Has the Development of Inter-Provincial Transportation Infrastructure Improved the Construction of China's Unified Market?

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***Abstract*—With the implementation of regional development policies in recent years, transportation infrastructure has greatly promoted regional economic development, but what impact it has on the construction of market integration in the local and surrounding regions has not been specifically answered. Based on the provincial panel data of China from 2010 to 2021, this paper uses the spatial panel method to study the impact of transportation infrastructure development and the construction of national unified market and its spatial spillover effects. The empirical results show that there is significant spatial auto-correlation between inter-provincial transport infrastructure and market integration. Railway density plays a greater role in promoting the national unified market. The government expenditure and foreign direct investment play a positive role in promoting the construction of a unified national market, while the dependence of foreign trade inhibits the development of market integration. In the analysis of spatial spillover effects, the direct effect of railway density is significantly higher than that of highway. The government should strengthen the quality and efficiency of railway transportation, promote the scale of foreign direct investment of enterprises, and actively promote the construction of national unified market.**

***Keywords*—national unified market, transportation infrastructure, spatial spillover effects, spatial durbin model**

I. INTRODUCTION

With the rapid development of transport infrastructure construction, one of the important strategic objectives of China's transformation and reform is to establish a unified national market, constantly promote the process of market integration in various provinces, and actively carry out regional economic and industrial cooperation. However, at the present stage, the economic development of various regions is slowing down, which restricts the free flow of production factors such as factors and resources between regions, reduces the efficiency of market allocation, and increases the risk of market segmentation. Therefore, it is necessary to start from the domestic circular market, fully understand the development network of inter-regional transportation infrastructure, and deeply analyze the impact of inter-provincial transport infrastructure development on the construction of national unified market.

The domestic and foreign literature on the development of transportation infrastructure mainly focus on the network characteristics of transport infrastructure and the analysis of the impact of economic growth. The construction of transport infrastructure has gradually become a booster for the rapid growth of regional economy [1–3]. The investment in transportation infrastructure is considered to be an important catalyst for the development and spatial integration within or between countries. Transport has direct and indirect effects on economic development, such as increasing investment and operating income, creating employment opportunities, etc. [4–6]. The construction of infrastructure can save costs by improving transportation efficiency and accelerate industrial agglomeration [7, 8], which will affect economic growth. In terms of time dimension, it found that transport infrastructure has a long-term promotion effect, but the short-term effect is not significant [9]. However, the current literature rarely considers the space-time characteristics of transportation infrastructure in the spatial dimension, and ignores the spatial impact of economic geography. Therefore, this paper focuses on the spatial-temporal characteristics of highway density and railway density in transportation infrastructure to better analyze the spatial spillover effects of transportation infrastructure.

In the construction of market integration, geographical barriers and cultural differences hinder the free flow of production factors, leading to serious regional market segmentation [10], while the intensification of inter-regional market segmentation and the promotion of inter-regional market integration may occur simultaneously [11]. Local governments have the motivation to block the free flow of production factors and commodities to protect local industries that lack competitive advantages, which may lead to duplicate industries and market segmentation. Accelerating the construction of a unified national market can give full play to the advantages of the market in promoting competition and deepening the division of labor, optimize the allocation of resources and improve efficiency in a wider range. At present, the literature rarely considers the space-time characteristics of market integration construction in the spatial dimension, and ignores the influence of the spatial-temporal characteristics between regions. Therefore, based on spatial econometric model, this paper empirically considers the characteristics of national unified market.

Therefore, there are few comprehensive studies on transportation infrastructure and national unified market at home and abroad, and there are still few spatial econometric analysis on the development of inter-provincial transport infrastructure and market integration. In summary, this paper will study the relationship between inter-provincial transport infrastructure and the construction of national unified market. The spatial weight matrix is added to the empirical methodology and the estimated effects of different spatial econometric models are compared to analyze the spatial spillover effects of transportation infrastructure on market integration.

The main innovations of this paper are as follows: First, a spatial econometric approach is used to analyze the spatial auto-correlation between inter-provincial transportation infrastructure national unified market. Three different spatial weight matrices are compared, and the analysis finds that highway density and railway density have significant positive spatial correlations under all three spatial weight matrices, while the degree of national market integration only shows significant spatial correlation under the second-order adjacency weight matrix. Second, this paper compares and analyzes three different spatial econometric models. It is found that the spatial durbin model has better R^2 and *Log-L* value than the spatial autocorrelation model and the spatial error model, and indicating the robustness of the spatial durbin model. Third, the spatial durbin model is used to analyze the spatial spillover effects of inter-provincial highway and railway density on the construction of unified national market. The results show that the development of market integration is greatly affected by the railway density in the region and surrounding areas, while the impact of the highway density in the region is the least.

The paper proceeds as follows. Section II, we analysis the spatial-temporal characteristics of inter-provincial transport infrastructure and the national unified market. Section III introduces the model, variables and data sources. Section IV shows the results of benchmark regression, model selection, spatial econometric analysis and the spatial spillover effects. Section V is conclusions and suggestions.

II. Spatial-Temporal Characteristics Analysis

In econometric analysis, the results of time series data and panel data of the variables in the model are often different from the spatial measures. The main reason is that the differences between data structure and variable structure are not fully considered, so that the possible biased estimation results are obtained. Therefore, it is necessary to fully consider the impact of economic geography and other factors on market construction, and focus on the analysis of the spatial spillover effects of inter-provincial transportation infrastructure on the construction of the national unified market.

A. Spatial Autocorrelation (SA) Test

Transportation infrastructure has network attribute. Considering that the construction of national market integration is not only related to the development of transportation infrastructure in this region, but also influenced by the transportation infrastructure in other regions. It is necessary to judge whether there is spatial correlation between the transportation infrastructure and the construction of a unified market in each region.

In spatial econometric analysis, the most commonly used test for spatial effects to determine whether economic variables between regions are spatially correlated is the Moran's *I* [12–15]. Moran's *I* can more clearly analyze the spatial clustering or spillover effects of variables.

This paper uses Moran's *I* index to examine the spatial correlation between the construction of national unified market and transportation infrastructure in 31 Chinese provinces, autonomous regions and municipalities directly (excluding Hong Kong, Macao and Taiwan). The calculation is as follows:

$$I = \frac{N}{W}\frac{\sum_{i=1}^{N}\sum_{j=1}^{N} w_{ij}\left(Y_i-\overline{Y}\right)\left(Y_j-\overline{Y}\right)}{\sum_{i=1}^{N}\left(Y_i-\overline{Y}\right)^2}$$

where, N represents the total number of provinces, autonomous regions and municipalities (i or j) in China. Y is the variable observation value of the i-th province. W reflects the geographical location relationship between provinces i and j, and describes the spatial dependency between individuals.

Moran's I takes values in the range of (-1,1). When $I > 0$, it indicates that the economic variables among China's 31 provinces, autonomous regions and municipalities are positively correlated in space, that is, there is spatial agglomeration. When $I = 0$, it shows that the variables among regions are independent of each other, which is irrelevant to the location choice. When $I < 0$, the inter-regional ones are spatially negatively correlated, i.e., there is spatial diffusion.

Spatial Weight Matrix (SWM) reflects the assumptions about a particular spatial phenomenon and is an important component in spatial econometric analysis. Generally, the size of Moran's *I* depends on the spatial weight matrix. According to the most common setting method in domestic and foreign literature, the first-order adjacency function matrix of distance is used to represent it [16]. That is, the two adjacent regions are assigned a value of 1, and the non-adjacent regions are assigned a value of 0. For the value of Moran's *I* and the effectiveness of spatial econometric analysis, this paper constructs the following three spatial weight matrices.

1) Geographic adjacency weight matrix *W1*. This is the simplest and commonly used spatial weight matrix, which mainly considers whether there is spatial proximity among 31 provinces, autonomous regions and municipalities in China. If province i is adjacent to province j, then the elements of *W1* is equal to 1, otherwise equals to 0. In general, if two regions are geographically closer, factors such as population and resources will flow more frequently through transportation infrastructure, and the development of unified national market will be better and better.
2) Second-order adjacency weight matrix *W2*. Since the first-order adjacency matrix fails to take into account the connection between a region and its non-adjacent regions, we construct the second-order adjacency matrix. This matrix is derived from *W1*, that is, taking into account the regions where provinces i and j in China are both adjacent, and expanding the spatial influence range of inter-regional variables.
3) Inverse-geographic distance weight matrix *W3*. In the trade gravity model, trade flows between two regions are inversely proportional to the distance [17–19]. The negative impact of geographical distance on the development of regional markets has become a widely

accepted view in academia. According to Tobler's First Law of Geography, the closer the distance, the greater the influence of weights. In spatial analysis, the elements of *W3* are usually considered the reciprocal of geographical distance between the capital cities, capitals and municipalities of 31 provinces, autonomous regions and municipalities *i* (or *j*) in China.

B. Analysis of Transportation Infrastructure

Before establishing the spatial model, it is necessary to test the spatial correlation of inter-provincial transportation infrastructure. In this paper, we select the highway and railway density (Unit: km/km^2) of 31 provinces, autonomous regions and municipalities in China from 2010 to 2021 to calculate the transportation infrastructure. The results of the global Moran's *I* for highway and railway density of each province in China under the three spatial weight matrices are given in Table 1 and Table 2, respectively.

Table 1. Moran's I index of China's inter-provincial highway density from 2010 to 2021

Matrix	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
W1	0.629***	0.626***	0.646***	0.629***	0.599***	0.627***	0.633***	0.638***	0.641***	0.643***	0.633***	0.638***
	(5.704)	(5.689)	(5.842)	(5.709)	(5.468)	(5.683)	(5.742)	(5.772)	(5.786)	(5.802)	(5.706)	(5.761)
W2	0.386***	0.382***	0.395***	0.382***	0.351***	0.375***	0.379***	0.379***	0.377***	0.379***	0.370***	0.370***
	(7.881)	(7.826)	(8.048)	(7.815)	(7.263)	(7.679)	(7.752)	(7.752)	(7.689)	(7.725)	(7.542)	(7.558)
W3	0.102***	0.107***	0.108***	0.107***	0.099***	0.103***	0.104***	0.104***	0.103***	0.102***	0.101***	0.102***
	(3.819)	(3.989)	(4.002)	(3.979)	(3.770)	(3.861)	(3.897)	(3.894)	(3.840)	(3.806)	(3.783)	(3.819)

Significance code: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. The values of *z* statistics are in parentheses.

Table 2. Moran's I index of China's inter-provincial railway density from 2010 to 2021

Matrix	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
W1	0.587***	0.600***	0.598***	0.619***	0.622***	0.622***	0.611***	0.605***	0.610***	0.612***	0.608***	0.642***
	(5.649)	(5.740)	(5.729)	(5.923)	(5.893)	(5.934)	(5.877)	(5.843)	(5.893)	(5.938)	(5.953)	(6.081)
W2	0.397***	0.405***	0.405***	0.409***	0.416***	0.419***	0.402***	0.399***	0.402***	0.403***	0.504***	0.428***
	(8.548)	(8.672)	(8.691)	(8.765)	(8.809)	(8.940)	(8.680)	(8.630)	(8.705)	(8.769)	(8.882)	(9.054)
W3	0.123***	0.118***	0.119***	0.119***	0.120***	0.117***	0.111***	0.109***	0.109***	0.111***	0.112***	0.123***
	(4.604)	(4.503)	(4.519)	(4.519)	(4.533)	(4.471)	()4.303	(4.257)	(4.285)	(4.336)	(4.415)	(4.604)

Significance code: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. The values of *z* statistics are in parentheses.

The results of Moran's *I* in Table 1 and Table 2 show that the inter-provincial transportation infrastructure (highway density and railway density) in China have global spatial correlation under the three spatial weight matrices, and all of them pass the significance test at the level of 1%. All Moran's *I* index statistics are positive, indicating that there is a spatially significant positive auto-correlation between inter-provincial transportation infrastructure in China. The test results of the three different spatial weight matrices also show that the transportation infrastructure variables have spatial correlation.

In terms of the magnitude of Moran's *I*, the density of highway and railway is increasing in *W1* and *W2* as a whole, which shows that with the development of domestic infrastructure construction, the inter-provincial transport infrastructure links are becoming closer and closer. In *W3*, the statistical value of Moran's *I* index fluctuates slightly over time, but the overall change is not significant. Therefore, it is reasonable to fully consider the spatial correlation of transportation infrastructure when studying the impact of inter-provincial transportation infrastructure on the construction of national unified market.

C. Analysis of National Unified Market

China's provinces have a wide variety and abundant resources, but the regional distribution is uneven. With the rapid development of transport infrastructure construction, the inter-provincial passenger and cargo transportation is increasing. Based on spatial econometric analysis, this paper selects the commodity retail price classification indexes of 31 provinces, autonomous regions and municipalities in China from 2010 to 2021 to measure the development degree of the national unified market. Table 3 shows the global Moran's *I* results of the market construction degree of 31 provinces, autonomous regions and municipalities under the three spatial weight matrices.

Table 3. Moran's I index of China's unified market construction variables from 2010 to 2021

Matrix	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
W1	0.242**	0.206*	0.230**	0.186*	0.217**	0.209*	0.226**	0.229**	0.231**	0.240**	0.256**	0.284**
	(2.341)	(1.995)	(2.232)	(1.722)	(2.218)	(2.053)	(2.184)	(2.215)	(2.245)	(2.318)	(2.693)	(2.997)
W2	0.189***	0.088**	0.060*	0.103***	0.114***	0.123***	0.144***	0.137***	0.131***	0.149***	0.158***	0.177***
	(4.142)	(2.213)	(1.771)	(2.771)	(2.819)	(2.874)	(3.273)	(3.036)	(2.998)	(3.402)	(3.650)	(3.965)
W3	0.034*	0.029	0.032*	0.026	0.030*	0.032*	0.036*	0.037*	0.047**	0.044**	0.049**	0.051**
	(1.873)	(1.453)	(1.706)	(1.279)	(1.506)	(1.795)	(1.908)	(1.915)	(2.106)	(2.001)	(2.276)	(2.361)

Significance code: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. The values of *z* statistics are in parentheses.

From the test results in Table 3, it can be seen that the Moran's *I* of the construction degree of the unified national market is mostly significantly positive under the three spatial-weight matrices. It shows that there is an obvious positive auto-correlation relationship in the construction of China's unified market, that is, it is reasonable to consider the spatial correlation of market development when studying the impact of inter-provincial transportation infrastructure on the construction of national unified market. From the level of significance, the estimated efficiency of *W2* is the most stable and more significant than *W1* and *W3*. Therefore, in the subsequent econometric analysis, in order to ensure the spatial correlation of the construction of national unified market, we use the spatial weight matrix *W2* to conduct the following spatial analysis to ensure the robustness of the spatial model estimation.

As a whole, there is spatial clustering in inter-provincial transportation infrastructure and the construction degree of national unified market. Therefore, introducing spatial weight matrix data on the basis of panel data and making full use of temporal and spatial information expressed by spatial-temporal data can more reasonably explain the role of inter-provincial transport infrastructure development in the construction of national unified market, and the spatial econometric model will get more reasonable results than the traditional econometric model.

III. Methods and Data

A. Methods

In the econometric analysis, the most common spatial econometric models are the Spatial Autoregression Model (SAR) [20] and the Spatial Error Model (SEM). SAR model, also known as Spatial Lag Model (SLM), only contains dependent variables with spatial auto-correlation. SEM model only contains the error term with spatial auto-correlation. Lesage and Pace [21] comprehensively considered the spatial transmission mechanism of the above two models, and constructed the Spatial Durbin Model (SDM).

SAR model can be expressed as follows:

$$Y_{it} = \rho W Y_{it} + X_{it}\beta + \mu_i + \xi_t + \varepsilon_{it}$$

where, Y is the dependent variable, X is the independent variable, i is the 31 provinces, autonomous regions and municipalities in China, and t is the time. ρ is the spatial regression coefficient, ρ and β are the parameters to be estimated. W is the spatial weight matrix, μ is the spatial fixed effect, ξ is the time fixed effect, and ε is the normal distribution random disturbance term.

If $\rho = 0$, SAR can degenerate into a general multiple linear regression model. Therefore, in order to test whether the model SAR has spatial effects, we can judge whether $\rho = 0$ is true.

SEM model can be expressed as follows:

$$Y_{it} = X_{it}\beta + \mu_i + \xi_t + u_{it}$$
$$u_{it} = \lambda W u_{jt} + \varepsilon_{it}$$

where, u is the random error term of independent and identical distribution, λ is the spatial auto-correlation coefficient. β and λ are the parameters to be estimated, and the definitions of the other symbols are the same as those in SAR model.

Similarly, if $\lambda = 0$, SEM model can be degenerated into a general multiple linear regression model. Therefore, we can judge whether there is spatial auto-correlation between perturbations by checking whether $\lambda = 0$ is true.

SDM model can be expressed as:

$$Y_{it} = \rho W Y_{it} + X_{it}\beta + W X_{it}\theta + \mu_i + \vartheta_t + \varepsilon_{it}$$

where, ρ and θ are spatial regression coefficients, ρ, β and θ are parameters to be estimated. WX represents the spatial lag explanatory variable, and it is used to explain that the Y of province i is affected by the explanatory variable X of other provinces in addition to the explanatory variable WX of its own region. θ is the spatial spillover effect coefficient. The definitions of other symbols are the same as those in SAR model.

Similarly, if $\rho = 0$ and $\theta = 0$, SDM model can degenerate into a general multiple linear regression model. Therefore, we can judge whether the SDM model has spatial effects by checking whether $\rho = 0$ and $\theta = 0$ are valid.

Given the differences in the economic implications revealed by different types of spatial econometric models, this paper selects specific spatial models based on the presence or absence of spatial interaction effects of the dependent or independent variables based on the method mentioned by Wang *et al*. [22].

B. Variables and Data

To study the spatial impact and spillover effects of transportation infrastructure development on the construction of national unified market, this paper uses inter-provincial panel data from 2010–2021, with detailed definitions and explanations of each variable as follows.

Explained variable: the construction degree of national unified market. In order to quantitatively analyze the degree of integration development of the unified domestic market, the relative price index method was used according to the commodity retail price classification index of the China Statistical Yearbook (2010–2022) to get the relative market segmentation index. Due to the negative correlation between market segmentation and the construction of national unified market, this paper uses the adjusted relative price variance index as the most important indicator of market integration. There is a positive correlation between the adjusted indicators and the progress of the construction of the unified market. According to the descriptive results of the national unified market index in Table 4, the minimum value of the index is 3.6448, and the maximum value is 3.6448, indicating that China's unified market level is relatively high on the whole, but there are differences in the degree of market construction between different regions.

Independent variable: transportation infrastructure. This paper selects the highway and railway density of 31 provinces, autonomous regions and municipalities directly to calculate the transport infrastructure. See Table 4 for the detailed explanation and description of the variables.

Control variables: (1) Dependence on foreign trade. The foreign trade export of each province has a significant impact on the development of unified domestic market. Generally, provinces with high dependence on foreign trade have low degree of market integration. (2) Government financial expenditure. Based on the consideration of developing the regional economy, the local government will appropriately increase the local financial expenditure, and usually provide more preferential development strategies for local enterprises, thus improving the market enthusiasm of the region to a certain extent. (3) Foreign direct investment. Foreign direct investment is crucial to China's economic development. Therefore, in order to accelerate the development of regional economy, local governments often attract foreign investment to join the regional market under their control, improve the efficiency of capital turnover in the market, and further improve the integrated development of the market.

Table 4. The variable definition, source and descriptive statistics

Variable	Description	Source	Mean	Std.Dev.	Min	Max
lnSe	Adjusted relative price variance index	China Statistical Yearbook (2010–2022)	4.9951	0.3924	3.6448	5.6601
lnHwden	Annual highway operating mileage/area of each province		−0.3576	0.8675	−3.0058	0.8039
lnRwden	Annual railway operating mileage/area of each province		−3.9838	0.9974	−7.8240	−2.3076
lnTrade	Annual export/GDP of each province		2.1377	0.9798	−0.8916	4.2665
lnEXP	Local government financial expenditure/GDP		8.3072	0.6491	6.3118	9.8118
lnFDI	Annual foreign direct investment/GDP of each province		8.4595	1.5939	3.5219	12.5848

IV. Estimation Results and Discussion

A. Benchmark Regression

Table 5 reports the OLS benchmark regression results of the impact of inter-provincial transportation infrastructure development on the construction of national unified market under the stepwise regression method.

Table 5. Benchmark regression results

Variable	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)	Model (6)	Model (7)
lnHwden	0.0699*** 3.01					0.0669** 1.96	
lnRwden		0.0633*** 3.14					0.0802*** 2.62
lnTrade			−0.0427** −1.68			−0.0705*** −2.73	−0.0553** −2.13
lnEXP				0.1494*** 4.91		0.1797*** 3.89	0.2132*** 4.43
lnFDI					0.0462* 1.63	0.0479* 1.78	0.0535** 2.27
lnC	5.0201*** 230.56	5.2474*** 63.31	5.0332*** 102.93	3.7536*** 14.79	4.7055*** 43.13	3.8561*** 12.65	4.0600*** 12.48
R^2	0.0239	0.0259	0.0120	0.0600	0.0193	0.0922	0.0996
F	9.04	9.85	6.73	24.09	5.29	9.32	10.15

Significance code: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

According to the benchmark regression results in Table 5, when the control variables are not considered, the density of inter-provincial highway and railway has a significant positive correlation with the construction of national unified market. When adding control variables, except for the significant negative impact of foreign trade dependence of each province on market integration, other control variables all promote the development of unified market. Among them, government expenditure has the largest positive elasticity effect on unified market. Considering the R^2 and F statistical values of model (1)-model (7), it can be seen that the statistical indicators of model (6) and model (7) are relatively large and can better fit the data in the model.

B. Spatial Panel Model Selection

In order to test whether SAR or SEM can better describe the data, the LM test is first performed by estimating the non-spatial panel model of two-way fixed effects. Table 6 shows the traditional Lagrange multiplier (LM) test results and robust LM test results based on the second-order adjacency weight matrix *W2*.

Table 6. The summary of LM test, Wald test and LR test

Test	LM test				Test	Wald test and LR test			
	Hwden		*Rwden*			*Hwden*		*Rwden*	
	Statistics	*p*	Statistics	*p*		Statistics	*p*	Statistics	*p*
Spatial lag by LM	322.704	0.000	308.374	0.000	Wald test for spatial lag	37.38	0.000	47.95	0.000
Spatial lag by robust LM	9.428	0.002	12.763	0.000	LR test for spatial lag	26.21	0.000	26.33	0.000
Spatial error by LM	317.907	0.000	300.207	0.000	Wald test for spatial error	31.35	0.000	32.52	0.000
Spatial error by robust LM	4.632	0.031	4.596	0.032	LR test for spatial error	21.33	0.000	21.43	0.000

According to the test results, in the LM test of highway density and railway density, the values of LM spatial lag and robust LM spatial lag are 322.704 and 9.428, 308.374 and 12.763, respectively, which reject the original assumption that there is no spatial lag term in the model at the level of 1% significance. The values of LM spatial error and robust LM spatial error are 317.907 and 4.632, 300.07 and 4.596, respectively, and both reject the original assumption that there is no spatial error in the model at the level of 5%. Therefore, it is appropriate to select a spatial measurement model to analyze the spatial impact of inter-provincial transport infrastructure on the construction of a unified national market.

After removing the non-spatial model and initially selecting spatial econometric model, consider three spatial models introduced earlier, namely SAR, SEM and SDM. Test the original assumptions $\theta = 0$ and $\theta + \rho * \beta = 0$ to determine whether SDM can be simplified to SAR or SEM. The results of Wald test and LR test are shown in Table 6.

It can be seen from Table 6 that both Wald test and LR test reject the original assumption that SDM can be simplified to SAR or SEM at the level of 1% significance. Therefore, both tests show that the SDM model best describes the data. Hausman test was used to test the random effect model and fixed effect model. The results (*Hwden*: Statistics = 25.15, p = 0.004 and *Rwden*: Statistics = 40.83, p = 0.000) showed that the random effect model must be rejected. Therefore, the model is extended to a spatial durbin model with fixed effects of spatial and temporal periods.

C. Spatial Panel Model Results

In this paper, we estimate the impact of inter-provincial transportation infrastructure development and the construction of national unified market using spatial panel data from 2010-2021, combined with the MLE method. Table 7 shows the estimation results of the ordinary least squares (OLS), SAR, SEM, and SDM, respectively.

Table 7. The estimation results of OLS, SAR, SEM AND SDM

Variable	Model (8)				Model (9)			
	OLS	**SAR**	**SEM**	**SDM**	**OLS**	**SAR**	**SEM**	**SDM**
lnHwden/ lnRwden	0.0669** 1.96	0.0748** 2.38	0.0858*** 2.67	0.0470* 1.66	0.0802*** 2.62	0.0660** 2.31	0.1033*** 2.73	0.0769** 2.55
lnTrade	−0.0705*** −2.73	−0.0664*** −2.94	−0.0984*** −3.84	−0.0968*** −3.73	−0.0553** −2.13	−0.0541** −2.37	−0.0928*** −3.49	−0.0939*** −3.48
lnEXP	0.1797*** 3.89	0.0750* 1.72	0.0785* 1.75	0.0768* 1.73	0.2132*** 4.43	0.0904** 1.97	0.0841* 1.80	0.0791* 1.75
lnFDI	0.0479* 1.78	0.0028 0.12	0.0485* 1.84	0.0503* 1.89	0.0535** 2.27	0.0098 0.37	0.0628** 2.69	0.0946** 3.21
*W*lnHwden*				0.2978*** 4.59				0.5659*** 6.09
*W*lnTrade*				−0.1139*** −4.34				−0.0621** −2.78
*W*lnEXP*				0.5476*** 3.88				0.5400*** 3.81
*W*lnFDI*				0.1843*** 2.35				0.2329*** 2.92
Rho		0.6835*** 12.86		0.5417*** 7.35		0.6740*** 12.51		0.5288*** 7.00
Lambda			0.7151*** 14.16				0.7135*** 14.01	
Sigma2_e		0.0869*** 12.51	0.0850*** 12.51	0.0858*** 12.52		0.0870*** 12.51	0.0849*** 12.51	0.0859*** 12.47
R^2	0.0922	0.4432	0.4454	0.9429	0.0996	0.4236	0.4345	0.9368
Log-Likehood	9.32	−111.2918	-108.8528	-98.1860	10.15	−111.3463	−108.9006	−98.1838

Significance code: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

From the study of the spatial analysis results of the inter-provincial highway density on the construction of national unified market, it can be seen that the highway density has a significant role in promoting the development of market integration in the OLS, SAR, SEM and SDM models. The variable estimation results of the three spatial models have little difference from the OLS results, but the spatial model has greater R^2 and Log_L, which indicates that the spatial model is superior to OLS regression in estimation effect. Comparing the results of the three spatial analysis, it can be seen that SDM can analyze the spatial spillover effect of the density of highway on the construction of national unified market than SAR and SEM. The spatial regression coefficients of the three models are significant at the level of 1%, which means that the estimation results obtained by selecting SDM analysis are robust.

Similarly, in the study of the spatial analysis results of the inter-provincial railway density on the construction of the national unified market, it can be seen that the railway density has a more significant role in promoting the development of market integration in the four models, but the spatial model has greater R^2 and Log_L, indicating that the spatial model is superior to OLS regression. Comparing the results of three spatial analyses, we can also find that the estimation results obtained by selecting SDM analysis are robust.

Comparing SDM estimates of inter-provincial highway and railway density, it can be seen that the development of inter-provincial railway has more promoting effects on the construction of unified national market. The main reason is that with the continuous increase of the national investment in high-speed railway, the frequency of passenger and freight transport through railway is becoming higher and higher, which accelerates the cooperation between regions and improves the process of national market integration.

In the control variables, the dependence of foreign trade of each region inhibits the development of integration construction. The main reason is that with the expansion of the scale of export trade, the share of commodity consumption will be relatively reduced, and cross-regional transactions will also increase the purchase cost, and thus have a certain degree of negative impact on the construction of a unified market in the region and even the whole country. Both government financial expenditure and foreign direct investment can significantly promote the development of inter-regional market integration, mainly because the local government will increase some preferential policies to ensure the efficient development of economic activities, and will expand the scope of investment to attract investment enterprises to cooperate across regions, which will greatly improve the economic efficiency of the region and promote market integration nationwide.

D. Effect Decomposition

The spatial lag term in SDM can not directly determine the size of the spatial spillover effect of transportation infrastructure. The spatial spillover effect of highway density and railway density on the construction of national unified market is analyzed separately through direct effect, indirect effect and total effect. The estimated results are shown in Table 8.

It can be seen from Table 8 that the three effects of railway density on the construction of national unified market are significantly positive at the level of 1%. The spillover effect of highway density is significant at the level of 5%, and the coefficient is smaller than that of railway density. It shows that the railway construction in this region and the surrounding areas can greatly promote the market integration development in this region.

In addition, it can be found from the table that the three effects of the three control variables, foreign trade dependence, government fiscal expenditure and foreign direct investment, are all significant at the level of 1%. However, trade dependence has a significant spatial diffusion effect on the development of the national unified market construction, while government expenditure and investment have a significant spatial agglomeration effect.

Table 8. Effect decomposition results

Variable	**Model (8)--SDM**			**Model (9)--SDM**		
	Direct effect	**Indirect effect**	**Total effect**	**Direct effect**	**Indirect effect**	**Total effect**
lnHwden / lnRwden	0.0595* (1.70)	0.2470** (2.36)	0.3065** (2.52)	0.1147*** (2.67)	0.3979*** (3.02)	0.5126*** (3.18)
lnTrade	-0.1315*** (-4.98)	-0.7242*** (-2.78)	-0.8557*** (-3.17)	-0.1141*** (-4.03)	-0.2429*** (-1.01)	-0.3570*** (-1.43)
lnEXP	0.1377*** (2.98)	1.1543*** (5.17)	1.2920*** (5.51)	0.1502*** (3.18)	1.1217*** (5.25)	1.2719*** (5.68)
lnFDI	0.0094 (0.35)	0.5194*** (3.64)	0.5288*** (3.94)	0.0021 (0.07)	0.6067*** (4.59)	0.6088*** (4.69)

Significance code: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. The values of t statistics are in parenthese.

Due to the possible reverse causal relationship between the construction of unified national market and transportation infrastructure, Table 9 reports the Granger causality test results of the panel model.

Table 9. Granger causality test results

Equation	**Excluded**	**Std. Err.**	**Chi2**	**Prob > chi2**
lnSe	*lnHwden*	4.1994	6.1228	0.0000
	lnRwden	2.9515	2.6489	0.0081
lnHwden	*lnSe*	1.3668	1.4441	0.1487
lnRwden	*lnSe*	1.8035	1.0494	0.2940

The results show that the Granger causality test p-values of *lnHwden* and *lnRwden* for *lnSe* are 0.0000 and 0.0081, respectively, rejecting the original hypothesis, indicating that the development of highways and railways has led to the construction of the unified market. On the contrary, the construction of national unified market is not the Granger reason for the development of highways and railways.

V. Conclusions and Policy Implications

This paper collects the density of China's inter-provincial highway and railway and the degree of market integration index from 2010 to 2021, uses the Moran's I to test the spatial correlation between transport infrastructure and national unified market, and compares and analyzes the estimation effect and spatial spillover effects of different spatial econometric model. Research shows that the inter-provincial highway density and railway density have significant positive spatial correlation under the three different spatial weight matrices, while the adjusted market integration index has spatial correlation only under the second-order adjacency weight matrix. In the selection of spatial model, SDM passed the LM test, Wald test and LR test, indicating that SDM has more effective model interpretation and robustness than SAR and SEM. In the spatial econometric analysis, the positive impact of railway density on market integration in a region is significantly greater than the effect of highway density, and the railway density has greater direct effect and spatial spillover effects on the national unified market.

Therefore, China's commitment to the development of transportation infrastructure plays a significant role in promoting the construction of national unified market, especially the development of railway transportation in a region and its surrounding areas. In order to realize the national market integration, it is also necessary for to actively promote the scale of foreign direct investment, appropriately enhance the scale of local government financial expenditure and support efficiency, reasonably allocate the share of internal and external economic circulation of local enterprises and social production, continue to strengthen the construction of railway transportation network and the quality of transport, actively promote regional market cooperation, and promote the integration process of the national unified market.

Conflict of Interest

The author declares no conflict of interest.

Author Contributions

Xueyan Wang conducted the research, collected background information from literatures, collected and analyzed the data, interpreted the results and wrote the paper; The author had approved the final version.

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