
_cons	6.788***	3.881***
	(0.0448)	(0.119)
$Control_{i,t}$	No	Yes
Time	Yes	Yes
Individual	Yes	Yes
N	6,210	6,210
R^2	0.800	0.758

After score matching, it is also necessary to check the data balance before and after matching (Table 8). The original assumption of the T-test in the table is that there is no systematic difference between the experimental and controlled groups. It can be seen from the table that the p values of the $Control_{i,t}$ are basically less than 0.05 before the matching, so it can be concluded that there is a big difference between the control group and the treatment group before the matching, and the p values of the propensity score after the matching are basically greater than 0.05, which means that there is almost no difference between the sample enterprises before and after the opening of HSR. After passing the matching score and balance test, the PSM-DID method can be used for re-test (Table 9). According to the data in Table 9, we can find that the Hsr_{it} coefficients under the PSM-DID method are 0.0694 and 0.0503, which are significant. This indicates that the results are robust from a model point of view.

VI. CONCLUSION

In 2008, when other countries were still affected by the financial crisis leading to economic downturn, China's HSR was officially opened, and the economy also still maintained a medium-high-speed development. However, with the rapid development of the economy, China's labor force population has started to shift from surplus to shortage, which means that the improvement of TFP has become the next pillar for China's economy to maintain stable and rapid development, and one of the necessary ways for the sustainable development of enterprises. Based

on this realistic background, this paper examines the impact of HSR opening on the TFP of manufacturing enterprises, draws conclusions, and puts forward the following suggestions:

(1) Emphasize the mechanism of the impact of HSR opening on the TFP of manufacturing enterprises.

From the point of view of the impact mechanism of the opening of HSR on the TFP of manufacturing enterprises, although HSR can improve the TFP of enterprises as a whole, there are three phases of its impact effect, and there are positive and negative aspects of its impact path, so it is necessary to rationally plan the stations and routes of HSR, and scientifically balance the impact effect of HSR under the role of time and space. For developed cities, they must pay attention to the negative effects of HSR, such as the structural imbalance and the increase of production cost caused by excessive industrial agglomeration, If the developed cities have already begun to experience the negative effects of industrial agglomeration, they should consider whether to support the opening of HSR in neighboring cities and promote the formation of an intercity HSR network pattern, so as to expand the radiation area of industrial agglomeration, which can not only alleviate the pressure of production cost in the core cities, but also expand the radiation area of industrial agglomeration. This can not only alleviate the pressure of production cost in the core city, but also reduce the burden of urban population and optimize the industrial structure; it is also an important time for the economic development of its neighboring cities: a large number of employment opportunities, advanced technology, knowledge and talents will flow to the neighboring cities.

(2) Beware of the aggravation of regional imbalance by the HSR effect.

At present in China, the major contradiction at the present stage of our country has become the contradiction between people's growing needs for a better life and unbalanced and insufficient development. The opening of the HSR will aggravate this contradiction. The cities where the HSR is opened will receive a large number of labor and investment, which will cause the redistribution of resources to be tilted, and the development resources of the cities where the HSR is not opened will be "plundered", which will further aggravate the regional imbalance.

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