The Impact of Transportation Infrastructure on Manufacturing Agglomeration: A Study Based on 31 Provinces in China

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Abstract. This article examines the impact of transportation infrastructure on manufacturing agglomeration through an empirical analysis, utilizing data from 31 provinces (autonomous regions, municipalities) in China from 2013 to 2022. Research shows that transportation infrastructure plays a promoting role in the agglomeration of China's manufacturing industry. Highway density has a positive impact on manufacturing agglomeration in the eastern, central, and western regions, while railway density has a positive effect on the eastern and central regions. However, railway density has a negative impact on manufacturing agglomeration in the western region, and it disperses industrial agglomeration. Based on the above research conclusions, this paper puts forward three targeted policy recommendations: First, continue to increase investment in highway networks in the central and western regions, and improve the construction of county- and township-level highway branches. Second, optimize the railway construction layout—focus on connecting railways with characteristic industrial parks and resource-producing areas in the western region to avoid blind expansion. Third, promote the coordinated planning of transportation and industries in accordance with regional industrial endowments, so as to facilitate the coordinated development of regional manufacturing industries. This study not only provides the latest empirical evidence for the quantitative analysis of the relationship between transportation infrastructure and manufacturing agglomeration, but also offers important insights for addressing the imbalance in regional industrial development and formulating differentiated transportation and industrial policies.

Keywords: Transportation infrastructure, location entropy, manufacturing industry agglomeration.

1. Introduction

Transportation infrastructure, as a fundamental condition for the operation of social and economic life, is an important guarantee for communication between regions. It plays an important role in enhancing urban functions and quality, shaping industrial layout and economic geography at a deep level. Manufacturing is a pillar industry of the country, and it plays a leading role in the development of the national economy. As an important phenomenon in industrial development, manufacturing agglomeration not only brings economies of scale but also promotes technological innovation and industrial upgrading. At the same time, the formation and development of manufacturing agglomeration cannot be separated from the support and guarantee of transportation infrastructure. The construction of transportation infrastructure can improve the accessibility of transportation between regions, thereby reducing the logistics costs of manufacturing enterprises, attracting more enterprises to go to areas with convenient transportation, and affecting their site selection decisions to promote the agglomeration and development of the manufacturing industry, ultimately affecting the degree of agglomeration of the manufacturing industry in the region.

Currently, numerous scholars both domestically and internationally have studied the impact of transportation infrastructure on manufacturing agglomeration. In terms of theory, Thünen was the first to analyze the agglomeration effect of industries from the perspective of transportation infrastructure. He pointed out that depending on the distance from the central city, the agricultural areas surrounding the central city will exhibit a concentric ring structure, revealing the impact of transportation distance on industrial layout. New economic geographer Krugman pointed out that industrial agglomeration is the result of the interaction between transportation costs and economies of scale [1]. At the micro level, many studies focus on the impact of transportation infrastructure on enterprise site selection and decision-making. Ren Xiaohong and Zhang Zongyi found that there is a

local agglomeration phenomenon in both the stock of transportation infrastructure and the manufacturing industry in China, and transportation infrastructure is an important factor in the location selection of the manufacturing industry [2]. Yin Zhiqin's research shows that the construction of transportation infrastructure has a strong driving force for industrial collaborative agglomeration, and there is an "inverted U-shaped" nonlinear relationship between the improvement of transportation infrastructure construction level and industrial collaborative agglomeration [3]. At the macro level, many studies focus on the driving effect of transportation infrastructure on agglomeration. Tsekeris and Vogiatzoglou argue that increasing investment in highways and airports can promote the agglomeration of manufacturing industries [4]. Dai Tianqi's research shows that the construction of national transportation infrastructure is conducive to the formation of manufacturing agglomeration [5]. Zhu Wentao et al. further empirically found that high-speed railways have a significant positive impact on the agglomeration of manufacturing industries in underdeveloped cities along the route [6]. Guo Pengfei and Wu Zhiting pointed out that the construction of highway infrastructure is conducive to the agglomeration of manufacturing industries [7]. There are two main shortcomings in existing research: firstly, existing literature are limited to specific regions and lack empirical investigations based on the overall perspective of China; Secondly, existing research generally lack systematic analysis of the heterogeneity of different regions in the East, Central, and West, making it difficult to elucidate the regional characteristics and underlying mechanisms of the impact of transportation infrastructure on manufacturing agglomeration. From a national perspective, the degree of manufacturing agglomeration varies among the 31 provinces in China, and there are significant differences in the development level of transportation infrastructure. Therefore, studying the impact of transportation infrastructure on manufacturing agglomeration not only helps to reveal the inherent connection between the two but also provides a scientific basis for policymakers to promote the rational layout of manufacturing and the coordinated development of transportation infrastructure. This article is based on data from 31 provinces in China from 2013 to 2022, using econometric methods and basic panel models to explore the impact of transportation infrastructure on manufacturing agglomeration, and through heterogeneity analysis, to investigate the different effects of transportation infrastructure on manufacturing agglomeration in different regions. The possible research innovations of this article are mainly reflected in the following two aspects: firstly, based on panel data from 31 provinces in China, the research perspective is expanded from local regions to the overall national level. Secondly, systematically introduce and test the heterogeneity effects of the three major regions of East, Central, and West, and deeply explore the differences in the impact of transportation infrastructure on manufacturing agglomeration among different regions.

2. Model Setting and Variable Description

2.1. Model Setting

This article uses data from 31 provinces in China from 2013 to 2022 as a sample, constructs a panel data model to empirically analyze the impact of highway and railway infrastructure construction on manufacturing agglomeration. The specific empirical analysis model is as follows:

$$lnqws_{it}=\beta_0+\beta_1 X_{1it}+\beta_2 X_{2it}+\mu_i+\varepsilon_{it} \quad (1)$$

Among them, subscript i is the code of each province in China, t is the year, μ_i is the unobservable individual effect, ε_{it} is the random error term, β_0 is the constant term, and β_1 and β_2 are the coefficients of the corresponding variables. Lnqwsit represents the manufacturing industry location entropy of region i in year t, with X_1 as the independent variable, reflecting the transportation infrastructure status of each province in each year, and X_2 as other factors that affect manufacturing agglomeration, including economic development level, labor costs, foreign trade, urbanization level, and secondary industry scale, in addition to transportation infrastructure.

2.2. Data Source

The research object of this article includes 31 provincial-level administrative regions (autonomous regions, municipalities) in China, excluding the three administrative regions of Hong Kong, Macao, and Taiwan, where data is difficult to obtain. The main data comes from the China Statistical Yearbook and the Provincial statistical yearbooks from 2013 to 2022, as well as the China Transportation Statistical Yearbook.

2.3. Variable Selection

The dependent variable: location entropy (qws). Location entropy is an effective indicator for measuring the spatial distribution of factors and the degree of industrial specialization in a certain region; thus, it can effectively measure the degree of agglomeration of the manufacturing industry. In view of this, this article follows the research methods of multiple scholars and uses location entropy to evaluate the agglomeration status of manufacturing industries in various provinces of China. The calculation method of location entropy is as follows:

$$qws_{ij}=(q_{ij}/q_j)(q_i/q) \tag{2}$$

Among them, q_{ij} represents the number of employed people in the manufacturing industry j of region i, q_j represents the total number of employed people in region j, q_i represents the total number of employed people in China's manufacturing industry, and q represents the total number of employed people in China.

Explanatory variables: highway density, railway density. Railway and highway are the main modes of freight transportation in China, and considering the relatively small proportion of freight transportation modes such as sea and air, this article chooses highway density and railway density to represent transportation infrastructure. Highway density refers to the number of road miles per hundred square kilometers in each province; Railway density refers to the number of railway miles per hundred square kilometers in each province.

Control variable: Economic development level (lngdp), measured by per capita GDP, it is a key indicator for measuring regional market demand potential and has a significant impact on manufacturing agglomeration; Foreign trade, measured by the proportion of total import and export volume to GDP, reflects the degree of regional openness and international market connectivity, which affects the trend of manufacturing agglomeration; The scale of the secondary industry, measured by the proportion of the secondary industry to GDP, is an important factor reflecting the regional industrial foundation and manufacturing development level, and it promotes the agglomeration of related industries; Labor cost (lnwage), measured by wage levels, is one of the key factors affecting manufacturing production costs and location choices; The level of urbanization, measured by the urbanization rate, determines the labor supply and urban infrastructure, and plays an important role in the agglomeration of manufacturing industry.

3. Empirical Results and Analysis

3.1. Descriptive Statistics

Table 1 presents the descriptive statistical results of the study, reflecting the distribution characteristics and economic implications of each variable. Among them, the mean of the core explanatory variable location entropy (qws) is 0.8249, with a standard deviation of 0.5917, indicating significant differences in the degree of industrial agglomeration of manufacturing industries in different regions. The higher the entropy value of the location, the higher the degree of manufacturing agglomeration in the region. The highway density (mean 95.39) and railway density (mean 2.656) in the explanatory variables reflect the level of regional transportation infrastructure.

Table 1. Descriptive statistics

	Mean	Std. Dev.	min	Median	max
Qws	0.8249	0.5917	0.1368	0.5934	2.6861
Highway density	95.3919	53.3028	5.7391	91.8014	226.9963
Railway density	2.6560	1.4943	0.6376	2.5271	5.9570
Lngdp	10.9351	0.4316	10.0028	10.8829	12.1547
Proportion of total import and export volume to GDP	0.2525	0.2549	0.0076	0.1402	1.2576
Proportion of the secondary industry to GDP	0.4091	0.0820	0.1583	0.4161	0.5732
Lnwage	11.2143	0.3276	10.5532	11.2084	12.2666
Urbanization rate	0.6046	0.1235	0.2393	0.5968	0.8958

3.2. Benchmark Regression Analysis

Table 2. Benchmark regression analysis

VARIABLES	qws	qws
	(1)	(2)
Highway density	0.0031***	0.0018**
	(0.0008)	(0.0007)
Railway density	0.0865***	0.0426**
	(0.0213)	(0.0191)
Lngdp		-0.0369
		(0.1276)
Proportion of total import and export volume to GDP		0.0016
		(0.1068)
Proportion of the secondary industry to GDP		0.3038
		(0.2354)
Lnwage		-0.1975
		(0.1275)
Urbanization rate		3.6162***
		(0.4172)
Constant	0.4078***	1.0230
	(0.0742)	(1.7084)
Observations	310	310
Adjusted R-squared	0.0460	0.3234
YEAR FE	YES	YES
PROVINCE FE	YES	YES

Table 2 shows the results of benchmark regression, analyzing the impact of each variable on location entropy (qws). In both models without and with the addition of control variables, highway density showed a significant positive correlation, with regression coefficients of 0.0031 and 0.0018, respectively, indicating that an increase in highway density helps to enhance regional manufacturing agglomeration. The railway density is significantly positively correlated without the addition of control variables (coefficient 0.0865), and the coefficient decreases to 0.0426 with the addition of control variables, but still maintains significance, indicating that railway density is also an important factor affecting location entropy. It can be seen that the manufacturing industry in different regions is driven to varying degrees by different types of transportation infrastructure, with highways playing a more significant role compared to railways.

3.3. Robust Test

3.3.1 Add explanatory variable lagged by one period

Table 3. Robust test (add explanatory variable lagged by one period)

VARIABLES	qws
	(1)
L. Highway density	0.0014**
	(0.0007)
L. Railway density	0.0441**
	(0.0186)
Lngdp	0.1185
	(0.1328)
Proportion of total import and export volume to GDP	0.0812
	(0.1227)
Proportion of the secondary industry to GDP	0.0812
	(0.2317)
Lnwage	-0.2205*
	(0.1304)
Urbanization rate	2.9160***
	(0.4374)
Constant	0.0665
	(1.8152)
Observations	279
Adjusted R-squared	0.2282
YEAR FE	YES
PROVINCE FE	YES

Table 3 shows the impact of lagged variables on location entropy (qws) as a result of robustness testing. It can be concluded that the lagged highway density has a significant positive impact on location entropy, with a regression coefficient of 0.0014, indicating that the improvement of transportation infrastructure has a sustained driving effect on subsequent manufacturing agglomeration. The railway density with a lag of one period is also significantly positively correlated, with a regression coefficient of 0.0441, further verifying the key role of railway density in promoting manufacturing agglomeration.

3.4. Replace explanatory variables

The regression results using replacement variables for robustness testing are shown in Table 4, further verifying the impact of variables on location entropy (qws). The main findings are as follows: there is a significant positive correlation between highway transportation capacity, with a regression coefficient of 0.7484, indicating that the improvement of highway transportation capacity has a significant promoting effect on regional manufacturing agglomeration; The railway transportation capacity also showed a significant positive correlation, with a regression coefficient of 0.4668, further indicating that railway transportation capacity is an important factor affecting manufacturing agglomeration.

Table 4. Robust test (replace explanatory variables)

VARIABLES	Qws
	(1)
Highway transportation capacity	0.7484*
	(0.3982)
Railway transportation capacity	0.4668*
	(0.2730)
Lngdp	-0.0065
	(0.1252)
Proportion of total import and export volume to GDP	0.0740
	(0.1078)
Proportion of the secondary industry to GDP	0.3117
	(0.2313)
Lnwage	-0.1798
	(0.1296)
Urbanization rate	3.5689***
	(0.4508)
Constant	0.6245
	(1.6970)
Observations	310
Adjusted R-squared	0.3014
YEAR FE	YES
PROVINCE FE	YES

3.5. Heterogeneity Analysis

Table 5. Heterogeneity analysis

VARIABLES	eastern (1) qws	central (2) qws	western (3) qws
Highway density	0.0023	0.0045***	0.0002
	(0.0015)	(0.0014)	(0.0006)
Railway density	0.0107	0.0336	-0.0740**
	(0.0460)	(0.0273)	(0.0353)
Lngdp	0.1992	0.5620**	-0.0976
	(0.2884)	(0.2330)	(0.1124)
Proportion of total import and export volume to GDP	-0.2129	0.4049	-0.5384***
	(0.1593)	(0.4629)	(0.1444)
Proportion of the secondary industry to GDP	0.2138	-0.4130	0.7958***
	(0.5795)	(0.4020)	(0.1926)
Lnwage	-0.4574	-0.7286**	-0.1530*
	(0.3275)	(0.3186)	(0.0898)
Urbanization rate	6.4377***	-0.6634	0.2786
	(0.8534)	(1.1931)	(0.7511)
Constant	-0.2434	2.5702	2.7700**
	(4.2604)	(3.8051)	(1.2550)
Observations	120	90	100
Adjusted R-squared	0.5662	0.2890	0.3015
YEAR FE	YES	YES	YES
PROVINCE FE	YES	YES	YES

Table 5 shows the heterogeneous effects of variables in the eastern, central, and western regions on location entropy (qws). From this, it can be concluded that the impact of highway density on location entropy is positive in the eastern, central, and western regions, and there is a significant positive correlation in the central region, indicating that the increase in highway density has a more significant driving effect on manufacturing agglomeration in the central region. This may be due to the relatively complete road network in the central region, which improves the mobility of production factors, reduces transportation costs for enterprises, and thus attracts more manufacturing enterprises to gather.

The railway density is positively correlated in the eastern and central regions, but has not reached a significant level, indicating that railway transportation promotes the agglomeration of manufacturing industries in the eastern and central regions. There is a significant negative correlation (coefficient of -0.0740) in the western region, reflecting that the increase in railway density may lead to a dispersed industrial layout in the western region.

4. Conclusion

In summary, the construction of transportation infrastructure promotes the agglomeration of China's manufacturing industry. Highway density has a positive impact on manufacturing agglomeration in the eastern, central, and western regions, while railway density has a positive impact on the eastern and central regions. However, railway density has a negative impact on manufacturing agglomeration in the western region.

Based on this, this article proposes corresponding policy recommendations: firstly, increase investment in highways, and the central region should continue to improve the highway network to further strengthen the driving effect of highway density on manufacturing agglomeration. While increasing the density of highways in the eastern and western regions, attention should be paid to the rational planning and layout of the highway network to avoid the weakening of industrial agglomeration effects caused by excessive dispersion. Secondly, optimize railway construction and carry out more refined planning for railway construction, especially in areas with a relatively complete railway network. Attention should be paid to improving railway operation efficiency and service quality, rather than simply increasing density. At the same time, the western region should carefully consider the impact of railway construction on industrial layout, and avoid resource dispersion caused by excessive investment. Thirdly, promote regional coordinated development, strengthen transportation connections between the eastern, central, and western regions, and promote the free flow and rational allocation of production factors between regions through the construction of an efficient, comprehensive transportation system. For the western region, more preferential policies can be introduced to encourage manufacturing enterprises to cluster and develop, forming economies of scale.

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