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Review Article

The Impacts of Transportation Infrastructure on Economic Openness in Yangtze River Delta of China

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Abstract

The paper discusses the impacts of transportation infrastructure on economic openness within the 27 major cities of Yangtze River Delta of China. Through reviewing relevant literatures, it forms an influencing mechanism and research path based on the theories of New Economic Geography and comparative advantages. In the empirical test, the whole research chooses the panel data from the year 2005 to 2020 to observe the spatial autocorrelation through Global Moran Index (Moran's I) and Local Moran Scatterplots. Then, the paper builds an econometric function on the basis of Spatial Durbin Model (SDM) to measure the regression results and then decompose the effects. According to the test results, it can be concluded that transportation infrastructure generates positive impacts on economic openness and there truly exists the spatial spillover effect in the Yangtze River Delta. Finally, the paper gives proposals from three aspects which are combined with the policies on integration construction of national strategic deployment of China.

Keywords: Transportation, Economic Openness, Spillover Effects, Integration Construction.

INTRODUCTION

Pushing forward the construction of transportation infrastructure has long been one of the major development strategies and policy tools in China. Since the reform and opening up policy was carried out in 1978, China has transformed into a country with strong transportation network. According to the data collected from China Statistical Yearbook, during the period from the Tenth Five-Year Plan (2001-2005) to the Thirteenth Five-Year Plan (2016-2020), the investment on transportation construction accounted for 2.43%, 4.14%, 4.68% and 5.63% of China's GDP, compared with that of G7 countries in the corresponding periods, the proportion was 0.92%, 0.93%, 0.81% and 0.74%, based on the data from OECD websites. Meanwhile, the growth rate of Chinese traffic operating mileage reached 13.4%, 14.25%, 126.13% and 40.44%, with the rise of freight volume of 13.40%, 28.81%, 138.60% and 10.02%, respectively. It is widely acknowledged that China has achieved great success in developing transportation infrastructure like expressways, high speed railways, port construction and airways. With the further deepening of reform and opening up, the volume of both international and domestic trade has incredibly risen, which proves the effectiveness of transportation development against the background of 'Bringing In' and 'Going Out'. Therefore, as opening up becomes the basic state policy of China, transportation accelerates the economic openness, and makes the factors agglomerated in certain regions.

In recent years, since regional coordinated development has become the national strategic deployment of China, the construction of transportation infrastructure has been perceived as a powerful way to achieve the goals and keep stable and balanced economic growth (Reul, Grube, & Stolten, 2021; Herzog, 2021; Tsai, Merkert & Wang, 2021). As the antecedent condition of implementing regional economic integration, transportation can enormously reduce the traffic costs and promote free exchanges between regions (Zan & Ou, 2021; Ma, Cheng, & Yang, 2020; He, *et al.*, 2019). Yangtze River Delta is the largest and most comprehensively developed city cluster in China, consisting of three provinces, they are Jiangsu, Zhejiang and Anhui, and one municipality, Shanghai, located in the east of China. It is one of the earliest regions that were implemented opening up in 1980s and works as a key integration deployment of China currently. Based on the theory of New Economic Geography, economic activities will form spatial agglomeration and diffusion effects. Therefore, the paper presumes increasing returns to scale and imperfect competition, and then analyzes the impacts from the city itself and others nearby. Since the improvement of transportation infrastructure theoretically accelerates the optimization of industrial division, reduces the costs, forms the economic agglomeration and promotes the information delivery, the paper examines the concrete effects through empirical test.

The whole empirical study is based on the Spatial Durbin Model (SDM) which measures the spatial effects of transportation on economic openness. Firstly, it observes the autocorrelation among the 27 cities of Yangtze River Delta by Global Moran Index and Local Moran Scatterplots. Next, the paper builds the concrete econometric model to further analyze the impacts, and then tests the influence mechanism through decomposing effects. Finally, it draws the conclusion that transportation infrastructure can positively influence the economic openness and proves the existence of spillover effects between the 27 cities of Yangtze River Delta, verifies two hypotheses of the paper. After passing the robustness test, it confirms the result and gives relative conclusion and policy proposals.

1. CONCEPT DEFINITION AND LITERATURE REVIEW

1.1 Study of Transportation Infrastructure

Transportation infrastructure serves as vital public goods for a country; it is the prerequisite of economic growth. Its improvement on quality and quantity can reduce both time and logistics costs in socio-economic activity to a large extent. Nowadays, with the booming development of world economy, transportation infrastructure is no longer just one of major infrastructure construction programs that ensure daily traffic but an indispensable driving force which directly or indirectly promotes the productivities, outputs, factor mobility and so on. In the modern transport system, the construction of highways, railways, waterways and airlines has even become the indicator measuring whether the socio- economic circulation is efficient or backward within a region or a country. Since a growing proportion of capitals tend to be invested in the construction of transportation, it has been widely concerned by relevant researchers.

Transportation infrastructure is featured with considerable fundamentality, long construction cycle, large investment scale, low direct benefits, positive externalities and other characteristics. In fact, it provides the whole society with huge convenience and works as an essential cornerstone of economic development. Its definition can be concluded as all the forms of human's travelling which includes the transportation of highways, railways, waterways, air, bridges, pipelines and other kinds of traffic lines that are supposed to be used in different situations. According to their characteristics and construction requirements, transportation infrastructures are generally divided into two categories. The first type is characterized by strict traffic paths which can form intricate transport networks, such as highways and railways which need a large number of capitals at earlier construction stage. The second one is those with strong externalities, like waterways and air transport that are usually constructed owing to their special geographical environment and locations. Their infrastructures are stable and mainly focus on wharfs and airports and have strict requirements on site selection and construction. Therefore, when researchers take transportation infrastructure as indicator, its concrete measuring ways should be based on data availability, regions, trade types, etc. In terms of international business, countries throughout the world take shipping and land transportation as main export channels because of their tremendous capacities and low average costs. As for domestic trade, all kinds of transportation are available in most cases, but highways are always given the first priority between regions due to the efficient and flexible transport systems.

When reviewing the literatures on transportation infrastructure, it is common to find that transportation has been proven its great importance on socio-economic activities in many studies. For example, *Adam Smith* pointed out that it largely promoted trades and boosted the economic growth, so it is crucial for a country to improve the transportation in *The Wealth of Nations* in 1776. According to *Political Arithmetick*, *William Petty* thought that advanced transportation was one of the major features of national prosperity and contributed to resource allocation in 1690. *Friedrich List* proposed that transportation worked as both the result and cause of industrial development in *The National System of Political Economy* in 1841.*Alfred Marshall* said the reduction of transportation costs would provide convenience for free exchange in *Industry and Trade* in 1919. In *Industry Location Theory*, *Alfred Weber* firstly proposed that transportation would become the primary locational factor influencing industrial layout while labor was just the secondary one under the constraint of minimizing the transport costs in 1909. Sasaki *et al.,* (1997) found that the development of transport lines significantly improved the urban population and economic growth rate of Japan. Chandra and Thompson (2000) concluded that transportation could promote the through analyzing the highways of American states. Njoh (2012) thought that increasing investment in transport infrastructure would positively lead the regional economic growth, according to the research on East Africa and Indian Ocean Region.

In China, the research on transportation also mainly focuses on the effects brought by its improvement on economic development. Large funds invested in China's transportation construction in recent years had boosted the regional distribution and production cooperation (Xie & Wang, 2020; Dong& Jiang, 2019; Dong& Jiang, 2021). Transportation was considerably conducive to promote regional coordinated development between urban and rural areas, coastlands and inlands, eastern and western of China (Hu & Liu, 2009; Zhang, 2012; Wang & Ni, 2016; Gao, *et al.,* 2021). It influenced the industrial development and startups, and generated spillover effect (Liu, *et al.,* 2010; Dong & Zhu, 2016; Bian *et al.,* 2019; Zhu *et al.,* 2019; Yang *et al.,* 2019). As for the studies of urban cluster, it proved that there existed significant spatial autocorrelation and spillover effect in transportation and suggested that core cities were supposed to play leading roles in driving regional development and integration (Pan & Lin, 2022). There existed positive spatial spillover effect in transportation infrastructure and regional economic growth within Yangtze River Delta, and cities are more likely to be correlated with those nearby (Cheng & Chai, 2021).

1.2 Study of Economic Openness

Economic openness is an indicator measuring the degree of open economy, usually reflected by both the level of a country's integration into international market and the capability of absorbing foreign capitals. That is to say, it manifests how a country connects with the world and to what extent other countries can enter that country as well, which includes the exchanges of commodities, capitals, production, technologies and so on. At the beginning of the research on economic openness, export- import volume was regarded as the most typical indicator to evaluate the degree, so its calculation used to be based on international trades mainly. Although such method could directly explain the situation of open economy, it still neglected the factor mobility in the process of foreign trade. Since globalization keeps evolving, taking trade volume into consideration only fails to measure other important aspects to a large extent (Edwards, 1997; Sachs, *et al.,* 1995; Grossman & Helpman, 1993; Graham & Edward 2004). The consistent mobility has changed the world through altering international specialized division of labor, so the economic openness not only represented the standard of economic capabilities, but also revealed the international competitiveness. Moreover, it shall be weighted multi-dimensionally (Chen & Niu, 2010; Chen & Huang, 2018). When calculating the concrete value of economic openness, it was supposed to clarify the concepts and forms of economic openness first, and then select the indicators with those characteristics ((Lv, *et al.,* 2015; Peng, 2019). According to the mainstream research, the measurement of economic openness can be generally divided into two types, one of them is based on current systems or policies, such as customs tariffs, non-tariff measure, interest rate mechanism, etc., while another mainly considers from the foreign economic cooperation, like export-import volume, foreign investment, international tourism, technological cooperation and so on.

In terms of the first way of measuring economic openness, it is not hard to obtain the relevant data. However, since tariff reduction has gradually become a prevailing trend, it nearly fails to represent the integration degree of international market. In fact, most of the countries throughout the world have taken non-tariff measures which can also obviously increase the difficulty of market access, but the ways to select reliable variables for measuring are relatively obscure and hard to explain the transmission mechanisms. By contrast, on the basis of the contents and results of open economy, the indicator measurement turns much more feasible. Under normal circumstances, foreign trade dependency (Zhang & Gao, 2001), foreign capital dependency（Qu, 1997; Z. Liu & Wei, 2001; Long & Qiu, 2010）, foreign capital flow (Lan, 2002) has been chosen to calculate economic openness. Among the research of China, (Xie, 2003; Zhao, 2006; Gu, 2008; Zhao, *et al.,* 2016; Li & Tang, 2019) chose foreign trade dependency and foreign capital dependency as dimensions and calculated a comprehensive value through arithmetic mean method. From relevant studies, it can be concluded that economic openness is mainly measured from three aspects which include foreign trade, foreign investment and international finance. With the ever-changing world economy, the ways of measuring economic openness become increasingly various, some even innovated the indicator from technological side (Hu & Liu, 2005).

Owing to the national strategy made by the Chinese government, Jiangsu, Zhejiang, Anhui and Shanghai have been geographically incorporated into the Integration Construction of the Yangtze River Delta. Located in the east of China, this region is well-known as advanced transportation and prosperous economy. Therefore, this paper studies the influence brought by transportation infrastructure on economic openness according to the major political decision. Based on the literatures and given the data availability of 27 cities in Yangtze River Delta, the paper selects total export-import volume, foreign direct investment and foreign exchange earnings from international tourism and calculates the concrete value of economic openness by principal component analysis which can reflect the variables more objectively compared with subjective assignment method.

2. THEORETICAL MECHANISM

2.1 Theoretical Bases

The theory of New Economic Geography (NEG) was firstly proposed by Paul Krugman in 1990s.

Different from the traditional regional economic theory based on neoclassical economics, it takes transportation costs into consideration when the operation involves agglomeration economies, externalities and other possible aspects. Besides, the theory takes increasing returns to scale and imperfect competitive market as premise presumptions. It mainly expresses the thought that when there exists increasing trade costs and increasing returns to scale, the function of market mechanism is to generate agglomeration effect of enterprises in the places or fields with high market potentials, and then meet the demand of both consumers and producers. According to the current theoretical expansion, the most typical core principle of NEG is the home market effect which has been proven its existence in many economic studies especially in international trade theory. In the theory of NEG, this effect means that producers are more likely to choose local markets once the industries need high transportation costs. However, in terms of those industries which just need moderate transportation costs, producers will prefer the markets with larger scale and sell their products there. Upon most occasions, many products tend to be sent to the areas near their production places first and then enterprises will consider those regions with greater market potentials within a country. As for the circumstances of Yangtze River Delta, Shanghai plays a leading role in economic development, so it has the absolute advantage of forming industry agglomeration and home market effect. However, the cities nearby will also be gradually assimilated because of their geographical locations and relatively low transportation costs. As a result, with the deepening of integration implementation, transportation is expected to realize a high-efficient level within the Yangtze River Delta and promote the free exchanges of factors, commodities, technologies, capitals, information, and etc.

In foreign trade studies, the theory of comparative advantage always dominates in this field. Traditional comparative advantage started from the theory proposed by David Ricardo who held the opinion that the nature of foreign trade lied in the relative difference in production technologies and costs. Then it was improved by Heckscher- Ohlin (H-O) Model which proposed Factor Endowments Theory and emphasized the difference of relative price of production factors. From H-O Model, a country will export its factor-intensive commodities because of their different factor endowments. Such classical theory system of foreign trade plays an indispensable role even in the current international economic pattern. At present, regional comparative advantage has become one of the main theories for studying the comparative advantage of both domestic and foreign regional economics. Its thought lies in the integration of resources, geographical locations, production technologies, market potentials and other aspects with possible competitiveness. Therefore, in modern economic theoretical system, regional comparative advantage is a concept that emphasizes the improvement of resource utilization efficiency in certain areas and characterized by strong spatiality and timeliness. The economic activities and growth usually take place under the circumstance of disequilibrium that deviates from the assumptions, so within a region, the economic influences diffuse through a path under the spatial spillover effects, which can be applied to both regional countries and cities. In the situation of Yangtze River Delta, the industrial agglomeration mainly takes place in Suzhou, Wuxi, Changzhou, Nantong, Jiaxing and other cities which are greatly influenced by Shanghai's radiation effect. As the core city of Yangtze River Delta, Shanghai diffuses its economic influence to the cities nearby first and then they will gradually transform the exogenous radiation effects into endogenous driving factors. Therefore, the paper proposes the hypothesis 1 on the basis of theory and mechanism.

Hypothesis 1: Transportation infrastructure can generate positive impact on economic openness within the Yangtze River Delta.

2.2 Analysis of Influencing Mechanism and Research Path

The influencing mechanism of the paper is on the basis of theories and literatures above. To be specific, with the improvement of transportation infrastructure, it will accelerate the integration construction because of cost reduction, which encourages the mobility within the region to a large extent. Hansen (2015) thought that factor mobility would directly influence the industrial structure and tend to generate increasing returns to scales in certain regions where industrial agglomeration could emerge. Chen and Guan (2011) pointed out that the ever-changing development of transportation infrastructure could produce positive economic externalities, then some certain industries would cluster because of the decreasing logistics costs and spatial spillover effect. According to the theory of NEG, it tends to eliminate trade barriers as much as possible with the advancement of economic information spread and industrial division. Therefore, such improvement can speed up the mobility of both factors and commodities, promote industrial structural optimization and agglomeration in the meantime. As a result, it will form domestic comparative advantage within the region and international comparative advantage between the countries through the transmission mechanism. Since transportation is getting improved, it encourages the cities to exploit their own possible advantages to the full in economic development first, and then enhance the potential competitiveness through foreign trade or other kinds of international business, which will finally boost economic openness.

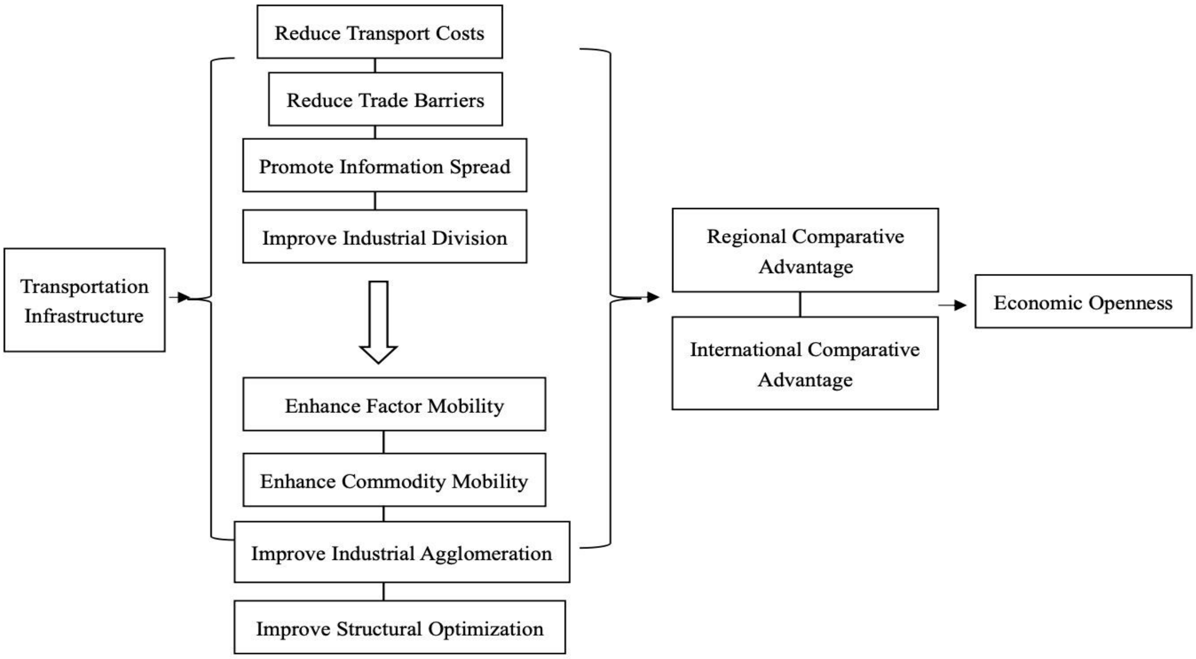


Figure 1: The Influencing Mechanism

As for the research path of this paper, it is going to analyze the influence of transportation infrastructure on economic openness from direct effect and indirect effect. Because Yangtze River Delta consists of Jiangsu, Zhejiang, Anhui and Shanghai, which are closely correlated with each other against the background of government policies and national development strategy. The analysis of mechanism implies that the economic mobility will probably generate strong spatial spillover effect in a region owing to the increasingly freer market and more similar development structure. By measuring the direct effect, we can draw the conclusion on the degree of transportation infrastructure's influence on economic openness for a city itself, but the impacts brought by those nearby cannot be neglected at the same time. Through studying these two different effects, it is conducive to know the influence degree and then provide suggestions for government policymaking based on the situation. In order to measure the effects, the paper proposes another hypothesis.

Hypothesis 2: There exists positive spatial spillover effects within the 27 cities of Yangtze River Delta.

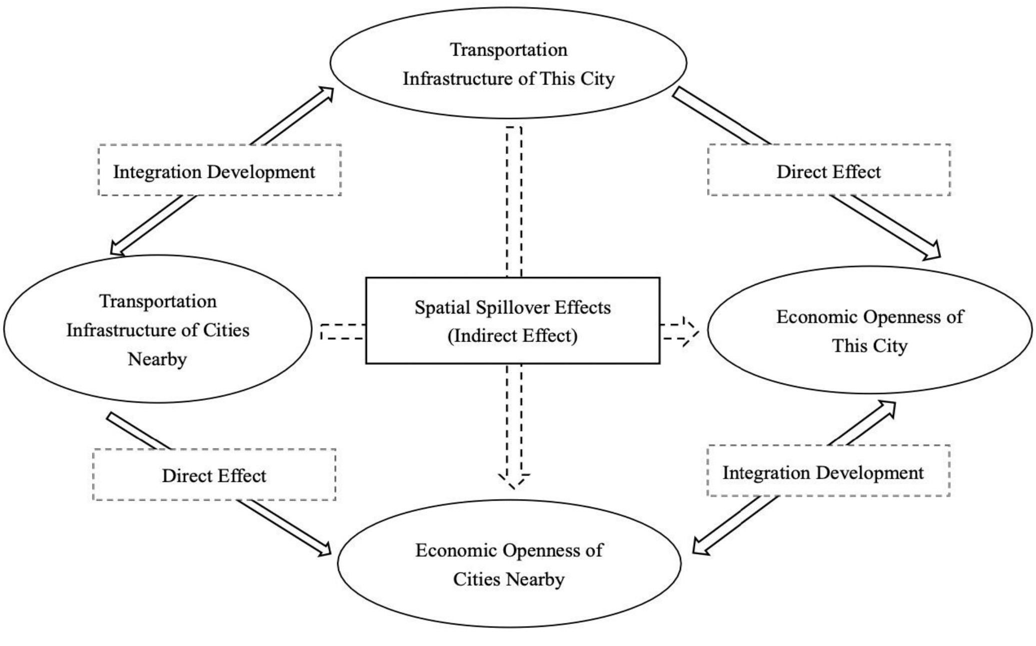


Figure 2: The Research Path

3. Empirical Research Based on Panel Data

The paper uses the data gained from China Statistical Yearbook, official websites of provincial and city statistical bureau. The research discusses the transportation infrastructure's impact on economic openness of 27 cities of Yangtze River Delta transportation infrastructure from the year 2005 to 2020. Since there probably exists strong spatial effect among study objects, the whole empirical research is based on spatial econometric model. Transportation infrastructure and economic openness are taken as dependent variable and independent variable respectively, and the concrete variable selection with explanation is shown in Table 1.

Table 1: Variable Selection and Explanation

Variables	Indicators	Explanation
Dependent Variable	Transportation Infrastructure (lnTI)	Calculate the highway density formula of each city
Independent Variable	Economic Openness (lnEO)	Take principal component analysis to calculate the weight of each indicator and sum up numeric value
Control Variables	Human Capital (lnHC)	Use total enrollment of students at secondary schools and institutions of higher education.
	Industry Level (lnIL)	Take the ratio of added value of the secondary industry to GDP
	Development Level (lnDL)	Use the data of GDP collected from statistical yearbook.
	Asset Level (lnAL)	Take the ratio of fixed asset investment to GDP
	Government Support (lnGS)	Use government budget expenditure

Note: *The highway density formula of each city is

$$\frac{\left(\frac{passenger\ transport\ volume}{\text{highway mileage}}+\frac{freight\ transport\ volume}{\text{highway mileage}}\right)}{2}\times\frac{\text{highway mileage}}{\text{administrative area}}.$$

*The independent variable is composed of three indicators; they are total export-import volume, foreign direct investment and foreign exchange earnings from international tourism.

Table 2: Descriptive Statistics of All Variables

Variable	N	Mean	Std. Dev.	Min	Max
lnEO	432	-0.2241446	0.5669599	-0.8388555	1.728777
lnTI	432	0.837713	0.1795681	0.3033561	1.348982
lnHC	432	0.0705017	0.0226564	0.0122153	0.1528826
lnIL	432	3.929074	0.1587177	3.317348	4.327236
lnDL	432	7.852403	1.073672	4.711151	10.56365
lnAL	432	0.5036392	0.1485495	0.2123349	0.8710706
lnGS	432	5.734622	1.094043	2.820664	9.030321

4.1 Spatial Autocorrelation Analysis

For the purpose of observing whether there truly exists spatial autocorrelation in both transportation infrastructure and economic openness within the 27 cities of Yangtze River Delta, the paper takes Global Moran Index (Moran's I) which is perceived as the most widely used and typical indicator in this field. To be specific, spatial autocorrelation means a city usually has similar result with others within a region through measuring the numerical values of variables or indicators, so it is expected that the data among those cities appear interdependence. If relatively higher numerical values agglomerate with higher ones (H-H), then the variables will internally form positive spatial autocorrelation, same as the lower ones with the lower ones (L-L). Likewise, if higher ones come with lower ones (H-L) or lower ones gather with higher ones (L-H), both situations indicate that there will generate negative spatial autocorrelation between each other. However, once the spatial distribution regularity is not obvious, it means there is no spatial autocorrelation among the selected variables. The concrete formula Moran Index is:

$$I=\frac{\sum_{i=1}^{n}\sum_{j=1}^{n}\omega_{ij}(x_i-\bar{x})(x_j-\bar{x})}{S^2\sum_{i=1}^{n}\sum_{j=1}^{n}\omega_{ij}}$$

Among which $S^2=\frac{\sum_{i=1}^{n}(x_i-\bar{x})^2}{n}$ is the calculation formula of sample variance, and ω_{ij} denotes spatial weight matrix (here is the simple 0-1 matrix). When ω_{ij} is standardized, then it gets $\sum_{i=1}^{n}\sum_{j=1}^{n}\omega_{ij}=n$ and $I=\frac{\sum_{i=1}^{n}\sum_{j=1}^{n}\omega_{ij}(x_i-\bar{x})(x_j-\bar{x})}{\sum_{i=1}^{n}(x_i-\bar{x})^2}$. The results of Moran Index are usually in the open interval (-1,1), if I>0, it means there exists positive spatial autocorrelation among the study objects, and I<0 denotes negative spatial autocorrelation. For the absolute value (|I|), the closer it is to 1, the stronger the positive or negative autocorrelation is, but if the value approaches 0, then it indicates that the study object randomly distributes in geographic location and there does not exist any correlation among the variables. Table 3 shows the Global Moran's I of both transportation infrastructure and economic openness.

Table 3: Global Moran's I of Transportation Infrastructure and Economic Openness

Transportation Infrastructure				Economic Openness			
Year	**Moran**	**Z-Value**	**P-Value**	**Year**	**Moran**	**Z-Value**	**P-Value**
2005	0.088	0.743	0.229	2005	0.327	2.341	0.010
2006	0.325	2.158	0.015	2006	0.372	2.585	0.005
2007	0.343	2.314	0.010	2007	0.390	2.690	0.004
2008	0.451	2.936	0.002	2008	0.347	2.443	0.007
2009	0.188	1.361	0.087	2009	0.319	2.266	0.012
2010	0.446	2.890	0.002	2010	0.318	2.263	0.012
2011	0.439	2.845	0.002	2011	0.285	2.037	0.021
2012	0.378	2.444	0.007	2012	0.260	1.881	0.030
2013	0.318	2.100	0.018	2013	0.223	1.695	0.045
2014	0.300	1.994	0.023	2014	0.217	1.656	0.049
2015	0.239	1.637	0.051	2015	0.187	1.460	0.072
2016	0.180	1.291	0.098	2016	0.179	1.411	0.079
2017	0.187	1.334	0.091	2017	0.190	1.464	0.072
2018	0.206	1.450	0.074	2018	0.227	1.698	0.045
2019	0.125	0.955	0.170	2019	0.259	1.995	0.023
2020	0.004	0.249	0.402	2020	0.263	2.042	0.021

According to the value of Moran Index from Table 3, it is clear that most of the 27 cities of Yangtze River Delta geographically interdepend with each other and appear positive spatial autocorrelation in transportation infrastructure and economic openness, so the variables are strongly correlated. However, Global Moran Index only reflects the existence of significant correlation within a region; it cannot tell the concrete difference of spatial agglomeration among the cities. That is to say, the result of Global Moran Index is not able to show what cities spatially agglomerate together and jointly generate economic effects. Thus, Local Moran scatterplots are going to be measured to further explain the spatial effect of both transportation infrastructure and economic openness among the cities.

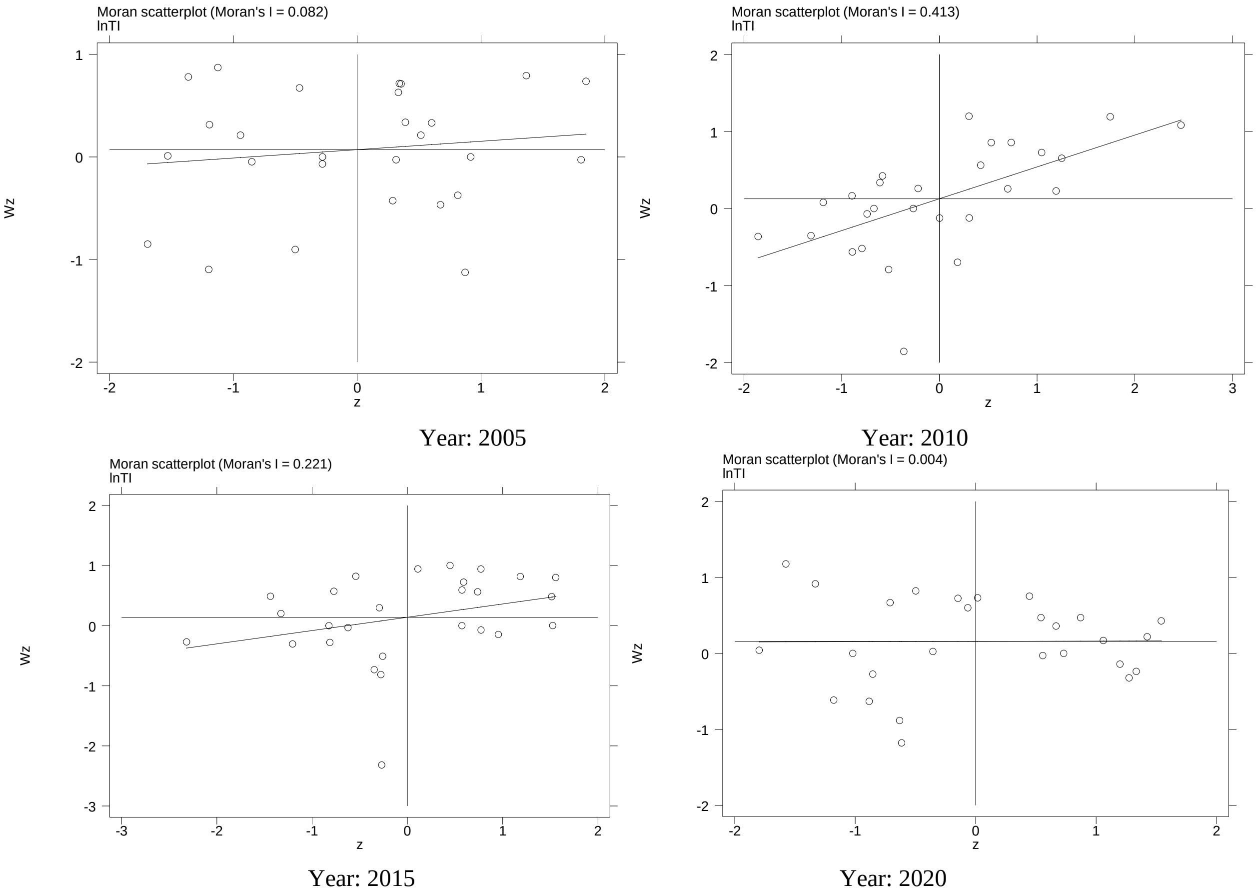


Figure 3: Local Moran Scatterplots of Transportation Infrastructure

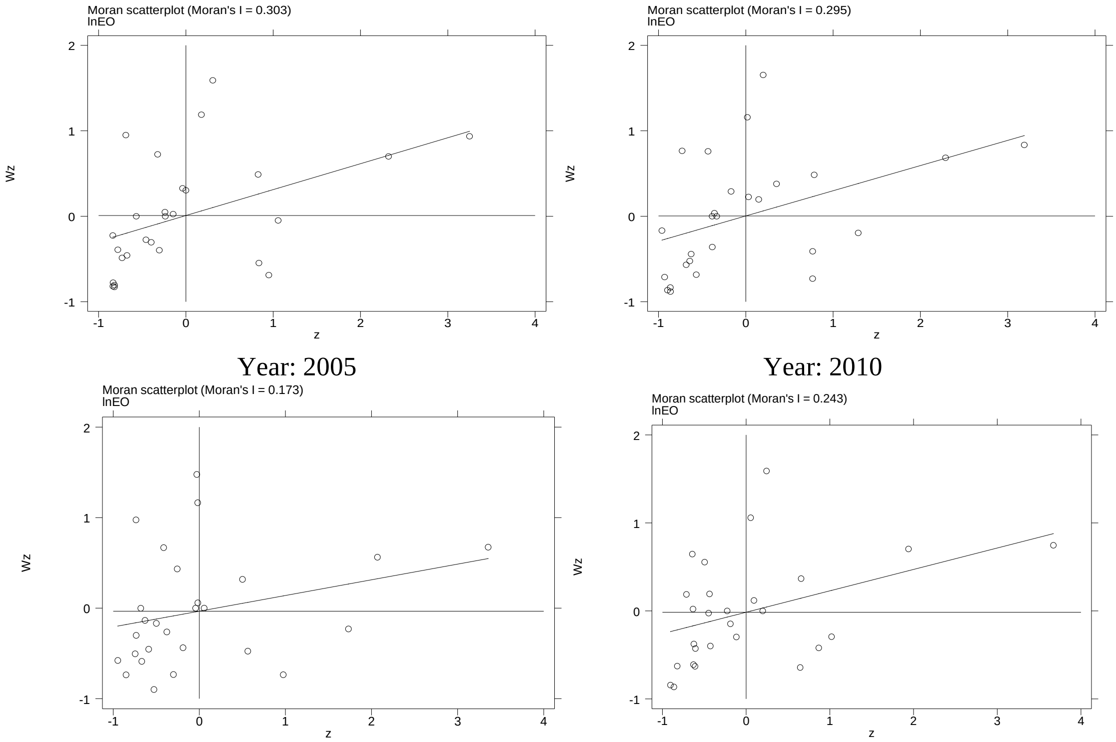
According to the features of Local Moran scatterplots, the first quadrant represents higher values agglomerate with higher ones (H-H), and followed by L-H, L-L and H-L in the second, third and fourth quadrants, respectively. In fact, both the first and third quadrants denote the positive spatial autocorrelation, while the second and fourth ones represent the negative spatial autocorrelation. Therefore, once it generates a fitted line in Local Moran scatterplot, it can manifest the positive or negative correlation among the selected variables. Seen from Figure3, transportation infrastructure forms a fitted line that goes through the first and the third quadrants in the year 2005, 2010 and 2015, among which the Moran's I of 2010 is the largest. Therefore, it can be speculated that the infrastructure construction of China truly propelled the rapid economic development when it was in the first decade of the 21st century. However, after China entered into its New Normal stage in 2012, the country has to make breakthroughs on economic structure and find new ways to develop, which is probably one of the main reasons why there is almost no spatial effect in transportation infrastructure in 2020 besides the breakout of COVID-19. To be specific, the situation of transportation infrastructure is concluded in Table 4.

Table 4: Explanation of Figure 1

Quadrant	Spatial Effect	Corresponding Cities
H-H (I)	Positive Spatial Autocorrelation	Shanghai, Suzhou(J), Nanjing(J), Wuxi(J), Changzhou(J), Zhenjiang(J), Nantong(J), Jiaxing(Z), Taizhou(J), Yangzhou(J)
L-H (II)	Negative Spatial Autocorrelation	Hangzhou(Z), Ningbo(Z), Zhoushan(Z), Yancheng(J), Huzhou(Z), Chuzhou(A), Xuancheng(A),
L-L (III)	Positive Spatial Autocorrelation	Shaoxing(Z), Wenzhou(Z), Jinhua(Z), Hefei(A), Chizhou(A), Anqing(A), Taichow(Z)
H-L (IV)	Negative Spatial Autocorrelation	Wuhu(A), Maanshan(A), Tongling(A)

Note: a. (J), (Z) and (A) represent the cities of Jiangsu, Zhejiang and Anhui, respectively.
b. Table 4 shows the overall situation of in those 4 years.

From Table 4, the H-H agglomeration effect generally focuses on those cities like Shanghai, Suzhou, Wuxi, Jiaxing, Nanjing and Nantong. Therefore, Shanghai is most likely to form spatial autocorrelation with cities of Jiangsu province in transportation infrastructure, which indicates that Jiangsu province is connected with Shanghai on transport and economic mobility most compared with the situation of other two provinces.



Year: 2005 Year: 2010

Year: 2015 Year: 2020

Figure 4: Local Moran Scatterplots of Economic Openness

The agglomeration effect of Economic Openness is significantly positive in 2005, 2010, 2015 and 2020, got from its distribution of Local Moran Scatterplots. The concrete situation is concluded in Table 5, showing that cities falling into the first and third quadrants in those 4 years account for 55.56%, 59.26%, 55.56% and 59.26%, respectively. And seen from the scatterplots, cities are more agglomerated in the L-L area than H-H area, which can be taken as one of the main differences from transportation infrastructure and reflects that they tend to be affected by negative factors in terms of open economy especially in Anhui and Zhejiang. Among the whole distribution, major cities of Jiangsu province are still closely linked with Shanghai (known from H-H area in Table 5), so it indicates that Shanghai has great effects on Jiangsu in both infrastructure construction and economic development.

Table 5: Explanation of Figure 2

Quadrant	Spatial Effect	Corresponding Cities
H-H (I)	Positive Spatial Autocorrelation	Shanghai, Suzhou(J), Wuxi(J), Changzhou(J), Nantong(J), Jiaxing(Z)
L-H (II)	Negative Spatial Autocorrelation	Yangzhou(J), Zhenjiang(J), Zhoushan(Z), Huzhou(Z), Shaoxing(Z), Jinhua(Z), Hefei(A), Chuzhou(A)
L-L (III)	Positive Spatial Autocorrelation	Yancheng(J), Taizhou(J), Taichow(Z), Wenzhou(Z), Wuhu(A), Maanshan(A). Tongling(A), Xuancheng(A), Anqing(A), Chizhou(A)
H-L (IV)	Negative Spatial Autocorrelation	Nanjing(J), Hangzhou(Z), Ningbo(Z)

Note: a. (J), (Z) and (A) represent the cities of Jiangsu, Zhejiang and Anhui, respectively.
b. Table 5 shows the overall situation of in those 4 years.

4.2 Spatial Econometric Analysis

Based on the results measured by Global Moran's I and Local Moran scatterplots, both transportation infrastructure and economic openness geographically have positive spatial autocorrelation among the 27 cities in Yangtze River Delta. To specifically test the relationship between the dependent and independent variables, the econometric model is built on the basis of Spatial Durbin Model (SDM) as follows:

$$\mathrm{lnEO_{it}} = \alpha_0 + \lambda \mathrm{WlnEO_{it}} + \beta_0 \mathrm{lnTI_{it}} + \beta_i \mathrm{C_{it}} + \theta_0 \mathrm{WlnTI_{it}} + \theta_i \mathrm{WC_{it}} + \varepsilon_{it}$$

Where i denotes the city, t represents the year, C is the set of control variables, λ, β, θ are relevant coefficients, W is the spatial weight and ε is the error term. Based on the Moran Index, those 27 cities mainly have positive spatial autocorrelation, so it may give rise to endogenous problem if continues the regression with OLS. Since SDM is regarded as the generalized form of Spatial Lag Model (SLM) and Spatial Error Model (SEM), its effectiveness is the best comprehensively compared with that of both SLM and SEM. In addition, according to the result of Hausman Test in Table 6, the p-value rejects the null hypothesis at 1% level of significance, which means that the research should go on with Fixed Effects Model (FEM), so the paper chooses SDM with FEM as the main model of empirical analysis. And the estimation result is shown in Table 7.

Table 6: Hausman Test

Test	Statistic	P-Value
Hausman Test	37.88	0.0000

Table 7: The Estimation Result of SDM with FEM

Variables	Coefficients	Variables	Coefficients
lnTI	0.1036*	W_lnTI	0.1617*
	(1.725)		(1.656)
lnHC	-1.6028**	W_lnHC	-0.1638
	(-2.315)		(-0.180)
lnIL	0.0386	W_lnIL	0.1996**
	(0.592)		(2.356)
lnDL	0.2425***	W_lnDL	-0.2840***
	(4.448)		(-3.645)
lnAL	0.1732**	W_lnAL	0.1633
	(2.298)		(1.589)
lnGS	-0.0692	W_lnGS	0.0778
	(-1.403)		(1.250)
λ	0.2601***	sigma2_e	0.0061***
	(4.926)		(14.520)
N	432	R^2	0.2003

Note: T-statistics are in parentheses. The *, ** and *** denote significant at the 10% level, 5% and 1%, respectively.

The estimation result of SDM in Table 7 suggests that transportation infrastructure is positively significant under the test, and economic openness will approximately have a 0.1036% growth once transportation infrastructure increases by 1%, human capital, GDP and Asset level also have significantly positive impacts on economic openness. Therefore, it shows the effectiveness on measuring the influence mechanism and relationship between the variables on the basis of SDM, which proves the correctness of Hypothesis 1 of the paper. To further explain the research path, the following test decomposes the whole effects of SDM into direct effect, indirect effect and total effect.

Table 8: Effects Decomposition of SDM with FEM

Direct Effect		Indirect Effect		Total Effect	
Variables	**Coefficients**	**Variables**	**Coefficients**	**Variables**	**Coefficients**
lnTI	0.1250**	lnTI	0.2189*	lnTI	0.3439**
	(1.960)		(1.839)		(2.294)
lnHC	-1.6859***	lnHC	-0.6813	lnHC	-2.3671**
	(-2.599)		(-0.730)		(-2.267)
lnIL	0.0675	lnIL	0.2505**	lnIL	0.3180**
	(1.050)		(2.554)		(2.384)
lnDL	0.2194***	lnDL	-0.2541***	lnDL	-0.0347
	(4.220)		(-2.841)		(-0.334)
lnAL	0.1926***	lnAL	0.2268**	lnAL	0.4194***
	(2.638)		(2.094)		(3.329)
lnGS	-0.0629	lnGS	0.0712	lnGS	0.0083
	(-1.279)		(0.986)		(0.092)

Note: T-statistics are in parentheses. The *, ** and *** denote significant at the 10% level, 5% and 1%, respectively.

The direct effect indicates the influence of dependent variable on its corresponding independent variable, while the indirect effect means the influence generated by dependent variables of nearby areas on the independent variable (spatial spillover effect). The total one is the aggregation of both direct and indirect effects, shows the overall situation between the dependent and independent variables. From the estimation result of effect decomposition in Table 8, it is clear that transportation infrastructure passes the tests and has positive impact on economic openness in all kinds of effects. Therefore, it can prove that the improvement of a city's transportation infrastructure not only promotes its own economic openness, but also generates positive spatial spillover effects on open economy of nearby cities. To be specific, when transportation infrastructure of a city improves 1%, it will accelerate the economic openness of other cities by 0.2198%, which verifies the Hypothesis 2. Moreover, GDP and Asset level also positively influence economic openness in direct effects, which explains the importance of economic level and fixed-asset investment. Meanwhile, industrial level and asset level become the factors promoting the economic openness in the situation of indirect effect. Thus, they can explain the influencing mechanism of spatial spillover effect. Finally, the paper evaluates the research through robustness test which aims to measure whether the empirical result can keep stable and prove its effectiveness when some of the coefficients are going to be altered.

Table 9: Robustness Test of SDM

Variables	**Coefficients**	**Variables**	**Coefficients**
lnTI	0.1078*	W_lnTI	0.1854**
	(1.716)		(2.576)
lnHC	-0.8238	W_lnHC	0.6284
	(-1.200)		(0.892)
lnIL	0.0520	W_lnIL	-0.1526**
	(0.813)		(-2.267)
lnDL	0.2270***	W_lnDL	0.0212
	(3.929)		(0.319)
lnAL	0.1815**	W_lnAL	0.1637**
	(2.420)		(2.011)
lnGS	-0.0071	W_lnGS	-0.0197
	(-0.137)		(-0.331)
λ	0.2075***	sigma2_e	0.0065***
	(5.757)		(14.575)
N	432	R^2	0.348

Note: T-statistics are in parentheses. The *, ** and *** denote significant at the 10% level, 5% and 1%, respectively.

The concrete method is to replace the simple 0-1 matrix with inverse economic distance matrix, according to Table 9, the robustness test supports the result of positive impact of transportation infrastructure on economic openness. Therefore, the whole empirical analysis proves two hypotheses and the theoretical mechanism.

4. CONCLUSION AND SUGGESTIONS

The paper discusses the impacts of transportation infrastructure on economic openness within the 27 cities of Yangtze River Delta, and the whole empirical analysis is based on the Spatial Durbin Model through testing the direct effect and indirect effect. From the concrete results of Table 7 and Table 8, both Hypothesis 1 and 2 have been proven. Therefore, it can be concluded that the improvement of transportation infrastructure will significantly promotes the degree of economic openness, and there truly exists spatial spillover effect among those 27 cities. Besides, it reflects the fact that the consistent improvement of transportation largely enables the region to develop its open economy through the convenience and benefits it has brought, so the strategic deployment of China's integration construction is undoubtedly of vital importance. But meanwhile, what cannot be ignored is that human capitals and government support have negative or little impacts on economic openness, so it is necessary to perfect both the well-educated workforce employment systems and financial transmission mechanism. On the other hand, since the relationship between the variables is based on statistical test and variable selection has some limitations on data availability, the real influence effects may still fail to be measured in the paper. Overall, the results of empirical test are within the expectation and in line with the reality, so the transportation construction works as an indispensable national program that needs to be continuously improving. Because integration construction is regarded as the major national strategy, transportation infrastructure has already become an indispensable factor to form a unified market which can keep optimizing the resource allocation, forming industrial agglomeration and realize common prosperity. In the current research, most of the studies focus on the relationship between transportation and economic growth, but this paper analyzes from the perspective of open economy, which can be seen as an innovation point. Based on the empirical results and conclusion, the paper gives the following policy proposals.

(1) Deepening the understanding of transportation construction: It is not an infrastructure construction program that blindly pursues the expansion of investment scale or political achievements. Regional construction should accord with the actual development standards and geographic features in each city, so it is supposed to consider both the overall situations and individual cases when planning the layout. Yangtze River Delta is located in the east of China, whose traffic lines nearly cover the whole territory from north to south of China, so the layout needs to put priority on macro coordination and comprehensive management. Jiangsu province connects with Shandong province that is mainly responsible for undertaking industry transfer and in Northern China. Zhejiang borders on both Fujian and Jiangxi provinces, so its economic development and industrial structure directly influences Southern China. Anhui province is near to the central part of China, close to Henan and Hubei provinces. Thus, once the transportation infrastructure and the degree of openness of Anhui get improved, it is highly likely that the development in central regions will also be significantly driven.

(2) Further expanding the openness: Since opening up is taken as one of the basic state policies in China, it prompts the country to keep raising the level of economic openness comprehensively. Yangtze River Delta is one of the earliest regions that were implemented the policy of opening up, so it has the absolute advantage of absorbing foreign capitals, industries, technologies, all forms of economic cooperation and advanced management models. Because it plays a leading role in China's international trade, it is urgently necessary to optimize the business environment and form combined effects with the countries throughout the world. Against the background of the widespread of COVID-19, digital economics has increasingly changed the trade pattern and investment structure. On the other hand, protectionism and unilateralism still restrain the development of international market and industry specialization. Therefore, it is now a timely moment for cities of Yangtze River Delta to seize the new opportunities and face the challenges, and then bring the experience into improving the level of opening up.

(3) Giving full play to the effects of core city: As the core city of Yangtze River Delta, Shanghai is spatially corelated with Jiangsu province most, but it has strong border effect especially for Anhui province, South Zhejiang and North Jiangsu. From one side, transportation is still one of the major programs that need to be push forward in Yangtze River Delta, among which the traffic connection between Shanghai and other cities should be put on the top priority. It is conducive to exerting the radiation effects of Shanghai within the region, which can keep promoting the industrial agglomeration and expansion. From another side, Shanghai also needs to make its non-core functions transfer to other cities where both regional comparative advantages and final international comparative advantages can possibly form, which helps to ensure the undertaking capacities of those cities and improve the whole economic openness of the region instead of Shanghai only.

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