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

Cheng-Jia Ning\textsuperscript{1,a,*}, Miao Xu\textsuperscript{2,b} and Yu Zhang\textsuperscript{3,c}

\textsuperscript{1}The office of North One-A, Southwest University of Science and Technology, 59 Qinglong Road, Mianyang Sichuan, P.R.China.
\textsuperscript{2}The office of East One, Southwest University of Science and Technology, 59 Qinglong Road, Mianyang Sichuan, P.R.China.
\textsuperscript{3}The office of Administrative building, Southwest University of Science and Technology, 59 Qinglong Road, Mianyang Sichuan, P.R.China.

\textsuperscript{a}695992643@qq.com, \textsuperscript{b}1344061652@qq.com, \textsuperscript{c}5972035@qq.com

*Corresponding author

Keywords: Total factor, DEA model, Logistics infrastructure efficiency, Management efficiency, Environmental efficiency.

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:

\[ S_{ik} = \alpha_i + \beta_i \cdot Z_{ik} + \mu_i, i = 1,2 \cdots M, k = 1,2 \cdots N \]  

(1)

\( S_{ik} = (1 - \theta_k) x_{ik} + s_{ik} \) is the input slack calculated about "i" by the DEA model in the first stage; \( Z_{ik} \) is exogenous environmental variable; \( \beta_i \) is coefficient vector of the environment variable; \( \mu_i \) 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:

\[ x_{ik}^{adj} = x_{ik} + \text{Max} \{ S_{ik}^\alpha - S_{ik}^\alpha \}, i = 1,2 \cdots M, k = 1,2 \cdots N \]  

(2)

Among them, \( \text{Max} \{ S_{ik}^\alpha \} \) 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:

\[
LTFIE = \frac{\text{the target value of logistics infrastructure}}{\text{the actual value of the logistics infrastructure}} \quad (3)
\]

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:

\[
LTFIE = \frac{\text{adjusted target value of logistics infrastructure}}{\text{adjusted actual value of logistics infrastructure}} \quad (4)
\]

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:

\[
LTFIEE=LTFIE/LTFIME \quad (5)
\]

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 |

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 | I2s | I3s |
|---------------------------|-----|-----|-----|
|                           | railway input slack | Inland river input slack | 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 should 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.

Acknowledgement

Fund Project: National Social Science Fund Project "Research on the Cooperation Mechanism of Renewable Energy between China and Latin America from the Perspective of Global Value Chain (18XGJ003)

References

[1] Liu Yuhong. Analysis of the Dynamic Relationship between Transportation Infrastructure Investment and Economic Growth in the Economic Belt of the New Silk Road[J].Statistics & Information Forum, 2012, 27(10):64-70.

[2] Zhang Jin, Chen Yiheng. External Economic Research and Empirical Analysis of Logistics Facilities [J]. China Circulation Economy, 2015, 29(12):46-53.

[3] Guo Wei, Zhuang Jing. The Integration of Logistics Facilities in Beijing, Tianjin and Hebei Based on Cloud Model [J]. China Circulation Economy, 2018, 32(01):113-121.

[4] Qian Zhiwang, Yu Jiali. Analysis of the total investment in infrastructure investment in the inter-city logistics industry in the Yangtze River Delta[J]. Industrial Technology Economy, 2017, 36(09):146-152.

[5] LI Zhong Min, Xia Deshui. Analysis on the Efficiency of Logistics Facilities in China Silk Road Economic Belt——Malmquist Index Method Based on DEA Model [J]. Journal of Xi’an University of Finance and Economics, 2014, 27(05):71-77

[6] Zhang Xuan, Yang Xuerong, Wang Feng. Evaluation of Logistics Efficiency of the New Silk Road Economic Belt——based on Three-stage DEA Empirical Analysis [J]. Learning and Practice, 2016(05):21-32.

[7] LI Jia Ling, Liao Zhigao. Analysis of logistics efficiency in 11 provinces and cities in western China under low carbon constraints [J]. Journal of Guangxi University of Science and Technology, 2015, 26(03):99-105.

[8] Liu Junhua, Liu Zhengang, Li Yanxia, Li Changqing. An Empirical Study on the Efficiency Change of Logistics Industry in Western China [J]. Journal of the Economics and Industry, 2014, 5(03):50-57.

[9] Fried H.O, Schmidt S.S, Yaisa W.S. Incoperiting the Operating Environment into a Nonparametric Measure of Technical Efficiency [J]. Journal of Productivity Analysis, 1999, 12 (3):249-267.

[10] Li Lanbing. Evaluation and Deconstruction of Chinese Total Factor Energy Efficiency—Based on the Dual Perspective of Management-Environment [J]. Chinese Industrial Economy, 2012(06):57-69.