A Study on the Spatial Spillover Effects of Logistics Agglomeration Level and Its Green Total Factor Productivity

Jiasheng Li and Liying Li(✉)

School of Business Administration, Liaoning Technical University, HuludaoLiaoning 125105, China
1273924346@qq.com

Abstract. This article selects panel data from 30 provinces (autonomous regions and municipalities) in China from 2015 to 2020, takes logistics industry carbon emissions as non-desired output, introduces environmental regulation and other control variables, uses the location entropy method and DEA-Malmquist model to measure the agglomeration level of the logistics industry and its green total factor productivity, and reveals its spatial evolution characteristics through spatial correlation tests. The space Durbin model with time-space double fixed effects is employed to empirically study the spatial spillover effects of logistics industry agglomeration on its green total factor productivity. The results show that the overall agglomeration level of China's logistics industry is relatively low, but there is significant spatial positive correlation among regions. Improving the agglomeration level of the logistics industry can effectively promote green total factor growth and generate positive spatial spillover effects in surrounding areas. The degree of openness, industrial structure, and economic development level have positive effects on the green total factor productivity of the logistics industry, while unreasonable environmental regulations will inhibit its growth. This study enriches the theoretical measurement of green total factor productivity in the logistics industry, helps to better understand the spatial spillover effects of logistics industry agglomeration on its green total factor productivity, and provides a reference for how to improve the total factor productivity of the logistics industry. It has important significance for promoting the low-carbon and efficient development of the logistics industry.

Keywords: Spatial spillover effects · green total factor productivity · environmental regulation · spatial Durbin model

1 Introduction

In the era of focusing on building a new development pattern of "dual circulation" and under the background of China's economy entering a new normal, the logistics industry, as a fundamental and strategic industry supporting social and economic development, aims to break through environmental and resource constraints and build a modern and

S. H. B. D. M. Zailani et al. (Eds.): ICMSEM 2023, 259, pp. 860–869, 2024.
https://doi.org/10.2991/978-94-6463-256-9_86

efficient logistics system with low-carbon and high efficiency, which is the focus of future development. With the deepening development of reform and opening up, energy consumption and corresponding environmental pollution problems have not been taken into account in the total factor productivity measurement system. To comprehensively consider the impact of production inputs on the environment and adapt to the development needs of the new era, green total factor productivity has become a standard for measuring the green and high-quality development of the economy.

Previously, the academic community mainly studied green total factor productivity in agriculture and did not consider the importance of improving green total factor productivity for the logistics industry. Moreover, research directions were mostly based on inter-provincial or economic belt units and did not consider the macro situation of different regions throughout the country. Therefore, exploring the spatial impact relationship between logistics industry agglomeration level and logistics industry green total factor productivity (GTFP) and seeking scientific strategies to improve logistics industry GTFP are the focus of this study.

2 Literature Review

After Marshall [1] proposed the concept of "agglomeration", academic interest in logistics industry agglomeration has intensified. On the economic development level, Chen Yunping [2] believes that logistics clusters have great competitive advantages, as they allow numerous enterprises to share the convenience brought by location concentration, resulting in advantages such as resource integration, rapid fulfillment, and cooperative competition. Kayikci [3] argues that logistics clustering can improve the efficiency of converting different logistics transport modes, thereby promoting stable socio-economic development. In terms of the impact of logistics industry agglomerations on total factor productivity, Ma Yueyue's [4] research demonstrates that the promotive effects of logistics industry agglomeration on local urban total factor productivity are not apparent and congestion effects have emerged.

In recent years, as environmental quality has declined and the impact of the logistics industry on economic growth has strengthened, scholars have begun to focus on exploring the green total factor productivity (GTFP) of the logistics industry. Liu Zhanyu et al. [5] measured the GTFP of China's logistics industry from 2004 to 2014, and analyzed its evolution stages and driving factors. They found that unexpected outputs have a significant impact on the actual productivity, and that the results of calculations that consider these unexpected outputs can better reflect the actual situation. Zhang Rui [6] used the SBM-ML model to measure the GTFP of the logistics industry in 30 provinces across China from 2004 to 2016, and analyzed the influencing factors and spatial spillover effects of the GTFP [7]. Their research showed that the green total factor productivity of the logistics industry has a significant dynamic evolutionary law, and there is a need to improve the coordination of inter-provincial logistics development [8].

In summary, the research on the impact of logistics industry agglomeration on the economy is relatively mature, and significant progress has also been made in measuring green total factor productivity in the logistics industry. However, there is a lack of research on the direct impact of green total factor productivity, based on national panel data and considering environmental regulations, on the logistics industry agglomeration. In this study, data from 30 provinces (autonomous regions and municipalities) in China from 2015 to 2020 was used after excluding regions with serious data gaps. The impact of unexpected output was considered [7], and environmental regulation factors were added as control variables to further investigate the spatial spillover effects of logistics industry agglomeration on its green total factor productivity in China [9].

3 Data Description

3.1 Variable Description

Core Explanatory Variable.

Based on existing literature measuring the agglomeration level of the logistics industry, this article uses the location entropy of the logistics industry to measure the regional agglomeration level of the logistics industry, and takes it as the core explanatory variable. The specific formula is as follows:

$$LQ_i = (q_i/q)/(Q_i/Q) \tag{1}$$

Formula (1) explains the agglomeration level of the logistics industry in a region using employment data. It is calculated by dividing the number of employees in the logistics industry of a region by the total number of logistics industry employees in the country and then dividing this value by the total number of employees in all industries in the region. The value reflects the intensity of regional concentration, where values less than 1 indicate lower agglomeration levels, and values greater than 1 indicate higher agglomeration levels. A value larger than 1.25 indicates a high degree of agglomeration in the logistics industry. As the logistics industry corresponds to multiple sectors, this measure may not be definitive, but it provides a useful approximation for evaluating regional agglomeration levels.

Explained Variable.

This study uses the DEA-Malmquist index method to calculate the efficiency evaluation with GTFP as the explained variable. The selected input variables for GTFP measurement include capital input, labor input and energy input, and expected output and unexpected output form the output variables.

Input variables.

The input variables include capital input, labor input, and energy input. In terms of input indicators, fixed asset investment in the transportation, warehousing, and postal industries of each province is selected as capital input; logistics employment is used to measure labor input, and for energy input, nine energy sources, including raw coal, gasoline, kerosene, diesel, fuel oil, liquefied petroleum gas, natural gas, electricity, and heat, which are consumed most by the logistics industry, are selected. These are then converted into standard coal energy data by using energy conversion coefficients.

Output variables.

The output variables in this article mainly include scale economy output and unexpected output. The scale economy output in the expected output is measured by the logistics value-added, with the data sourced from the value-added of transportation, postal, and warehousing industries in the tertiary industry.

Regarding unexpected output, the main source of pollutants generated by the logistics industry is carbon emissions produced during logistics operations. Therefore, carbon emissions generated from energy consumption in transportation, warehousing, and postal industries are used as unexpected output indicators.

Control variable.

In addition to the level of concentration in the logistics industry, the improvement of GTFP is also influenced by various other factors. In addition to analyzing the impact of logistics industry concentration on GTFP, four indicators including the degree of openness, environmental regulations, industrial structure, and economic development level were selected as control variables for green total factor productivity.

The degree of openness is measured by the ratio of total import and export volume to regional GDP for each province. The environmental regulation variable is represented by the ratio of CO_2 emissions from the logistics industry to logistics value-added for each province. The industrial structure variable is represented by the proportion of value-added of the tertiary industry to regional GDP for each province. As for the economic development level variable, the per capita GDP was used to represent each province's level of economic development.

Data source.

All data are from the "China Statistical Yearbook," "China Energy Statistics Yearbook," "China Population and Employment Statistics Yearbook," and relevant data from the National Tai'an Database from 2015 to 2020. For very few missing values, interpolation and moving average methods were used for filling in the gaps.

3.2 Model Building

DEA Malmquist model.

For the calculation of green total factor productivity in the logistics industry, this study uses DEA-Malmquist index method. This method does not require the assumption of cost minimization and can decompose the improvement of total factor productivity into changes in scale efficiency and changes in technical level. Furthermore, the feasibility of this method is relatively high. Overall, taking into account both expected output and unexpected output, the directional distance function is used to measure GTFP. The formula for measurement is as follows:

$$GTFP = \sqrt{\frac{D^t(a^{t+1}, x^{t+1}, y^{t+1})}{D^t(a^t, x^t, y^t)} \times \frac{D^{t+1}(a^{t+1}, x^{t+1}, y^{t+1})}{D^{t+1}(a^t, x^t, y^t)}} \tag{2}$$

In the formula, ‘a’ represents input variables, ‘x’ represents expected output variables, and ‘y’ represents unexpected output variables. (a^t, x^t, y^t), $(a^{t+1}, x^{t+1}, y^{t+1})$ represent input-output variables for the periods ‘t’ and ‘t + 1’, respectively D^t, D^{t+1} respectively represent the directional distance function for periods ‘t’ and ‘t + 1’. Furthermore, the green total factor productivity (GTFP) can be calculated as the product of the green efficiency change index (effch) and the green technical progress index (techch).

Spatial autocorrelation test.

Since this study focuses on the spatial spillover effects of logistics agglomeration and GTFP, it is necessary to conduct a spatial autocorrelation test for logistics agglomeration and GTFP. In this study, two methods, namely global spatial autocorrelation and local spatial autocorrelation, are used for the test.

Global spatial autocorrelation.

To measure the degree of global spatial autocorrelation, the Moran’s index is commonly used. This index can indicate the similarity between logistics agglomeration and green total factor productivity. The formula for calculating the Moran’s index is as follows:

$$I = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}(x_i - \overline{x})(x_j - \overline{x})}{S^2 \sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}} \tag{3}$$

Equation (3) defines the Moran’s I statistic, which ranges between -1 and 1. Values above 0 indicate positive spatial autocorrelation, while values below 0 denote negative spatial autocorrelation. Values approaching 0 signify no spatial autocorrelation. Here, n represents the number of regions. The translation aims for precision and brevity. S^2 represents the sample variance; $X_i(X_j)$ denotes the GTFP or logistics agglomeration level of region i (j); W_{ij} represents the 0–1 spatial weight matrix; w_{ij} is determined by W_{ij}, When region i and j are adjacent, w_{ij} is 1; otherwise, it is 0.

Local spatial autocorrelation

To prevent overlooking local spatial relationships, the local Moran’s I statistic is used to measure local spatial autocorrelation. Its formula is as follows:

$$I_2 = \frac{(x_i - \overline{x})}{S^2} \sum_{j=1}^{n} w_{ij}(x_j - \overline{x}) \tag{4}$$

In Eq. (4), I_2 denotes local Moran’s I, with values greater than 0 indicating a spatial clustering of high values with neighboring high values or low values with neighboring low values in region i. Values less than 0 denote dissimilar spatial clustering patterns of high and low values.

Spatial Durbin Model Testing

Considering spatial autocorrelation effects, this paper constructs a general spatial econometric model based on the spatial Durbin model. The model is as follows:

$$GTFP_{it} = \alpha + \rho W_{it} \sum_{j=1, j \neq i}^{n} W_{ij} GTFP_{it} + \beta_1 WLQ_{it} + \beta_2 WLQ_{it}^2 + \gamma X_{it} + \theta \sum_{j=1, j \neq i}^{n} W_{ij}(LQ_{it} + LQ_{it}^2 + X_{it}) + \mu_i + \lambda_t + \tau_{it} \quad (5)$$

In formula (5), i and t respectively represent the region and year. W_{ij} represents the 0–1 spatial adjacency matrix. ρ represents the spatial autocorrelation coefficient. β and γ are both regression coefficients, θ is the coefficient of the lagged variable, μ_i represents the spatial fixed effects, λ_t represents the time fixed effects, τ_{it} represents the random error term. GTFP represents the green total factor productivity of the logistics industry, LQ represents the agglomeration level of the logistics industry and X represents the control variables. If $\rho \neq 0,\ \theta = 0$, Then formula (5) is transformed into a spatial lag model; if $\rho = 0,\ \theta = 0$, Then formula (5) is transformed into a spatial error model.

4 Calculation and Analysis

4.1 The Measurement and Analysis of Agglomeration Level in the Logistics Industry

The calculation of Formula (1) shows that the average LQ values of 30 regions across China from 2015 to 2020 remain relatively stable within the range of 0.648–1.635. The national average LQ value is 1.092, indicating that further improvement is needed.

Among the cities that maintained an LQ value of 1.25 or above during the six-year period, there are Beijing, Shanghai, Inner Mongolia, Heilongjiang, Hainan, and Qinghai. These cities can be classified into two types: Cities with strong economic development and high logistics demand represented by Beijing and Shanghai; Resource-based provinces represented by Inner Mongolia and Heilongjiang. These areas have a vast territory, but non-mobile resources determine the agglomeration of the logistics industry around them.

4.2 The Measurement and Analysis of GTFP

The GTFP of 30 regions in China was calculated using DEAP-xp1 software and Formula (2), which showed that the mean value of GTFP was 1.003, with green efficiency change index and green technical progress index being 1.005 and 0.997, respectively. The top three regions with the highest GTFP index were Liaoning (1.076), Hebei (1.041), and Yunnan (1.025), with a significant growth in GTFP, driven mainly by technological progress. These regions exhibited higher synergy between logistics industry development and environmental protection. The three regions with the lowest GTFP index were

Jilin (0.971), Heilongjiang (0.979), and Gansu (0.986), with lower values of technical efficiency change and an imbalance between the development of the logistics industry and environmental protection.

4.3 Analysis of Spatial Correlation Between LQ and Its GTFP

Using StataMP 17 statistical analysis software and combining formulas (3) and (4), the Moran's I index values of both LQ and GTFP were calculated using a 0–1 spatial adjacency matrix.

Global Moran's I Test.

Table 1 shows that the global Moran's I index for LQ of all 30 regions in China from 2015 to 2020 is positive, and passed significant tests at the 5% and 1% levels in 2019 and 2020, respectively. This indicates a clear spatial positive correlation for the agglomeration of the logistics industry in China. The majority of GTFP data are negative, with generally low values and no significant test results, suggesting weaker correlation for GTFP in China.

Local Moran's I Test.

As there is a weaker correlation for GTFP in China, further analysis was conducted to examine spatial heterogeneity between regions. Moran scatter plots were created for GTFP in 2015 and 2017 to observe local spatial correlations. Figure 1 shows the Moran scatter plots.

In 2015, 12 regions were in quadrants I and III, indicating positive spatial correlation (H-H, L-L), while 18 regions were in quadrants II and IV, indicating negative spatial correlation (L-H, H-L) for GTFP. In 2017, only Tianjin, Hebei, Liaoning, and Shandong remained in quadrant I (H-H). This suggests significant spatial heterogeneity in GTFP among different regions in China.

Table 1. Global Moran's I Index of Agglomeration Level and GTFP in 30 Regions of China from 2015 to 2020

time	LQ	GTFP
2015	0.02	0.024
2016	0.043	-0.198
2017	0.053	0.024
2018	0.13	-0.191
2019	0.219**	-0.042
2020	0.256***	-0.024

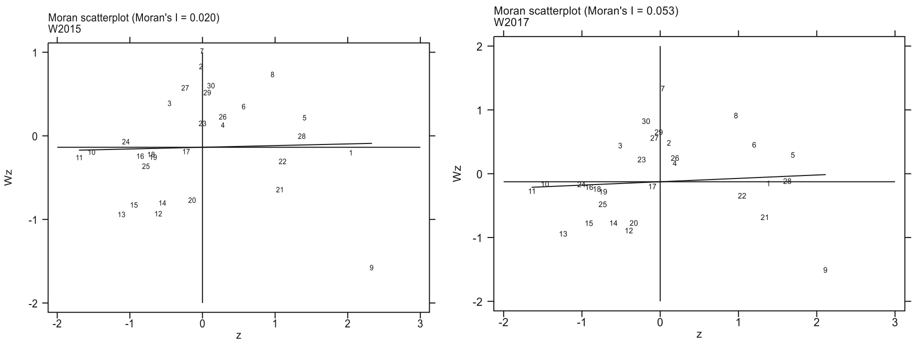

Fig. 1. Local Moran Scatter Map of GTFP in 30 Regions of China in 2015 and 2017

4.4 Spatial Effect Testing of LQ and Its GTFP

By conducting LM, Robust LM, Wald, and Hausman tests sequentially, it is determined that a time and space double fixed effect model should be adopted to analyze the spatial relationship between LQ and GTFP. This model takes into account both temporal changes and spatial correlations, as well as introduces appropriate control variables.

Regression and Effect Decomposition.

Regression and effects decomposition data in Table 2 show that the direct coefficient of LQ is 0.076 and passes a 5% significance test, indicating that an increase in LQ is beneficial to GTFP growth. However, the lag term coefficient did not pass the test. The highly concentrated logistics industry in this area attracts customers from the surrounding areas to carry out business, so it does not have a significant impact on the GTFP growth in the surrounding areas.

The direct coefficient of openness to the outside world is positive and relatively high, indicating that improving it will promote local GTFP growth. However, it did not pass the significance test, indicating that China needs to further improve its level of openness to the outside world. Environmental regulation has a negative impact on both this area and the surrounding areas, and passes the significance test. The high pressure of environmental regulation can put great pressure on logistics companies and limit their

Table 2. Regression Results and Decomposition Effects

variable	Direct impact	Lag	Total effect	direct effect	indirect effect
LQ	0.076**	0.053	0.117**	0.076**	0.041
openness	0.129	0.460***	0.481***	0.105	0.377**
environmental	-0.020***	-0.030*	-0.041**	-0.018***	-0.0225*
industry	0.063	0.077	0.126	0.059	0.067
economic	0.002	0.123	0.118	0.001	0.118

development, leading to reduced investment in output. Neither industrial structure nor economic development level passed the significance test, indicating that they do not have a direct impact on GTFP growth.

Regarding control variables, when the level of openness to the outside world increases by 1%, GTFP will increase by 0.481%, with an indirect contribution of 0.377%. Both the total effect and spatial spillover effect pass the significance test, indicating that the level of openness to the outside world in the surrounding areas has a stronger positive impact on GTFP growth in the local area. Environmental regulation has negative effects on both this area and the surrounding areas, and all effects pass the significance test. If it increases by 1%, GTFP will decrease by 0.041%, with a direct contribution of 0.018% and an indirect contribution of 0.0225%. Neither industrial structure nor economic development level passed the significance test.

5 Conclusion and Proposal

According to the research, the following conclusions can be drawn:

Firstly, the overall LQ value in China needs to be improved, and there are regional differences. Over the past six years, the overall LQ value in China has remained stable, with a mean ranging from 0.648 to 1.635, indicating room for improvement. Beijing and Shanghai have significantly higher LQ values due to their developed economy and advanced industrial system, while Inner Mongolia and Heilongjiang have abundant resources and thus a concentration of logistics industry serving resource-based industries.Secondly, China's GTFP is showing a growing trend, driven by efficiency changes. The GTFP index has been on the rise, with 11 regions having a GTFP value greater than one. The green efficiency change index has increased significantly, indicating that the main driver of GTFP growth is the improvement of logistics industry's green efficiency.Thirdly, there is a clear positive spatial correlation between the concentration of the logistics industry in China, while the overall correlation of GTFP is weak. Further local spatial correlation tests reveal significant negative local spatial correlation between GTFP in different regions, indicating the existence of spatial heterogeneity.Fourthly, the growth of GTFP relies mainly on the improvement of direct effects. An increase of 1% in LQ value results in a 0.117% increase in GTFP, with a direct effect contribution of 0.076%, which is significant, and a spill-over effect contribution of 0.041%, which is not significant. The control variables show that enhancing openness is conducive to the growth of GTFP; excessively strict environmental regulations inhibit its growth; while industrial structure and economic development level have a positive effect but only to a small degree.

Based on these findings, the following recommendations are proposed:

- Promote the concentration and development of the logistics industry in different regions according to their specific conditions.
- Reduce non-expected output and improve the technological progress efficiency of the logistics industry.
- Reasonably utilize spill-over effects and strengthen internal and external exchanges in different regions.

– Promote the healthy development of the logistics industry through multiple measures, enhancing openness, paying attention to environmental regulations, optimizing industrial structure and improving economic development level to further increase GTFP.

References

1. Marshall, Alfred (1890) Principles of Economics. The Macmillan Press, London. https://yuedu.163.com/source/c93232b0e3934262ac07f3952894c547_4.
2. Chen Yunping. The Competitive Advantage and Formation Mode of the Logistics Industry Cluster [J]. Science and Technology Progress and Policy, 2010, 27(21): 85–90.
3. Kayikci Y. A Conceptual Model for Intermodal Freight Logistics Centre Location Decisions [J]. Procedia Social and Behavioral Sciences, 2010(2).
4. Ma Yueyue. Logistics Industry Agglomeration, Spatial Spillover Effects and Urban Total Factor Productivity: An Empirical Study Based on Liaoning Province[J]. Statistics and Decision Making, 2021(14): 101–104.
5. Liu Zhanyu, Sun Xialing. The Temporal-Spatial Evolution and Motivation Analysis of Green Total Factor Productivity in Chinese Logistics Industry [J]. Soft Science, 2018, 32(04): 77–81+114. DOI: https://doi.org/10.13956/j.ss.1001-8409.2018.04.17.
6. Zhang Rui, Sun Xialing. The Evolution and Spillover of Green TFP in China's Provincial Logistics Industry. Business Research, 2020(03): 29–38. DOI: https://doi.org/10.13902/j.cnki.syyj.2020.03.004.
7. Zijing Liang, Yung-ho Chiu, Xinchun Li, Quan Guo, Yue Yun. Study on the Effect of Environmental Regulation on the Green Total Factor Productivity of Logistics Industry from the Perspective of Low Carbon[J]. Sustainability, 2019, 12(1).
8. Yan, Caozheng, Yin Lüjiang, and He Bo. Logistics Industry Aggregation, Space Spillover Effects, and Agricultural Green Total Factor Productivity[J]. China Circulation Economy 36, no. 9 (2022): 3–16. DOI: https://doi.org/10.14089/j.cnki.cn11-3664/f.2022.09.001.
9. Wang Dongfang, Tarasov Arthur, Zhang Huarong. Environmental regulation, innovation capability, and green total factor productivity of the logistics industry[J]. Kybernetes, 2023, 52(2).