Empirical Research on Reasonableness in Spatial Distribution and Investment of Transportation Infrastructure in China

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Abstract—From the perspective of manufacturing location choice, this paper analyzed and tested the reasonableness in spatial distribution and investment of transportation infrastructure in China by developing spatial econometrics model etc., and it found that the transportation infrastructures in China are excessively concentrated in its eastern and central regions due to excessive concentration of transportation investment in these areas over the years. At the same time, the spatial econometric model shows that transportation infrastructure stock has a very significant influence to manufacturing location in 31 provinces in China as well. So it concluded that there is too much unreasonableness in the spatial distribution and allocation of investment of transportation infrastructure in China, so China should focus immediately on increasing transportation investment in the western region, and pay more attention to the development in the undeveloped regions by new lines to induce manufacturing sites located in those areas to improve the endogenous economic development power of the undeveloped regions to reduce regional disparities.

Keywords—empirical research; transportation infrastructure; transportation investment; reasonableness

I. INTRODUCTION

Transportation infrastructure including road, rail, bridges, tunnels, airports, ports, pipelines and so on is a kind of public resources, and it can be shared in a certain area and provide transportation services for product transportation and residents travel. Because this variety of public resources could change the distance between economic factors in space and time and it can result in some changes in return of economic factors, transportation infrastructure will ultimately affect the spatial distribution of economic activity (Yang Libo, Liu Xiaoming, 2006; Yao Ying, 2009). Currently, the researches in China pay most attention to the supply and the location in facilities and fail to effectively combine accessibility with equity (Gu Mingdong, Yinhai Wei, 2010). In fact, the rationality of public facilities in spatial distribution is not only connected with whether various structural elements supplied by it can meet the needs of peripheral people but also directly with the spatial distribution of industry. But so far, few people studied the reasonability of transportation infrastructure in spatial distribution from the perspective of regional disparities and the spatial distribution of industries which result from transportation infrastructure. However, the problem will undoubtedly worth being explored deeply because the regional disparity is growing in China, and the government has put huge amount of investment on the transportation infrastructure to cope with the world financial crisis in 2008 to stimulate economic recovery. At the same time, the allocation in transportation investment can directly affect spatial distribution of transportation infrastructure in the future, so it can impact broadly on the spatial distribution of economic activities including the manufacturing location choice. One of the prerequisites for effective transportation investment policy is accurate grasp in the distribution of transportation infrastructure in reality. So it is practically significant analyzing reasonableness of the spatial distribution of transportation infrastructure in China before 2008, and whether the Chinese government could reduce regional disparities by reasonable distribution in new infrastructure investment. Krugman (Krugman, 1991a) find that a country can endogenously become differentiated into an industrialized core and an agricultural periphery because of manufacturing firms tend to located in the region with larger demand, but the location of demand itself depending on the distribution of manufacturing. Emergence of a core-periphery pattern depends on transportation costs, economics of scale, and the share of manufacturing in national income, and the development level of manufacturing, to a large extent, reflects the level of capital stock in a region (Krugman, 1991b), while the manufacturing assets in 2006 account for 74.41% of total assets and regional disparities are mainly from the second industry in China where the manufacturing sector is dominant (Fan Jianyong, 2008), and Ren and Zhang (Xiaohong Ren, Zongyi Zhang, 2010, 2011) found that transportation infrastructure is one of the determinants in the location choice of manufacturing enterprises as well as capital flows in China, so this paper will analyze and test the reasonableness of transportation infrastructure in spatial distribution in China by developing a spatial econometrics model etc. from the perspective of manufacturing location choice, and examine the impact of allocation in transportation investment in recent years as well.

II. SPATIAL DISTRIBUTION AND ITS REASONABLENESS OF TRANSPORTATION INFRASTRUCTURE IN CHINA

A. Spatial Distribution of Transportation Infrastructure

This paper chooses 2002 and 2006 data to examine spatial distribution of transportation infrastructure in China. Based on that rail, road, and inland waterway transport play important role in China's economic activities, relevant researches mostly use one or two of the transportsations to represent transport infrastructure level in a region (such as: Holl, 2004), while its representation is questionable, so this paper choose three indicators including rail, road and inland waterway transport to characterize the composite index of stock of transportation infrastructure. Since the roles played by the three transport...
facilities in our economic are different, and the direct sum of length of the three transport facilities cannot reflect effectively the respective roles, this paper chooses weighted density of the transportation routes of the provinces to characterize the composite index of stock of transportation infrastructure. Among them, the transport line density equals the ratio of the weighted sum of the length of the three transportation routes to the regional area which they are located in, while the weight of various transportation facilities length is equal to the proportion of its annual freight to the annual total freight. According to the "China Statistical Yearbook", this paper calculates the physical stock of transportation infrastructure in China's 31 provinces except Hong Kong, Macao and Taiwan in 2002 and 2006, and looks it as a composite index to reflect the level of transportation infrastructure. Thus China's 31 provincial transportation network densities in 2002 and 2006 are obtained, see Figure 1.

After comparative analysis, we found that there is great heterogeneity in level of transport infrastructure in China's provinces between in 2002 and 2006. Among them, the corresponding indicators of Beijing, Shanghai, Tianjin, Jiangsu and Guangdong in the forefront, where the densities of transportation routes are much higher than the national average. While the corresponding indicators of Guizhou, Qinghai, Tibet, Xinjiang and Inner Mongolia and other western provinces are far below the national average. Meanwhile, China's transportation network density in 2006 has a relatively large increase based on 2002. Among them, the transportation network density of Henan and Chongqing increased significantly, and that of Guangdong and Hainan relatively slightly decreased. But spatial distribution of transportation infrastructure in China is still of great imbalance, there are still a large gap among the provinces, fluctuations in 2006 between the province domains are more than in 2002, so the gap of level of transportation infrastructure among provinces in China was expanded further.

According to the above data, we map fifth bitmaps of spatial distribution of transportation infrastructure stock for China's 31 provinces by Geoda095i, see Figure 2 and 3. It can be seen that geographic distribution of transportation infrastructure shows great different in China in 2002 and a significant gradient from the eastern, to the central, and then to the western region that is the stock of transportation infrastructure in the eastern region was significantly higher than it in the central region, and the stock of transportation infrastructure in the central region was significantly higher than the stock in the western region. In 2006, the fifth bitmap on geographical distribution of transportation infrastructure also showed a similar gradient from the eastern to the central, and then to the western region in 2002. By comparing Figure 2 and Figure 3, it can also be found that transportation infrastructure in China has a trend of further concentration to the provinces in coastal and central regions.

B. The Reasonableness of Spatial Distribution of Transportation Infrastructure in China

1) Excessive Concentration on Spatial Distribution of Transportation Infrastructure Leads to Excessive Concentration in Manufacturing

The traditional location theory and new economic geography advocate transportation infrastructure can change the relative importance of concentration (market size and agglomeration economies) and dispersion forces (elements of cost and competition), and the reducing transport costs and factor mobility costs can increase the factor mobility, which ultimately affects the spatial distribution of manufacturing industry (such as, Weber, 1929; Losch, 1939; Krugman, 1991b). Improving the level of transportation infrastructure can change the output efficiency of enterprises, and change the performance of the transport network and transport costs (commuting costs and transportation costs), which leads to the corresponding changes for labor, capital and technology, manufacturing location and concentration economic effects, and then it has an impact on the spatial distribution of
economic activities which has been supported by empirical research, such as Ren and Zhang (2010). In the examination of causal relationship between manufacturing industry and the stock of transport infrastructure of each province in China, it was found that the two has a strong consistency in the spatial distribution, and the spatial concentration of the transportation infrastructure is one of the most significant factors resulting in concentration of manufacturing industries. As transportation infrastructure presents a very significant gradient from the eastern to the central, and then to the western regions in China, what's more, transport infrastructure has a trend of further concentration to these regions, it probably could aggravate further differentiation of the manufacturing location. There are many means measuring industrial agglomeration, in which Lorenz curve and Gini coefficient is more common. Krugman (1991b) used space Gini coefficient (spatial Gini coefficient) to measure the degree of concentration on U.S. manufacturing. Considering the availability of data and analytical convenience, we selected two time points in 2002 and 2006, referred to Zhao Wei, Zhang Sui (2009) method, used the proportion of gross output value of manufacturing industry in the provinces to the country's gross output value of manufacturing industry to measure the degree of agglomeration, then we get the trend map on concentration level of manufacturing industry in China's 31 provinces in 2002 and 2006, see Figure 4.

![Figure 4. Trend of Concentration Level of Manufacturing in China](image)

It can be seen from Figure 4, China's manufacturing industry was of a high concentrated both in 2002 and 2006, and it presents a very significant gradient from the eastern, to the central, and then to the west region, and this trend is furthering. Ren and Zhang (2011) analyze how improving of the level of the transport infrastructure would impact capital flows which is another form of industrial location choice, then they found that the gap in transportation infrastructure among provinces in China is one of the determinants for the inter-regional capital flows, and it probably results in the change in regional disparities in China.

Use investment intensity in the manufacturing to measure the regional concentration trends in manufacturing, we can get quantile map of manufacturing investment intensity in China in 2006, see Figure 5. Comparing Figure 5 and Figure 3, we can find that there is consistent in concentration of manufacturing with the spatial distribution of transportation infrastructure stock in 31 provinces in China, that is, higher concentration in the eastern coastal areas except Hainan, followed by the central areas, and the minimum concentration in the western regions, the specific case is shown in Figure 3 and Figure 5.

\[
\ln(I/Area) = \beta_0 + \beta_1 \ln(Mks) + \beta_2 \ln(Wage) + \beta_3 \ln(Edu) + \beta_4 \ln(RRD) + \mu
\] (1)

2) Empirical Analysis of the Impacts of Transportation Infrastructure Stock on the Manufacturing Location

Firstly, the paper analyzes the variable selection and sample data processing. It selects investment intensity (I/Area) of new fixed assets in manufacturing in 31 provinces in China as dependent variable, and assumes investment intensity equals to manufacturing investment in total fixed assets minus the reconstruction of it to measure the manufacturing location.

According to the typical researches at present on manufacturing concentration and location, such as, Wei Zhao, Sui Zhang (2009), the independent variables are included of market size (Mks) with per capita GDP approximately representation; labor costs (Wage) with total wages of the manufacturing workers in each province divided by the total number of manufacturing employees in its domain; The education (Edu), with the proportion of population in high school to the total population in 31 provinces in China; RRD is transportation infrastructure stock, and it is calculated as the same way as the above.

The paper use data comes from China Statistical Yearbook over the years, mainly use the data in 2006 based on that the Chinese government has taken on investment largely to public infrastructure including of transportation infrastructure in Asian financial crisis in 1997 and 2008 combined with transportation infrastructure has a lag effect, so it is not suitable for selection the data within very short time interval to 1997 and 2008, so this paper mainly use the data in 2006 to examine impacts on the location of manufacturing industry from the transportation infrastructure stock in 31 provinces in China.

Secondly, this paper make a model to analyze the impacts from transportation infrastructure stock on the manufacturing location by developing a double-logarithmic model which is specifically expressed, as fellows:
In the equation (1), $\beta$ represent the regression parameters, $i = 1, 2, \cdots, 31$, $\mu_i$ represents the random disturbance term.

Thirdly, we test the spatial dependence in concentration of manufacturing. According to Anselin (1988) described the spatial statistics and spatial econometrics principles and methods. Firstly, we use Moran index ($-1 \leq \text{Moran}' I \leq 1$) to test spatial dependence of investment intensity (explained variable) in 31 provinces in China in 2006. When Moran index value is larger, spatial economic behavior among regions is positive correlation, on the contrary, negative correlation. Moran index scattering in the four quadrants respectively corresponds to 4 types of local space contact forms among the region cell and its neighboring regions. Quadrant 1 represents high observation value areas are surrounded by high value regions (HH), quadrant 2 represents low observation values areas are surrounded by high value regions (LH), quadrant 3 represents low observation values areas are surrounded by low value regions (LL), and quadrant 4 represents high observation units are surrounded by low value regions (HL). Quadrant 1, 3 are representative of positive spatial contact form between similar observations, while quadrant 2, 4 are representative of negative spatial contact form between similar observations. If the observations are distributed uniformly in four quadrants, the spatial autocorrelation among the regions does not exist. If it exists, we need make spatial econometric model to find determinants of manufacturing concentration, as follows:

$$\text{Moran'} I = \frac{n \sum_{i=1}^{n} \sum_{j=1}^{n} w_{ij} (x_i - \bar{x})(x_j - \bar{x})}{\sum_{i=1}^{n} \sum_{j=1}^{n} w_{ij} \sum_{i=1}^{n} (x_i - \bar{x})^2} \quad (2)$$

In the equation (2), $x_i, x_j$ are respectively the observations in region $i$ and $j$; $n$ is the number of spatial units, $w_{ij}$ is neighboring spatial weight matrix. Spatial weight matrix $w_{ij}$ includes the two standards of neighboring or distance, and the binary system neighboring matrix is generally used, as follows:

$$w_{ij} = \begin{cases} 1 & \text{region } i \text{ is adjacent with region } j \\ 0 & \text{the other} \end{cases} \quad (3)$$

In the equation (3), $i = 1, 2, \cdots, n$ ; $j = 1, 2, \cdots, m$ ; $m \neq n$, or $m = n$.

By spatial econometric software Geoda-095i, we find that Beijing, Shanghai, Tianjin, Hebei, Shandong, Shanxi, Henan, Jiangsu, Anhui, Hubei, Zhejiang, Jiangxi, Hunan, Fujian and Liaoning are located in quadrant 1 (HH); Heilongjiang, Xinjiang, Ningxia, Tibet, Yunnan, Gansu and Sichuan in the third quadrant (LL); Inner Mongolia falls on quadrant 2 (LH), Guangdong is located in the quadrant 4 (HL); Hainan, Guangxi, Shaanxi are both across quadrant 2 and 3, and Chongqing and Jilin are both across quadrant 1 and 4, and the form of LH or HL mean the manufacturing concentration’s negative correlation, while most provinces are located in quadrant 1 and 3, which shows a significant differentiation of HH and LL. For Moran'I of the explained variables equal to 0.4541, and the significance test by Monte Carlo simulation, running 999 times, and $p$ is lower than 0.01, it indicates that Moran'I is significant reasonableness in 99% confidence, Logarithmic investment intensity of new fixed assets in manufacturing in 31 provinces in China has a strong spatial dependence, and manufacturing concentrated further to the provinces where manufacturing concentrated relatively, So, this paper makes spatial econometric models and OLS (Ordinary least squares) as well to analyze the problem. The result of spatial dependence test is shown in Figure 6.

![Figure 6. Spatial dependence of investment intensity in manufacturing in 31 province in China](image)

Now, we begin to analyze the determinants in manufacturing location. Respectively, using OLS (ordinary least squares, OLS) and SLM(spatial lag model, SLM) and SEM (spatial error model, SEM) to analyze the main factors which can affect the location choice of manufacturing industry, and the results of various empirical methods are shown in Table 1, see Appendix 1.

From Table 1, it can be seen that the transportation infrastructure variable in the three models have passed the 1% significance level test, and it indicates that transportation infrastructure stock has a very significant influence to manufacturing location in 31 provinces in China, and it verifies the above analysis, that is, transportation infrastructure stock is one of the determinants for the location choice in manufacturing industry in China.

3) High concentration of manufacturing location can expand regional disparities

The level of manufacturing industry reflects capital stock level in the region, while prices of non-mobile factors are determined by the industry of increasing returns to scale, which means the manufacturing sector in developed regions can provide greater economies of scale, so that the region’s income and consumption level can be improved (Krugman, 1991). Baldwin, Martin and Ottaviano (2001) found that the spatial agglomeration of regional economic activities would lower the cost of innovation and stimulate economic growth, so that the higher the concentration level of the manufacturing sector in a region the more conducive to the creation of the capital in the
the spatial distribution is extremely unreasonable. From this point of view, China's transportation infrastructure in so it is also the most important factor to the formation of regional income gap. The manufacturing sector largely determines the level of a region's capital and economic strength, so that excessive concentration of manufacturing industry inevitably results in the strong getting stronger and the weak getting weaker. In other words, China is an undeveloped country, so in this stage, backwash effect is of a dominant position, the concentration of manufacturing industry can strengthen the gradient of agglomeration tendency in the eastern, central and western regions, and expand regional disparities.

4) Reasonableness in the Spatial Distribution of Transportation Infrastructure in China

Through the above analysis it can be found that the extreme imbalance of the spatial distribution of transportation infrastructure is a main cause which leading to a high concentration of manufacturing industry in spatial distribution, and the location choice of manufacturing industry caused by imbalance of the spatial distribution of transportation infrastructure can strengthen the regional disparities in China. From this point of view, China's transportation infrastructure in the spatial distribution is extremely unreasonable.

III. THE REASONABLENESS OF THE ALLOCATION OF TRANSPORT INVESTMENT IN CHINA

Transportation infrastructure investment patterns can affect factors flow as well as the spatial distribution of manufacturing industry, while a country can endogenously become differentiated into an industrialized core and an agricultural periphery result from the distribution of manufacturing (Krugman, 1991a), so transportation infrastructure investment patterns can affect the trends in the regional disparities. Use the data of transportation infrastructure investments from 2000 to 2008 to get distribution of transport investment in recent years in China, see Figure 8.

From Figure 8, we can find that the transportation infrastructure investment shows a very significant gradient from the eastern, to the central, and then to western region in recent years in China. Although the transportation infrastructure investment in each region has a trend of increasing, the increasing rate in the central region and eastern region is much higher than that in the western region. Traffic investments too much were paid in the eastern and central region for many years, which in fact, have caused the extreme imbalance of transportation infrastructure spatial distribution in China. "Five vertical and seven horizontal" national trunk road traffic infrastructure which is linked up basically by the end of 2007, however, the total length is about 3.5 million kilometers only changed the extreme imbalance a little which is not conducive to narrowing regional disparities in China. Since 2008, the reasonableness of new allocation in transportation investment has been increased in China. In the new investment arrangements for 28.0 billion yuan in 2008, the eastern accounted for 13.3%, the central accounted for 25.7% and the western accounted for 61% (Bin, 2009). However, on the whole, the overall distribution of transportation infrastructure investment still is much irrational. In the nine years from 2000 to 2008, the transportation infrastructure investments in the eastern whose land areas account for 13.5% in the total China land areas are 3.91 times in the western whose land areas account for 56.4% in total land areas, and the transportation infrastructure investments in the central region whose land areas account for 29.3% in total land are 6.23 times in the western. Western transportation infrastructure investments still account for a very small proportion. So the reasonableness in investment direction and distribution of the transportation infrastructure need to be improved immediately.

IV. CONCLUSION

The spatial distribution of transport infrastructure and the transport investment allocation in recent years are very irrational, and the state of the excessive concentration on
transportation infrastructure has not been effectively improved which was formed by too many transportation investments being paid in eastern and central regions in China. This is not conducive to narrow the gap between our regions and coordinately develop between regions. Therefore, the direction of China’s transportation investment should incline to the western regions and the investment proportion should be increased. Meanwhile, the transportation infrastructure is one of the most important factors that influence the manufacturing location choice, so in investment of transport networks should be considered traffic demand in the real economy, and also be considered developing new lines in the undeveloped regions to induce the inflow of economic factors and manufacturing sites to improve the endogenous economic development power of the undeveloped regions, thus the further expansive gap between regions can be inhibited.

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REFERENCES


APPENDIX 1:

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<th>Table 1. Determinants of Manufacturing Location</th>
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Note: **, *** represents respectively the result when the significance level is 5% and 1%, and dependent variable is logarithmic investment intensity in manufacturing industry.