Research on the Efficiency Evaluation of Logistics Infrastructure in Western Regions from the Perspective of Total Factors

Cheng-Jia Ning[1,a,*], Miao Xu[2,b] and Yu Zhang[3,c]

[1]The office of North One-A, Southwest University of Science and Technology, 59 Qinglong Road, Mianyang Sichuan, P.R.China.

[2]The office of East One, Southwest University of Science and Technology, 59 Qinglong Road, Mianyang Sichuan, P.R.China.

[3]The office of Administrative building, Southwest University of Science and Technology, 59 Qinglong Road, Mianyang Sichuan, P.R.China.

[a]695992643@qq.com, [b]1344061652@qq.com, [c]5972035@qq.com

*Corresponding author

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Abstract. This paper based on the all-factor perspective, applies the DEA method to analyze the logistics infrastructure efficiency, exogenous influencing factors and improvement paths of 12 provinces in western China in 2000-2016. Moreover decomposed the Facility Total Factor Efficiency (LTFIE) into two angles - Total Factor Management Efficiency (LTFIME) and Total Factor Environmental Efficiency (LTFIEE). The result shows that the LTFIE is between 0.72-0.83 in western China, Management inefficiency is the main reason. In individual provinces both LTFIME and LTFIEE; currently, the LTFIE improve is mainly due to changes in external environmental factors; industrial structure, urbanization level and openness are favorable factors for LTFIE improvement. However, cultural quality is not significant.

Introduction

The Western Development of China is a large-scale systematic project, achieve common prosperity, protect social stability, expand domestic demand and promote economic growth, including Sichuan, Chongqing, Yunnan, Guangxi, Guizhou, Tibet, Shanxi, Gansu, Ningxia, Qinghai, Xinjiang and Inner Mongolia 12 provinces. In the past 18 years, the development of the western region has achieved remarkable results, especially as the logistics infrastructure has played an important role in the economics of the western region. The investment of logistics infrastructure is the premise of the logistics industry development. Logistics industry is the artery and foundation of national economic, and the conditions for economic development fast, too. As the Chinese economy enters a new normal, the international political and economic environment is becoming more and more complex. How to in-depth promote the western development requires an assessment of the LTFIE in the western region. The logistics infrastructure efficiency, the external factors affecting efficiency, and the future strategy in the western of China are the focus of this paper.

Literature Review

The relationship between logistics infrastructure and economic growth is a hotspot for scholars. Liu Yuhong [1] used the co-integration theory and Granger Causality Test to explore the relationship between transportation infrastructure investment and economic growth of the “New Silk Road” from 1980 to 2010, the result shows they have a long-term co-integration relationship. Zhang Jin et al [2] analyzed the economic externalities of logistics facilities from five aspects: regional economy, industrial structure and agglomeration, foreign trade, corporate competitiveness, and household income. Guo Xi et al [3] based on the cloud model to analysis the logistics facilities in Beijing-Tianjin-Hebei, the result shows that the logistics integration process has completed 60%.

Continuously improve the construction of logistics infrastructure is necessary. Qian et al [4] conducted an analysis of the Yangtze River Delta, based on the total investment in the inter-provincial logistics industry. The research shows that the total investment in logistics infrastructure per capita has a certain correlation with economic development.

In Model aspect. Li Zhongmin et al [5] based on the DEA-Malmquist index method, measured the efficiency of the logistics facilities of China's Silk Road economy, and found the main reason for the decline of logistics infrastructure efficiency is that the negative change of the trade. Zhang et al. [6] evaluated the logistics efficiency of the western provinces and surrounding countries based on the DEA method. The result shows that the logistics efficiency varies greatly from region to region, and the returns to scale has upward trend after the exclusion of environmental factors. Li Jialing et al. [7] studied the logistics efficiency under low carbon constraints of 11 provinces in the western region. The research shows that external environmental factors have a significant impact on logistics efficiency. Liu Junhua et al. [8] used the DEA-Malmquist index to measure the efficiency changes of the logistics industry in 12 western provinces. The research found that technological progress is the most important factor affecting the total factor productivity increase in the western provinces, and proposed that the western provinces should upgrade their management level.

In summary, domestic scholars mainly study the logistics efficiency and logistics industry efficiency in the western region, there are few studies on the logistics infrastructure efficiency; the logistics infrastructure research focuses on its relationship with regional economic growth and regional coordinated development. However, on the logistics infrastructure efficiency is lack of evaluation research. This paper evaluates the logistics infrastructure efficiency in the western region with the perspective of total factors, and deconstructs it into environment and management, analyzes the root causes of the logistics infrastructure inefficiency, and then provides the further implementation of the national strategy for promoting regional economic development and western development suggestions.

Model Construction and Variable Selection

Model Construction

Fried et al. [9] proposed a DEA evaluation model, which considers the impact of exogenous environmental variables on technical efficiency. It means to eliminate the impact on technical efficiency based on equalization of exogenous environment, then, the pure management efficiency evaluated [10].The DEA model can achieve the purpose that filtering the influence of environmental variables, make up for the defects inherent in the classical DEA model, obtain more objective and accurate efficiency.

Based on the BBC model, Operation the initial data with Tobit regression. Identify exogenous environmental variables. The specific model is as follows:

$$S_{ik} = \alpha_i + \beta_i Z_{ik} + \mu_i, i = 1,2 \cdots M, k = 1,2 \cdots N \quad (1)$$

among them, $S_{ik} = (1 - \hat{\theta_k^{}})x_{ik} + s_{ik}^-$ is the input slack calculated about "i" by the DEA model in the first stage; Z_{ik} is exogenous environmental variable; β_i is coefficient vector of the environment variable; μ_i is random interference term.

Based on the worst environment, we will increase the input D-value to each DMU in the dominant environment, and then eliminate the exogenous environmental impact and achieve the equality exogenous environment. The adjustment methods are as follows:

$$x_{ik}^{adj} = x_{ik} + \left[\mathrm{Max}^k\{\hat{S_{ik}^{}}\} - \hat{S_{ik}^{}}\right], i = 1,2 \cdots M, k = 1,2 \cdots N \quad (2)$$

Among them, $\mathrm{Max}^k\{\hat{S_{ik}^{}}\}$ is the maximum fit relaxation, equivalent to the worst external environment set. Use the BBC model to achieve pure management efficiency.

This paper reference to the research of Hu and Wang. Making the ratio between the target value of logistics infrastructure and the actual value of the logistics infrastructure, which used as an indicator of the Logistics Total-Factor Infrastructure Efficiency (LTFIE). The target value of

logistics infrastructure and the actual value of the logistics infrastructure come from the first stage DEA calculation, as follows:

$$\text{LTFIE} = \text{the target value of logistics infrastructure} / \text{the actual value of the logistics infrastructure} \quad (3)$$

Among them, the target value of logistics infrastructure = the actual value of the logistics infrastructure - the total slack of the logistics infrastructure.

Logistics Total-Factor Infrastructure Managerial Efficiency (LTFIME) is obtained by analyzing the input and output data, which eliminating external environmental factors. As follows:

$$\text{LTFIE} = \text{adjusted target value of logistics infrastructure} / \text{adjusted actual value of logistics infrastructure} \quad (4)$$

From the above, the LTFIE mainly affected by management and environmental factors. So, the environmental factors attributed to the difference with LTFIME and LTFIE. Logistics Total-Factor Infrastructure Environmental Efficiency (LTFIEE) as follows:

$$\text{LTFIEE}=\text{LTFIE}/\text{LTFIME} \quad (5)$$

Like LTFIE, LTFIME values are also between 0-1, but LTFIEE values are not 0-1. If LTFIEE>1, the DMU is in a superior environment, the logistics infrastructure inefficiency mainly comes from management factors, and environmental factors play a promoting role. If LTFIEE < 1, the DMU is in a disadvantaged environment, environmental factors are the main reason for the inefficiency of the logistics infrastructure. If LTFIEE=1, means LTFIE is the same as LTFIME, and environmental factors have no significant impact on the logistics infrastructure efficiency.

Variable Selection

Based on the characteristics of the logistics infrastructure in the western region and the availability of data, with the research of other scholars. Railway operating mileage, inland waterway mileage and highway mileage are selected as input variables; transportation, warehousing and postal industry benefit are selected as output variables.

In the process of evaluating the LTFIE, in order to eliminate the impact of the exogenous environment, use for the research of other scholars, this paper selects cultural quality, industrial structure, urbanization level, and openness to examine the efficiency with environmental differences. The tertiary industry proportion measures the industrial structure, and the proportion of regional import and export trade measures openness.

Data Analysis

Based on the panel data of 12 provinces in the western region from 2000 to 2016. There were 204 observations used. The data comes from < China Statistical Yearbook >, < Local Statistical Yearbook > and other yearbook data.

Comprehensive Evaluation of LTFIE

From the overall average level, the LTFIE in the western of China is between 0.72-0.83, which in the low level. As shown in Table 1, 17%-28% of the logistics infrastructure in the western region has not effectively configured, and there have large space to improve, which is consistent with the actual level of real economic development in the western region.

Table 1 LTFIE values of provinces in western China from 2000 to 2009

Province	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
Inner Mongolia	0.598	0.667	0.691	0.647	0.607	0.990	1.000	1.000	1.000
Guangxi	0.876	0.862	0.924	0.951	0.945	0.668	0.977	1.000	1.000
Chongqing	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Sichuan	0.833	0.838	0.803	0.867	0.973	0.735	1.000	1.000	0.864
Guizhou	0.528	0.551	0.448	0.463	0.434	0.481	0.479	0.551	0.817
Yunnan	0.754	0.769	0.630	0.633	0.718	0.609	0.644	0.674	0.389
Tibet	1.000	1.000	1.000	1.000	1.000	1.000	0.413	0.580	0.554
Shanxi	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Gansu	0.359	0.340	0.358	0.392	0.411	0.862	0.781	0.755	0.670
Qinghai	0.290	0.295	0.345	0.407	0.286	0.381	0.301	0.313	0.255
Ningxia	0.535	0.505	0.503	1.000	1.000	1.000	1.000	1.000	1.000
Xinjiang	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
average value	0.731	0.736	0.725	0.780	0.790	0.811	0.800	0.823	0.796
Province	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	
Inner Mongolia	0.975	0.860	0.909	0.977	1.000	1.000	0.999	0.930	
Guangxi	0.828	0.997	1.000	1.000	0.953	0.940	1.000	1.000	
Chongqing	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	
Sichuan	0.648	0.628	0.574	0.565	0.573	0.678	0.711	0.789	
Guizhou	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	
Yunnan	0.428	0.395	0.352	0.337	0.327	0.324	0.315	0.302	
Tibet	0.708	0.791	0.758	0.655	0.608	0.445	0.442	0.411	
Shanxi	0.927	0.902	0.887	0.883	0.851	0.866	0.885	0.940	
Gansu	0.627	0.676	0.703	0.702	0.707	0.466	0.408	0.381	
Qinghai	0.223	0.260	0.244	0.232	0.212	0.213	0.215	0.221	
Ningxia	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	
Xinjiang	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	
average value	0.780	0.792	0.786	0.779	0.769	0.744	0.748	0.748	

Deconstruction of the LTFIE

As shown in Table 2, there is a significant difference between the LTFIE and the LTFIME. To test whether there is a significant difference between the mean values of the two populations, this paper runs Mann-Whitney U test, that the results pass the significance test. This shows that the filtered exogenous environment has a significant impact on the LTFIE. Therefore, it is necessary to study the LTFIE and the LTFIME.

Table 2 Difference analysis of LTFIE and LTFIME efficiency in western China, 2000 to 2016

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008
LTFIE	0.731	0.736	0.725	0.78	0.79	0.811	0.8	0.823	0.796
LTFIME	0.613	0.572	0.638	0.594	0.51	0.706	0.594	0.702	0.572
Year	2009	2010	2011	2012	2013	2014	2015	2016	M-U test
LTFIE	0.78	0.792	0.786	0.779	0.77	0.744	0.748	0.748	-4.979
LTFIME	0.687	0.682	0.604	0.644	0.684	0.634	0.71	0.674	

From the change trend, LTFIME showed a volatility upward trend from 2000 to 2016, while LTFIE first rose and then decreased, but it was always in an effective state. This indicates that the fluctuation of the total factor efficiency of the logistics infrastructure in the western region at this stage is mainly due to changes in exogenous environmental factors. In order to improve the efficiency of logistics infrastructure in the western region, this paper has carried out identification for the efficiency improvement path of each province, as shown in Table 3.

Table 3 Identification of improvement strategies for LTFIE in various provinces

province	2000-2016 Efficiency		Key strategies for improving efficiency	
	LTFIME	LTFIEE	Improve management	Improve environment
Inner Mongolia	0.898	1.026	○	
Guangxi	0.854	1.137	○	
Chongqing	0.849	1.289	○	
Sichuan	0.884	0.886	○	○
Guizhou	0.719	1.076	○	
Yunnan	0.528	0.974	○	○
Tibet	0.123	8.455	○	
Shanxi	0.925	1.047	○	
Gansu	0.507	1.141	○	
Qinghai	0.188	1.548	○	
Ningxia	0.426	2.735	○	
Xinjiang	0.737	1.498	○	

Note: The strategy for each province's options indicated by○.

Identification of Exogenous Environmental Variables

This paper intends to examine the external environment of logistics infrastructure in the western region from four aspects: cultural quality, industrial structure, urbanization level and openness. Specifically, the LTFIE is the dependent variable, using Tobit regression model constructed for the four environmental variables, and the regression results shown in Table 4.

Table 4 Tobit model regression results

variable	I1s railway input slack		I2s Inland river input slack		I3s highway input slack	
Constant term	4661.408***	(0.000)	7058.764***	(0.000)	232930.1***	(0.001)
Cultural quality K1	-13.91909	(0.820)	25.39	(0.788)	1753.607	(0.612)
Industrial structure K2	-83.41386***	(0.001)	-126.0239***	(0.001)	-3491.326***	(0.008)
The level of urbanization K3	-25.24434	(0.256)	-66.51156*	(0.055)	-2775.427**	(0.030)
Openness K4	-77.70473***	(0.006)	-60.00288	(0.127)	-2875.189*	(0.051)

Note: ***, **, * Represented at significant levels of 1%, 5%, and 10%; The number in parentheses is the P test.

From the regression coefficient, that cultural quality has a positive effect on the efficiency of railway facilities, but has no significant effect on the efficiency of inland rivers and highway facilities. The optimization and upgrading of the industrial structure is also an important way to improve the logistics infrastructure, which from the external environmental factors. The higher level of urbanization, the logistics infrastructure will be continuous improve. Improving the level of import and export trade is an effective way to promote the LTFIE in the western region.

Conclusions and Suggestions

Based on the DEA method and Tobit regression model, this paper's conclusion as below: From the overall average level, most of the provinces with high efficiency in logistics infrastructure are located in the southwestern part, which economically developed. Due to the difference in exogenous environment, improvement needs to be carried out at both the management and environmental. At this stage, the change of LTFIE is mainly due to changes in exogenous environmental factors.

In response to the above conclusions, the following suggestions are proposed:

First, improving the openness of the western region, and deepen the implementation of the strategy for the development of the western region. The western trade ports and platforms shoud be optimized and improved.

Second, optimize the industrial structure and develop the tertiary industry vigorously. Increase the proportion of the tertiary industry in the western region, and thus improve the efficiency of logistics infrastructure.

Third, deepen logistics management. Logistics management level is the key to the improvement of logistics infrastructure efficiency.

Fourth, the provinces in the western region should be study, which province is the efficiently of logistics infrastructure operations.

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