THE IMPACTS OF TRANSPORT INFRASTRUCTURE ON MANUFACTURING AGGLOMERATION IN WESTERN CHINA

ผลกระทบของโครงสร้างพื้นฐานด้านการขนส่งต่อการรวมตัวด้านการผลิตในภาคตะวันตกของประเทศจีน

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Abstract

This paper makes empirical analysis on transport infrastructure's impacts on manufacturing agglomeration. The study finds that there is a consistency in spatial distribution of transport infrastructure and manufacturing agglomeration. Different types and levels of transport infrastructure show significant differences in the degree of their facilitation for manufacturing agglomeration. Highway facilities show greater facilitation for manufacturing agglomeration than railway facilities. First-class highway plays the most important roles in facilitating manufacturing agglomeration, followed by second-class highway. The more low-grade highways are built, the more adverse impacts they have on manufacturing agglomeration. Though expressway greatly facilitates the manufacturing agglomeration, the impacts are not significant. Transport infrastructure show more significant impacts on manufacturing agglomeration in the regions with higher marketization.

Keywords: Western China, Transport infrastructure, Manufacturing agglomeration, Location entropy

บทคัดย่อ

บทความนี้ได้ทำการวิเคราะห์เชิงประจักษ์เกี่ยวกับผลกระทบของโครงสร้างพื้นฐานการขนส่งที่มีต่อการรวมตัวด้านการผลิต จากการศึกษาพบว่า มีความสอดคล้องสำหรับการกระจายตัวของโครงสร้างพื้นฐานด้านการขนส่งและการรวมตัวด้านการผลิต รูปแบบ และระดับของโครงสร้างพื้นฐานด้านการขนส่งที่แตกต่างกันแสดงถึงความแตกต่างอย่างมีนัยสำคัญในระดับของการอำนวยความสะดวกให้กับการรวมตัวด้านการผลิต ทางหลวงและสิ่งอำนวยความสะดวกที่เกี่ยวข้องสามารถอำนวยความสะดวกให้กับการรวมตัวด้านการผลิตมากกว่ารถไฟ ทางหลวงชั้นหนึ่งมีบทบาทที่สำคัญที่สุดในการอำนวยความสะดวกให้กับการรวมตัวด้านการผลิต ตามด้วยทางหลวงชั้นสอง ทางหลวงที่มีคุณภาพระดับด้อยลงยิ่งส่งผลกระทบในทางลบต่อการผลิตมากขึ้น ถึงแม้ว่าทางพิเศษจะเพิ่มความสะดวกต่อการรวมตัวด้านการผลิต

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แต่ผลกระทบนั้นไม่ได้มีนัยสำคัญ โครงสร้างพื้นฐานด้านการขนส่งมีผลกระทบอย่างมากต่อการรวมตัวด้านการผลิตในภูมิภาคที่มีการตลาดเพิ่มขึ้น

คำสำคัญ: ภาคตะวันตกของจีน โครงสร้างพื้นฐานด้านการขนส่ง การรวมตัวด้านการผลิต เอนโทรปีสถานที่

Introduction

In this paper, Western China refers to 12 provinces, autonomous regions or municipality, including Chongqing, Sichuan, Guizhou, Yunnan, Guangxi, Shaanxi, Gansu, Qinghai, Ningxia, Tibet, Xinjiang, and Inner Mongolia. It covers 6.81 million square kilometers of areas (about 71% of China's total land territory) and is home to approximate 350 million people (28% of China's total population). Western China shares border with 12 countries including Russia, Mongolia, kazakhstan, tajikistan, Pakistan, kyrgyzstan, Afghanistan, India, Nepal, Bhutan, myanmar, Vietnam, and Laos. It has more than 18,000 kilometers of land boundary, accounting for 91% of China's total land border. Being across the sea with several Southeast Asian nations, it has 1,595 kilometers of continental coastline, accounting for about 10% of China's total coastlines. Most regions in this vast territory remain economically underdeveloped.

To accelerate the economic development of its western region, China implemented the West Development Strategy and massive transport infrastructure construction in its western region since 2000. Both China's operating highway mileage and railway mileage keep sustained growth in recent years. Based on the China Transportation Statistical Yearbook (2001-2015), the operating highway mileage and railway mileage were 655,654 km and 28,474 km respectively in 2000 and increased to 1,793,877 km and 43,536 km respectively in 2014, increasing respectively by 1.74 times and 0.53 times over 2000. Meanwhile, the labor costs in China's eastern coastal region keep increasing. The manufacturing industry began to shift from eastern to western region. As a result, Chinese government established 3 demonstration areas for receiving industrial shift in western region. The manufacturing sector also shows a trend of rapid development in Western China. Based on the China Statistical Yearbook (2001-2015), the added value of manufacturing sector in western China was 287.269 billion yuan in 2000 and increased to 1.927494 trillion yuan, 5.71 times higher than that in 2000.

During the industrial agglomeration process, does transport infrastructure pose impacts on industrial agglomeration? How are the impacts? These are practical and theoretical issues that need to be addressed.

Literature Review

Location theory and new economic geography theory study the influence of transport infrastructure on industrial agglomeration from the perspective of transportation cost. Thünen (1826) and Weber (1909) claimed that transport costs affected the location of enterprises. Krugman

(1991) stated that industrial agglomeration was the result of both transport costs and scale economy. Holl (2004) held that new expressway had an impact on the spatial distribution of manufacturing industry. Tsekeris & Vogiatzoglou (2014) claimed that improving road investment helped facilitate manufacturing agglomeration. Chinese scholars also analyzed via empirical analysis the impact of transport infrastructure on China's industrial agglomeration from the perspective of national and eastern regions. For example, Ren & Zhang (2016) found that there was a consistency in spatial distribution between transport infrastructure and manufacturing development. Ling, Liu & Zheng (2013) claimed that transport cost was an influencing factor for industrial agglomeration. Wei, Li & Zhang (2014) found that increased density of transport infrastructure helped facilitate industrial agglomeration. Liu & Wang (2014) concluded that railway had more positive effect on manufacturing agglomeration than highway.

Existing researches do not cover the impacts of transport infrastructure on industrial agglomeration in western China. And existing researches lack systematic variables. To take selection of variables for transport infrastructure as example, the researches mainly focus on highway or railway rather than their classifications. Those researches do not cover the impacts of transport infrastructure on manufacturing agglomeration from the perspective of regulated variables. Lack of some key control variables affects to certain extent the accuracy of conclusions. Therefore, it becomes necessary to make systematic research on the impacts of transport infrastructure on manufacturing agglomeration.

Theoretical analysis and research hypothesis

1. Spatial distribution relationship between transport infrastructure and manufacturing agglomeration

Transport cost is an important factor for industrial agglomeration. Thünen (1826) claimed that transport cost was a key factor for site selection of agricultural enterprise. Weber (1909) stated that saving transport cost and labor cost were key motivations for site selection of industrial enterprises. Krugman & Venables (1995) found that there was a consistency in spatial distribution between transport cost and industrial agglomeration. Other scholars have also noted the correlation between transport infrastructure and industrial agglomeration in China. For example, Ren & Zhang (2016) have noted that there is a consistency in spatial distribution between transport infrastructure and industrial development. Ji & Wen (2016) concluded that transport infrastructure facilitates the industrial agglomeration. Thus, this paper proposes the following hypothesis:

H1: There is a consistency in spatial distribution between transport infrastructure and industrial agglomeration in western China.

2. Facilitation of different types and grades of transport infrastructure for manufacturing agglomeration

Different types and grades of transport infrastructure show different facilitation for manufacturing agglomeration due to their diverse transport function focuses. Liu (2010) found that highway played bigger roles than waterway in driving regional economic growth. Jiang & Jiang (2012) found that railway outweighed highway in promoting industrial growth. Ye & Wang (2013) have noted that the lower grade the highways are built, the fewer roles they will play on driving economic growth. Liu & Wang (2014) found that railway outweighed highway in facilitating industrial agglomeration. Therefore, this paper proposes the following hypothesis:

H2: Different types of transport infrastructure show significantly different facilitation for manufacturing agglomeration in western China.

H3: Different grades of transport infrastructure show significantly different facilitation for manufacturing agglomeration in western China.

3. Regulating effects of marketization in transport infrastructure's impacts on manufacturing agglomeration

Western China is more affected by the planned economy and has relatively low degree of marketization, which is not good for industrial agglomeration. Depner & Bathelt (2005) found that non-market behavior has negative impacts on automobile industry agglomeration. Xia & Wang (2015) noted that reducing the proportion of state-owned economy helped facilitate industrial agglomeration. Thus, the higher degree of marketization, the more facilitation it has for industrial agglomeration. The marketization has regulating effects on industrial agglomeration. As a result, this paper proposes the following hypothesis:

H4: Transport infrastructure in western China show more significant facilitation for manufacturing agglomeration in areas with high degree of marketization.

Empirical analysis

1. The selection and definition of variables

1.1 Independent variables

Transport infrastructure includes railway, highway, waterway, air travel and pipeline facilities. Air travel costs are too high, and pipeline facilities are not the main mode of transport for manufacturing industry. Most areas of western China are far away from sea and thus waterway transport is very limited. Thus, this paper selects railway and highway as the proxy variables of transport infrastructure. Based on the methodology of Ji & Wen (2016), highway density and railway density are selected to represent transport infrastructure. Their specific definitions are as follows:

(1) Highway density: it refers to the highway mileage per hundred square kilometers of each province in western China. Given that the logarithm of location entropy becomes dependent variable, the highway after logarithm is used as independent variable, as signified by

lnhwydy. To verify the different impacts of different grades of transport infrastructure on manufacturing agglomeration, the highway density is further classified as the densities of expressway, first-class highway, second-class highway and other grade highway, which are signified by *expydy, hwy-Idy, hwy-IIdy and hwy-Ody* respectively.

(2) Railway density: it refers to the railway mileage per hundred square kilometers of each province in western China. The railway after logarithm is used as independent variable, as signified by *lnrlwydy*[1].

1.2 Dependent variable

(1) Location entropy: It is an indicator to measure the degree of industrial agglomeration from the regional perspective. It has advantages such as comprehensiveness, calculated value and good realistic fitting. Based on the methodology of Liu & Wang (2014), this paper uses location entropy to measure the degree of industrial agglomeration. The specific calculation is as follows:

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

Where qws_{ij} represents the location entropy of industry *i* in a given region *j*. q_j refers to relevant indicators (such as output value, number of enterprise and employment figure) of all industries in a region *j*. q_{ij} represents relevant indicators of industry *i* in the region *j*. q refers to relevant indicators of all industries in China. q_i represents relevant indicators of the industry *i* in China. Given that the industrial agglomeration is analyzed from the perspective of factor agglomeration, the employment figure is selected as the basic indicator for calculating location entropy. Since the value of location entropy is less than 1, the logarithm of location entropy is selected as the dependent variable.

1.3 Regulated variable

(1) Degree of marketization: Existing researches do not use marketization as regulated variable to analyze the impacts of transport infrastructure on industrial agglomeration. This paper attempts to conduct analysis by using marketization as a regulated variable. Given that western China has relatively low degree of marketization and a large proportion of state-owned economy. Based on the methodology of Wang (2012), the contrary indicator of marketization—the proportion of employees in state-owned economy against the total number of employees in a region is used as the proxy variable of marketization, as signified by *dm*.

1.4 Control variable

(1) Scale economy: Marshall (2012) claimed that external scale economy was a key factor for industrial agglomeration. Krugman & Venables (1995) stated that internal scale economy was a key factor for industrial agglomeration. Liu & Wang (2014) concluded through empirical analysis that regional scale (total assets of industrial enterprises in a region/number of enterprises) helped facilitate

[1] Though the railway is classified as three grades, Class I, II and III, this paper does not consider the grades of railway due to lack of data on different grades of railway in relevant provinces.

manufacturing agglomeration. This paper selects regional scale as the proxy variable of scale economy, as represented by *se*.

(2) Research and Development funds (R&D): The more investment is made in research and development, more professional talents are attracted into a region. As a result, it helps attract more enterprises and facilitate industrial agglomeration. Liu & Chai (2011) found that R&D activities have significant correlation with industrial agglomeration. Liu & Wang (2014) noted that R&D input intensity (ratio of R&D input to GDP) has significantly positive correlation with manufacturing agglomeration. This paper uses the R&D input intensity as the proxy variable of R&D, as shown by *rd*.

(3) Labor cost: Weber (1909) and Lösch (1940) claimed that labor cost had significant impacts on site selection of industrial enterprises. Western China has relatively low labor cost and helps facilitate industrial agglomeration. This paper uses annual average salary of employees in each province of western China as the proxy variable for labor cost, as represented by *lc*.

(4) Foreign trade: Shao (2012) concluded through empirical analysis that foreign trade accelerates the manufacturing agglomeration in China. This paper uses the ratio of total import and export volume to the GDP of each province in western China as the proxy variable for foreign trade, as represented by *ft*.

(5) Consumer demand: The stronger purchasing power the consumers have in a region, it is more likely to attract enterprises into the region, which as a result facilitate the industrial agglomeration. Krugman & Venables (1995) claimed that enterprises prefer to locate in the areas with huge demands. Xu (2011) found that consumer demand helped facilitate industrial agglomeration. This paper uses the per capita GDP of each province in western China as the proxy variable for consumer demand, as represented by *cd*.

(6) Human capital: The higher the human capital in a region, it is easier for new enterprises employ the talents they need. Xu (2011) found that human capital significantly facilitated the agglomeration of transport equipment manufacturing. This paper uses the per capita education year of each province in western China as the proxy variable for the level of human capital in a region, as represented by *hc*.

2. Data sources

This paper analyzes relevant data of transport infrastructure and manufacturing development in 12 provinces in western China over 10-year (2003-2013) period. The primary data are from *China Statistical Yearbook, China Economic and Social Development Statistical Database, China Transport Statistical Yearbook,* and *China Population & Employment Statistics Yearbook.*

3. Econometric model

Basic panel model and the panel model with regulating effect are built to analyze the impacts of transport infrastructure on manufacturing agglomeration in western China.

Basic panel model:

$Y_{it} = \beta_0+\beta_1X_{1it}+\beta_2X_{2it}+\mu_i+\varepsilon_{it}$

The panel model with regulating effect:

$Y_{it} = \beta_0+\beta_1X_{1it}+\beta_2X_{2it}+\beta_3X_{3it}+\beta_4X_{1it}*X_{3it}+\mu_i+\varepsilon_{it}$

Where, i and t represent respectively the code and year of each province in western China. μ_i refers to unobservable individual effect. ε_{it} represents random error term. β_0 refers to constant term. β_1-β_4 represent the coefficients of the corresponding variables. Y_{it} refers to dependent variable of manufacturing agglomeration in each province of the year. X_1 refers to independent variable of transport infrastructure. X_2 represents a series of control variables affecting the manufacturing agglomeration. X_3 represents regulated variable affecting manufacturing agglomeration. The interaction between transport infrastructure and marketization is used to represent the regulating effects of transport infrastructure on manufacturing agglomeration in western China.

4. Hypothesis testing

EViews7.2 software is used in the analysis. The fixed effect model is adopted based on the test results of Hausman. The specific regression results are shown in Table 1:

Table 1 Regression results of transport infrastructure's impacts on manufacturing agglomeration in western China

	Model (1) Fixed Effect	Model (2) Fixed Effect	Model (3) Fixed Effect	Model (4) Fixed Effect	Model (5) Fixed Effect
lnhwyd	0.1380***			0.1270***	
	(0.0309)			(0.0353)	
lnrlwydy		0.0947**			-0.1880**
		(0.0410)			(0.0916)
*lnhwyd*dm*				-0.0397*	
				(0.0225)	
*lnrlwydy*dm*					-0.1880**
					(0.0916)
dm	-0.0594**	-0.1480**	-0.0350**	-0.0476**	-0.3311**
	(0.0275)	(0.0738)	(0.0184)	(0.0181)	(0.1282)
expydy			0.00133		
			(0.00484)		
hwy-ldy			0.0929*		
			(0.0547)		

Table 1 Regression results of transport infrastructure's impacts on manufacturing agglomeration in western China (cont.)

	Model (1) Fixed Effect	Model (2) Fixed Effect	Model (3) Fixed Effect	Model (4) Fixed Effect	Model (5) Fixed Effect
hwy-lldy			0.0339*		
			(0.0202)		
hwy-Ody			-0.0025***		
			(0.0007)		
se	0.0036**	0.0037**	0.00323*	0.00360**	0.00385**
	(0.0017)	(0.0018)	(0.00179)	(0.00166)	(0.00180)
lc	-0.0977***	-0.0423*	-0.0125**	-0.0136**	-0.0482**
	(0.0240)	(0.0233)	(0.0055)	(0.0049)	(0.0232)
cd	0.0128*	0.0036*	0.0110*	0.0133*	0.0019*
	(0.0075)	(0.0022)	(0.0066)	(0.0077)	(0.0011)
hc	0.0182	0.0077	0.0194	0.0256	0.0101
	(0.0301)	(0.0326)	(0.0321)	(0.0325)	(0.0332)
ft	0.0420***	0.0807*	0.1011*	0.0330**	0.0932*
	(0.0143)	(0.0481)	(0.0623)	(0.0141)	(0.0534)
rd	0.0704*	0.0518*	0.0686*	0.0750*	0.0429*
	(0.0374)	(0.0303)	(0.0414)	(0.0382)	(0.0259)
Constant	0.3400	-0.1790	-0.0829	0.370	-0.385
	(0.2550)	(0.2420)	(0.238)	(0.260)	(0.259)
Observations	117	117	117	117	117
R-squared	0.483	0.392	0.457	0.485	0.417

Notes: The value in parentheses is the standard deviation. ***, ** and * refer to the significance level of 1%, 5% and 10% respectively.

4.1 Impact analysis of different types of transport infrastructure on manufacturing agglomeration in western China

The regression results of model (1) and (2) show that the coefficient of highway density and railway density are significantly positive, indicating that highway and railway have significantly positive impacts on manufacturing agglomeration. H1 is thus verified. The coefficient of highway density is higher than that of railway density, indicating highway outweighs railway in facilitating manufacturing agglomeration. H2 is thus verified. This is contrary to the conclusions of Liu & Wang (2014), reflecting the particularity of manufacturing agglomeration in western China.

4.2 Impact analysis of different grades of transport infrastructure on manufacturing agglomeration in western China

The regression results of model (3) show that the coefficients of first-class highway and second-class highway are significantly positive, indicating that first-class highway and second-class highway have significant facilitation for manufacturing agglomeration. However, the first-class highway outweighs second-class highway in facilitating manufacturing agglomeration. The coefficient of expressway density is positive but is not significant, indicating that the expressway does not show significant facilitation for manufacturing agglomeration. One possible reason may be that the expressway lags relatively behind over a long period of time and the expressway toll is too high, making its potential not put into full play. The coefficient of other low grade highway is significantly negative, indicating that the higher density of low-grade highways, the more negative impacts they have on manufacturing agglomeration. One possible reason may be low speed on low-grade highway drives up transport time cost. As a result, more low-grade highways are built, the more negative impacts they have on manufacturing agglomeration. Therefore, H3 is verified.

4.3 Impact analysis of transport infrastructure with regulatory effects on manufacturing agglomeration in western China

The regression results of model (4) and (5) show that highway density and railway density have significantly negative correlation with marketization. The degree of marketization is represented by a reverse indicator. The lower the value is, the higher degree of marketization it represents. This shows that the higher degree of marketization in western China, the more facilitation transport infrastructure has on manufacturing agglomeration. Thus, H4 is verified.

4.4 Impact analysis of control variables on manufacturing agglomeration in western China

In addition to their different impacts, the conclusion that the impacts of control variable from above model on manufacturing agglomeration is consistent. That is, scale economy, consumer demand, foreign trade, research and development funds all show significantly positive impacts on manufacturing agglomeration in western China. Labor cost has significantly negative impacts, indicating that the

lower labor cost is, the more facilitation it has for manufacturing agglomeration. The coefficient of human capital is positive and is not significant, showing that the manufacturing agglomeration in western China may still be driven by low labor cost. The role of human capital has not brought into full play.

Conclusions

The main conclusions are as follows:

1. There is a consistency in spatial distribution between transport infrastructure and manufacturing agglomeration in western China. Transport infrastructure facilitates the manufacturing agglomeration in western China.

2. Different types of transport infrastructures show significant difference in facilitating manufacturing agglomeration in western China. Highway outweighs railway in facilitating manufacturing agglomeration, which is contrary to the conclusions made by previous researches that railway outweighs highway in facilitating from national and eastern region perspective, indicating the particularity of manufacturing agglomeration in western China.

3. Different grades of transport infrastructures show significant difference in facilitating manufacturing agglomeration in western China. First-class highway shows biggest positive impacts on manufacturing agglomeration, followed by second-class highway. Other low grade highways have slow speed and high transport time. As a result, the more low-grade highways are built, the more negative impacts they have on manufacturing agglomeration. Though expressway greatly facilitate the manufacturing agglomeration, such facilitation is not significant due to high toll of expressway.

4. Marketization has significant regulating effects during the impacts of transport infrastructure on manufacturing agglomeration in western China. Transport infrastructure has more significant impacts on manufacturing agglomeration in the areas with higher degree of marketization.

5. Scale economy, R&D funds, consumer demand and foreign trade all show significantly positive impacts on manufacturing agglomeration in western China. Low labor cost accelerates the manufacturing agglomeration in western China. However, the manufacturing agglomeration in western China may still be driven by low labor cost. The role of human capital has not brought into full play.

This paper would like to put forward the policy advice as follows:

1. Western China should make full use of its geographical advantages, ethnic identity and frontier position to develop comprehensive transport system featuring interconnection home and broad by railway and high grade highway and covering urban and rural areas. Efforts should also be made to promote the mobility of production factors such as capital, technology and labor so as to facilitate manufacturing agglomeration.

2. The construction of expressway should be accelerated in the future. However, the expressway toll should be gradually reduced

or even cancelled to bring into full play of expressway in facilitating manufacturing agglomeration.

3. The construction of first-class and second-class highways should be accelerated in the future. In addition, low grade highways need to be renovated or upgraded.

4. More efforts need to be made to facilitate manufacturing agglomeration in western China through multiple channels, such as enhancing marketization, making scale economy bigger, expanding consumer demand, making full use of low labor cost, nurturing human capital, expanding foreign trade, increasing R&D funds etc.

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