The Impact of Rail Transit Infrastructure Carrying Capacity on Economic Development: A Comparative Study of Central and Western of China

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Abstract. This paper examines the pattern of rail transport development and economic development in the central and western regions of China during the period 1999–2020. The extent and mechanism of the impact of rail transport on economic development are analysed by measuring the relative carrying capacity and OLS models. It was found that there is a certain surplus of rail transport infrastructure carrying capacity, but the supply and demand matching degree differs significantly between the central and western regions; rail transport infrastructure has a good positive propulsive effect on economic growth, but the impact factor is smaller in the western region than in the central region; there is a two-way interactive causal relationship between rail transport infrastructure and economic development in regions with good economic development, while in less developed regions, the existing rail transportation will lead the growth of the regional economy in a certain period in the future.

Keywords: Transport infrastructure · Carrying capacity model · Economic growth

1 Introduction

Rail transport establishes connections between cities and is considered an important foundation and prerequisite guarantee for regional economic development. Particularly in China, rail transport has become a key infrastructure for carrying regional economic growth. Specifically, a well-functioning rail transit facility has sufficient capacity to carry a certain amount of economic activity, increasing regional and national resource mobility and productivity to drive sustainable development [1]. However, for less developed regions, rail transport infrastructure by itself is not sufficient to facilitate economic activities in these regions [4], the "build first, use later" development model not only increases construction and operation costs but also has a large surplus of traffic carrying

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capacity [2]. Therefore, it is necessary to explore a new path for sustainable regional development in terms of the mechanism of the impact of rail transport carrying capacity on economic growth.

The relationship between transport infrastructure and the carrying capacity of economic growth is dynamic. As economic, industrial, and social factors continue to change [13], it is worthwhile to investigate how to effectively use infrastructure's abundant carrying capacity for valuable and rewarding economic activities. Established studies have found that rail infrastructure can directly reduce travel costs, attract investment and expand regional resource sharing [10]. In terms of indirect effects, rail transport has significant spatial spill over effects on regional factor mobility and redistribution in agricultural modernization and industrialization [6], there are also negative spill over effects on economic growth from differentiated infrastructure investments [12], which are usually reflected in uneven geographical location and socio-economic development [3]. A study of different countries and regions around the world also found a unidirectional causal relationship between rail transport and economic growth in India [5]. A two-way interactive causality exists in some less developed regions of China, while in wealthier regions, rail transport leads to high economic growth [9]. In addition, some studies on the economic carrying efficiency of infrastructure have shown that high efficiency in the use of rail transport infrastructure is a necessary prerequisite for carrying a large amount of urban economic development [7, 8].

In recent years, China has significantly increased investment in rail transport infrastructure in the hope of promoting sustainable regional economic development. To explore the extent and mechanisms of influence between rail transport investment and economic development, this paper examines the relationship between the carrying capacity of rail transport infrastructure and economic development patterns in central and western of China in a comparative manner using panel data for the period 1999–2020. To provide reference suggestions for the optimization of infrastructure and regional interconnection in the perspective of economic development.

2 Data and Methods

2.1 Data Description

In this paper, rail transport infrastructure mainly refers to railway transport, including mainline railway, inter-regional and inter-city rail transport, excluding intra-city rail transport such as the metro. Rail transit mileage, converted turnover (a comprehensive indicator of total passenger and freight transport turnover in the transport sector), and the number of people employed in the railway transport industry are selected to reflect railway transport capacity indicators. The main data were obtained from the National Bureau of Statistics of China, the National Statistical Yearbook, and provincial statistical yearbooks, covering the period 1999–2020 (http://www.stats.gov.cn/tjsj/ndsj/. Collected on 13 may 2021). Five provinces in the northwest region, Xinjiang, Gansu, Ningxia, Qinghai, and Shaanxi, five provinces in the central region, Henan, Shanxi, Hubei, Anhui, and Hunan, were selected for the study.

2.2 Research Methodology

2.2.1 Relative Bearing Capacity Model

Rail facility is a quantitative and qualitative resource itself. Which has a supporting role in the development of the region and the country. The carrying capacity is a measure of the upper limit of a resource's contribution to economic growth [11]. This study using the relative resource carrying capacity model to analyse the supporting capacity of rail transport infrastructure to the regional economy. The calculation formula is as follows.

$$S_{tl} = \sum_{i=1}^{n} \omega_i S_i \tag{1}$$

$$S_i = I_i \times Q_i \tag{2}$$

$$I_i = E_0 / Q_{i0} \tag{3}$$

S_{tl} denotes the relative resource economic carrying capacity, ω_i is the resource weight, S_i is the corresponding indicator resource carrying capacity, E_0 is the corresponding economic total for the reference area, Q_i denotes the corresponding indicator resource for the study area, and Q_{i0} is the corresponding resource for the indicator in the reference area.

Due to the different degrees of influence of the variables, the principle of promoting economic development by some of the superior resources and the possibility of inhibiting its development by another part of the inferior resources are considered, so constraints are added to the original model to objectively reflect the strength of rail transport for supporting economic development. The improved relative integrated carrying capacity model.

$$\begin{gathered}
\max \mathrm{S}_{tl}^{1} = \omega_1 S_1 + \omega_2 S_2 + \omega_3 S_3 \\
s.t. \begin{cases} \alpha \le \left|\omega_i - \omega_j\right| \le \beta \\ \theta < \omega_\mathrm{i}, \omega_\mathrm{j} < 1, (\mathrm{i}, \mathrm{j} = 1, 2, 3, \mathrm{i} \ne \mathrm{j}) \\ \sum_{i=1}^{3} \omega_i = 1, \sum_{i=1}^{3} \omega_j = 1 \end{cases} \\
\max \mathrm{S}_{tl}^{2} = \omega_1 S_1 + \omega_2 S_2 + \omega_3 S_3 \\
s.t. \begin{cases} \alpha \le \left|\omega_i - \omega_j\right| \le \beta \\ \theta < \omega_\mathrm{i}, \omega_\mathrm{j} < 1, (\mathrm{i}, \mathrm{j} = 1, 2, 3, \mathrm{i} \ne \mathrm{j}) \\ \sum_{i=1}^{3} \omega_i = 1, \sum_{i=1}^{3} \omega_j = 1 \end{cases}
\end{gathered} \tag{4}$$

Where θ is the lower limit of the weight of each factor; α, β are the upper and lower limits of the difference between the weights of each factor. It is generally considered that the maximum difference between ω_i is not more than 0.3, the minimum is not less than 0.05, and ω_i is not less than 0.1. The geometric weighted average of the relative bearing capacity indicators obtained is the Comprehensive traffic carrying capacity (CTCC).

2.2.2 OLS Regression Model

OLS (Ordinary least squares) regression analysis can reflect more accurately whether rail transport infrastructure has a good explanatory relationship to economic growth, determine the degree of influence of rail transport factor variables on economic development. After determining the long-term equilibrium relationship, the OLS method was used to construct a regression equation to investigate the degree of influence and support of rail transport infrastructure on the economy, the regression equation is as follows.

$$LnZ = \alpha_i LnHZL(t) + \beta_i LnTYL(t) + \theta_i LnTJR(t) + C_i \tag{5}$$

Z denotes economic indicators, *LnHZL, LnTYL,* and *LnTJR* denote the logarithms of converted turnover, railway mileage, and the number of employees respectively, α_i, β_i and θ_i are the contribution rates of different variables to *Z* respectively, and C_i denotes the random error term.

2.2.3 Granger Causality Test

The OLS regressions while reflecting significant relationships between variables, are not sufficient to explore uncertainty in causality. The Granger test examines whether a change in X causes a change in Y. It not only examines the extent to which past values of X have had an impact on Y, but also accurately reflects the 'prediction' based causality.

$$\begin{cases} Y_t = \sum_{i=1}^{m} \alpha_i X_{t-i} + \sum_{i=1}^{m} \beta_i Y_{t-i} + \mu_1 \\ X_t = \sum_{i=1}^{m} \theta_i Y_{t-i} + \sum_{i=1}^{m} \delta_{\mathrm{i}} X_{t-i} + \mu_2 \end{cases} \tag{6}$$

- If $\beta_i = \delta_{\mathrm{i}} = 0$ (i = 1,2,3, …, q), So Y_t and X_t are independent;
- If $\beta_i = 0$, $\delta_{\mathrm{i}} \neq 0$ (i = 1,2,3, …, q), So Y_t is the cause of X_t;
- If $\beta_i \neq 0$, $\delta_{\mathrm{i}} = 0$ (i = 1,2,3, …, q), So X_t is the cause of Y_t;
- If $\beta_i \neq 0$, $\delta_{\mathrm{i}} \neq 0$ (i = 1,2,3, …, q), So Y_t is Y_t is causal.

3 Results

3.1 Relative Resource Carrying Capacity

According to the relative comprehensive carrying capacity model to measure the time evolution of relative rail transportation and economic growth in the central and western regions of China for a total of 20 years since 1999, the comprehensive carrying capacity of rail transportation in the central and western regions from 1999 to 2020 showed an overall growth trend, with the growth rate in the western region slightly higher than that in the central region, specifically, the average growth rate of rail transportation infrastructure carrying capacity and economic development (GDP) in the central region was

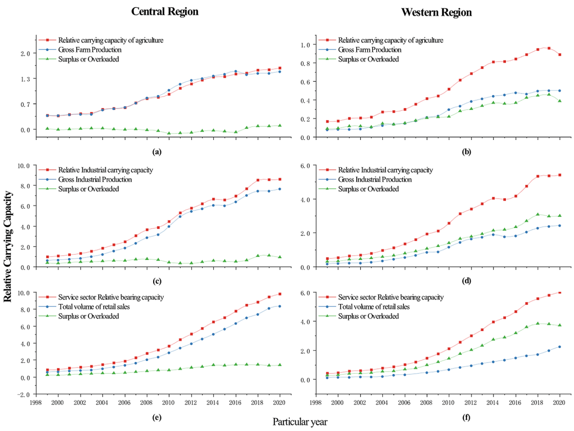

Fig. 1. Comparison of the extent to which rail infrastructure is carried about to with concerning agriculture (a, b), industry (c, d) and retail services (e, f).

0.53% and 0.56%, the western region grew 0.59% and 0.56% respectively, especially after 2010, with the western development and the construction of the Belt and Road, the state significantly increased the western comprehensive rail transport investment, it is also these favourable policies to promote the western region's transportation and economic development. A horizontal comparison between the comprehensive traffic carrying capacity and economic growth rate shows that the growth rate of economic development in the central region is slightly greater than the growth rate of infrastructure carrying capacity, indicating that the economic and social development in the central region has gradually approached the carrying capacity of rail transportation, and the rapid growth of economic development needs to force the improvement of traffic infrastructure. On the contrary, in the western region, although the construction of rail transport infrastructure has a certain extent promoted the development of the regional economy, the endogenous impetus of the region's own economic development is insufficient to promote the construction of rail transport infrastructure. It is easy to see that the effect of the rail transport carrying capacity in promoting regional economic growth in the western region is weak, indicating that most of the rail transport construction and operation is only for the convenience of travel and such low-level needs, but in promoting regional economic and social quality and sustainable development, there is still a lot of room for improvement. There is still much room for improvement in terms of promoting high-quality and sustainable regional economic and social development.

The impact of the construction of rail transport infrastructure on agriculture, industry, and retail services in the central region is explored separately in terms of industrial structure. As is shown in Fig. 1, for the western region, the construction of rail transit infrastructure is sufficient to carry the region's economic and social development needs a long period time in the future, and taking into account the population density and environment of the western region, the western region needs to reduce the scale of investment in rail transit infrastructure and make use of the existing facilities to optimize the industrial structure and enhance the efficiency of economic growth, which is more conducive to reducing the capital investment pressure and rail transit operation and maintenance costs. Compared with the western region, although the central region has a certain overall surplus of rail transport carrying capacity, from the industrial structure, subsystem is better matched, such as Fig. 1a shows the agricultural industry and rail transport carrying capacity curve, from 2008 to 2017, the rail transport carrying capacity is not enough to support the transport demand of finished agricultural products, mainly because the central region is an important grain-producing area and facility breeding area in China, at any time The rapid increase in demand for cross-region movement of agricultural products due to the development of agricultural technology has led to insufficient rail transport capacity, and after 2017, the situation of rail transport overrun has been alleviated. Figures 1c and 1d show that the industrial industry carrying capacity in the central and western regions fluctuates significantly, mainly due to government guidance on industrial development and industrial supply-side reform under the requirements of environmental protection, with each industrial restructuring mostly accompanied by investment in the construction of rail transport infrastructure. Figures 1e and 2f show the tertiary industry represented by the retail service industry and the rail transport carrying capacity curve. It is found that the demand for the tertiary industry in the western region is much lower than the investment in the construction of rail transport infrastructure, and the gap is further widening, reflecting the relatively backward development of the tertiary industry in the western region, and the role of rail transport investment in promoting the development of the tertiary industry in less developed regions is not obvious. While in the central region, where economic conditions are better, it can better promote regional economic and social development.

3.2 OLS Regression Results

3.2.1 Tests for Smoothness

To analyses the influencing factors and magnitude of rail transit infrastructure on economic development, we used OLS (Ordinary Least Squares) model to carry out regression analysis on independent variables. to eliminate the interference of heteroskedasticity, the logarithm of each variable was selected for unit root test in the analysis to determine whether a steady state was reached. If the ADF value was less than the critical value at some, it is less than the critical value at a certain level of significance, the series is considered to have no unit root and is a smooth series, and the original hypothesis is rejected; otherwise, the original hypothesis is accepted and the series is considered to have a unit root of non-smooth series. The ADF values of the four variables *LnGDP* (Gross Domestic Product), *LnNY* (Gross Agricultural Industry), *LnGY* (Gross Industrial Industry) and *LnLS* (Gross Retail Services) for the Midwest region are all less than the critical value at the 5% level of significance and are all considered to be smooth series, with the result that all variables are not single integer of the same order. The Johanson cointegration test was further conducted on the four smooth series and the results are shown in Table 1.

Table 1. Covariance results.

Central Region	Variables	LnGDP	LnNY	LnGY	LnLS
	params	≤ 3	≤ 3	≤ 3	≤ 3
	Eigenvalue	0.4278	0.3609	0.573	0.6484
	Max	9.4901	7.6126	14.4672	17.768
	5%	3.8415	3.8415	3.8415	3.8415
	P	0.0021	0.0058	0.0001	0.0001
Western Region	Variables	LnGDP	LnNY	LnGY	LnGY
	params	≤ 2	≤ 2	≤ 2	≤ 2
	Eigenvalue	0.7029	0.8315	0.7281	0.7583
	Max	21.7234	30.6718	22.9301	25.3515
	5%	15.4947	15.4947	15.4947	15.4947
	P	0.0051	0.0001	0.0032	0.0001

3.2.2 OLS Regression Analysis

Using global least squares (OLS) to test the relationship between economic development indicators and each explanatory variable, the regression coefficients of the explanatory variables passed the significance test at the 0.05 level of significance, except for the number of railway employees in the western region (Table 2), and the maximum value of the fit R2 was 0.986 and 0.997 respectively, so the railway infrastructure construction was considered to have a significant impact on economic development. From the regression coefficients of the variables, for every unit increase in the volume of railway cargo transfer, business mileage, and the number of employees in the central region, GDP grew by 1.695, 1.585, and 1.464 units respectively; for every unit increase in the volume of railway cargo transfer and business mileage in the western region, GDP grew by 1.353 and 1.248 units respectively, which is slightly lower than the growth in the central region, and railway infrastructure. The impact of investment growth on the primary, secondary and tertiary industries is similar that of GDP, thus inferring that the increase in the carrying capacity of railway infrastructure promotes the sustainable development of the regional economy, and the promotion of economic growth in the central and western regions has obvious spatially divergent characteristics.

3.3 Granger Test Results

The causality test method is to examine whether one variable is the cause of another variable based on determining the existence of some relationship between the variables. For the transport industry, increased investment in the construction of rail transport infrastructure is conducive to promoting the economic benefits of the regional industry, but whether the increase in the economic benefits of the industry can push back the investment in the construction of rail transport infrastructure needs to be further explored.

Table 2. Regional regression equations.

Central Region	Indicator	LnNY	LnGY	LnLS	LnGDP
	R^2	0.947	0.986	0.979	0.97
	Turnover	1.184	2.201	1.338	1.695
	Mileage	0.994	1.192	2.124	1.585
	Practitioners	1.255	1.445	1.764	1.464
Western Region	Indicator	LnNY	LnGY	LnLS	LnGDP
	R^2	0.995	0.991	0.997	0.992
	Turnover	1.078	1.703	1.089	1.353
	Mileage	0.971	0.925	1.838	1.248
	Practitioners	-	-	-	-

Table 3. Granger causality test results.

	Original assumptions	F-s	P-v	Y/N
Central Region	LnGY is not LnTYL for Granger reasons	3.908	0.044	Y
	LnLS is not LnTYL for Granger reasons	4.090	0.04	Y
	LnGDP is not LnTYL for Granger reasons	4.333	0.033	Y
Western Region	LnGY is not LnTYL for Granger reasons	4.389	0.032	Y
	LnNY is not LnTYL for Granger reasons	6.270	0.012	Y

Using Eviews software to Granger causality test for *LnGDP, LnNY, LnGY, LnLS* and *LnTYL,* the results of the optimal lag order of 3, as shown in Table 3, 10% significance level, the central region *LnGDP, LnNY* and *LnGY* are the cause of *LnTYL* generation, that is, the regional GDP, agricultural industry, industrial industry development are all responsible for the increase in rail transit mileage, indicating that economic growth in the central region has had a positive effect in pushing back investment in rail transit infrastructure. In contrast, only the increase in industrial GDP and total retail sales in the western region had a certain stimulating effect on rail transport infrastructure; indicating that the economic development in the western region is relatively lagging and the growth in GDP is not sufficient to support the investment and operation of infrastructure, therefore, the economic growth in the western region has a weaker supporting effect on rail transport construction, which may also be a reason why the correlation between the number of railway employees and economic growth is not This may also be one of the reasons why the correlation between the number of railway employees and economic growth is not significant.

4 Conclusions

This paper analyses the direct relationship between rail transport infrastructure and economic development in China's central and western regions, selecting rail transport capacity indicators and national economic development statistics for 10 provinces in central and western China from 1999–2020, and comparing the impact of rail transport infrastructure carrying capacity on economic development in China's central and western regions through co-integration tests, OLS correlation analysis and causality tests The empirical analysis led to the following conclusions: The relative carrying capacity analysis showed that the carrying capacity of rail transport infrastructure and economic development in China have been substantially improved over the past 20 years of development, but the supply and demand match between the central and western regions is inconsistent, especially in the western region where there is a large surplus of rail transport carrying capacity, which is not conducive to the sustainable development of the regional economy and society. Through OLS correlation analysis, it is found that the increase in rail infrastructure carrying capacity positively drives regional economic growth, but the driving effect of economic growth in the central and western regions has obvious spatially divergent characteristics. The Granger causality test proves that economic development has a reverse stimulating effect on rail transport infrastructure, and there is a two-way interactive causality in regions with good economic development, while in the less developed western regions, the existing rail transport will lead the growth of the regional economy in a certain period time in the future.

Therefore, based on the above conclusions, the following recommendations are made for the construction and operation of transport networks in the central and western regions of China: Firstly, to balance the investment in rail transport infrastructure construction in the central and western regions. Given the lag in the role of rail transport carrying capacity on economic development, rail transport infrastructure construction should be moderately ahead and surplus to meet the needs of economic growth in a certain period time in the future, to avoid a bottleneck in development arising from the mismatch between economic growth and infrastructure construction. On the contrary, in areas with an excessive surplus of infrastructure carrying capacity, it is necessary to slow down the investment in rail infrastructure and make use of existing resources to effectively improve the efficiency of industrial flow to promote sustainable development of the regional economy and society. Secondly, the regional advantage effect should be brought into play to optimize the industrial structure. The central and western regions of China have obvious differences in population, resource environment, and economic characteristics. Therefore, it is important to make full use of such differences to bring into play the mobility effect of rail transportation, cultivate and explore the characteristic advantages of cities along the route, and further expand the scale development of labour-intensive facility agriculture and high-tech processing industry in the central region to accelerate the spatial gathering of industrial factors. The western region, on the other hand, will make use of a large amount of surplus transport carrying capacity, play the role of a hub for the expansion of the Belt and Road to the west, give full play to ecological resources and the cultural advantages of many ethnic groups to promote the high-quality development of regional tourism and culture and trade and circulation, form an economic growth pole for the concentration of wealth in the new three industries, and narrow the spatial differences between the central and western regions to promote the integrated development of the region. Finally, focus on long-term investment in rail transit working capital. It is evident from the research results that the economic growth output value of China's central and western regions has a significant difference in the pushback effect of rail transit, especially in the western region where economic growth is not sufficient to support infrastructure investment and operation. Coordinated development.

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