Research Article

Area Differences in Regional Logistics Efficiency and the Law Governing Its Temporal and Spatial Evolution

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Because logistics is an important service industry with regard to national economic development, the development level of this industry has emerged as one of the most significant indicators of a country or region’s comprehensive strength. An in-depth study of the regional differences in China’s logistics efficiency and its evolution law in time and space can help promote the high-quality development of the logistics industry. To this end, this study collects data pertaining to the development of the logistics industry in China’s eight economic regions during the period 2009–2018. Moreover, it uses DEA models to calculate the logistics efficiency of 31 provinces and cities in these eight economic regions. Results indicate the following: (1) affected by external environmental factors, the pure technical efficiency is underestimated and the scale efficiency and integrated technical efficiency are overestimated; (2) it reveals that residents’ consumption level and the total retail sales of social consumer goods are negatively correlated with regional logistics efficiency, whereas the regional per capita gross domestic product is positively correlated with regional logistics efficiency; (3) in terms of space, the logistics industry in the same region displays characteristics of high aggregation and cooperation, whereas serious segmentation and opposition are found among different regions. The logistics efficiency of China’s eight economic zones is unbalanced. It displays a pattern of high efficiency in the east and low efficiency in the west on the whole. Moreover, valuable suggestions were propounded to improve regional logistics efficiency in China.

1. Introduction

Since the reform and opening up of China’s economy, with the help of the huge demographic dividend and market scale advantages, the country has achieved unprecedented development and become the second largest economy in the world [1]. According to the data from the 2020 National Statistical Bulletin, the added value of China’s tertiary industry in 2019 was 5.34 billion, accounting for 53.9% of GDP [2]. The logistics industry is one of the essential components of the tertiary industry; hence, its development level has become a significant yardstick to measure the degree of regional economic development. Furthermore, the performance of this industry is even used to evaluate how developed a country or region is. For a long time, the regional government has been prioritizing local economic growth under the influence of administrative division, which directly results in the imbalance of regional logistics industry development [3]. Such imbalance is primarily reflected in the fact that the quality of the logistics industry in eastern coastal areas is better than in western inland areas. The obvious differences in the scale distribution of the logistics industry in various regions are not conducive to the high-quality development of the total logistics industry. Therefore, it is necessary to measure and analyze the difference pattern from a spatial perspective [4]. We should build a scientific evaluation system to identify the key factors affecting logistics efficiency accurately, which can reveal the spatial differences in logistics industry efficiency among regions effectively. It can weaken the “Matthew effect” of logistics industry development and promote the high-quality development of the regional logistics industry. Logistics
efficiency refers to the relationship between ratio of logistics resource input and effective output [5]. An improvement in logistics efficiency can not only promote the social demand for logistics services but also enhance competitiveness and enhance the financial performance of enterprises. The world’s retail giant, Walmart, has the most advanced logistics efficiency, which should be benefited by its strong logistics distribution system. At present, logistics efficiency has been considered from many aspects by predecessors. First, from the perspective of theoretical research, Wang et al. based on the grey prediction theory analyzed the Efficiency of Third-Party Logistics Providers and found the increasing and decreasing variation index of third-party logistics providers which will help customers to select the best TPL providers [6]. Dai’s results show that the logistics efficiency of developed cities is better [7]. Ma and Lou used the neural network calculation principle and logistic regression algorithm to optimize the trapezoidal network structure, which can not only reduce unnecessary circulation links but also effectively improve logistics efficiency [8]. Second, from the perspective of empirical research, Lu et al. calculated China’s regional logistics efficiency and its influencing factors by using data envelopment analysis. It is found that in recent 10 years, China’s low-carbon logistics efficiency has been on the rise and the gap between regional logistics efficiency has widened, among which logistics management level and operation level are the core factors to improve logistics efficiency [9]. Bai et al. analyzed the ecological efficiency of logistics in China and its influencing factors based on Super-SBM and Dubin models and found that the ecological efficiency of logistics in China was relatively low, with significant regional differences and a decreasing pattern of “east-central-west” on the whole [10]. Zheng et al. combined the SBM model with hierarchical regression to analyze the regional logistics efficiency and performance of the Belt and Road initiative in China and found the large imbalance in logistics efficiency among China’s regions along the B&R initiative [11]. Yu evaluates the development efficiency of Ningbo port logistics and its synergies with the urban economy from 2000 to 2014, using the data envelopment analysis and grey relational analysis method. The results indicate that Ningbo port logistics has high development efficiency, while the efficiency of input and output is not high in some years [12]. Finally, from the perspective of provincial research in China, Li and Lin attempted to investigate the logistics energy efficiency and main influencing factors of the Yangtze River Economic Belt; the research results show that the logistics energy efficiency of the Yangtze River Economic Belt needs to be further improved and that energy efficiency differs greatly among cities and provinces, indicating that the development is quite unbalanced in different areas [13]. Deng et al. used PCA-DEA to measure and evaluate the logistics performance with and without carbon emissions constraints of 30 provinces/municipalities in China. The results show that large regional differences in China’s logistics efficiency and regional economic and logistics development are positively related to logistics efficiency [14].

In summary, recent research results related to logistics efficiency are relatively rich, reflecting the current situation of the development of the regional logistics industry, but many deficiencies remain. First, although some studies have expanded the evolution trend of regional logistics efficiency, most of them focus on the evaluation and influencing factor analysis of China’s regional logistics efficiency. The comparison of the characteristics of and differences in logistics efficiency is ignored. Second, existing research ignores the impacts of internal and external environmental factors on regional logistics efficiency. Finally, most previous studies paid attention to the topic of regional logistics efficiency in the three regions of Eastern, Central, and Western China. In-depth research on the further subdivision of provinces is lacking. The regional logistics efficiency improvement strategy with the eight comprehensive economic zones as the core is an important support for the logistics development strategy in the new era. Therefore, we should conduct an in-depth study of the regional differences and master the temporal and spatial evolution law of China’s logistics efficiency, which has important guiding significance for the high-quality development of China’s logistics industry.

2. Research Objects and Methods

2.1. Research Objects. To effectively explore the differences in logistics efficiency among regions in China, 31 provinces in the country are divided into eight regions for a specific analysis with reference to the research of Chen et al. [15]. Among them are Middle Reaches of the Yellow River, Middle Reaches of the Yangtze River, Northwest Region, Southwest Region, Northeast Region, East Coast, North Coast, and South Coast. In view of the availability of data, the research objects do not include Hong Kong, Macao, and Taiwan. The specific area range is shown in Table 1.

2.2. Three-Stage DEA Research Model. DEA is an analytical method that studies efficiency problems within operational research, drawing from concepts in management and mathematical economics [16]. Charnes et al. proposed the DEA analysis method [17]. However, later research revealed that this method cannot eliminate the effects of management inefficiency, environmental factors, random noise, and other factors. To solve the above problems and realize the effective evaluation of the efficiency of decision variables, this study uses the three-stage research method proposed by Fried et al. to evaluate China’s regional logistics efficiency on the basis of further processing environmental and random variables [18]:

Stage I (traditional DEA model): the regional logistics efficiency evaluation of China is reflected in the logistics efficiency value and relaxation variable value from the original input and output data of each decision-making unit at different time points [19]. The calculation formula is as follows:
According to the consistency and 0.3. Data Source and Variable Selection
Macao, and Taiwan) from 2009 to 2018 are selected as output data of 31 provinces in China (excluding Hong Kong, region. Therefore, the regional logistics efficiency input and they cannot fully reflect the regional logistics efficiency of the region. The consistency of indicators, percentage values are found in the indicators of ideal output and all absolute values are divided by local GDP to relative values. The evaluation index system is shown in Table 2.

2.3. Variable Selection. On the basis of the careful consideration of data availability, representativeness of variable indicators, and existing research [Deng [14], Zhang [20], Xu and Ding [21], and Sun [22]], this study selects three inputs, four outputs, and three environmental indicators. According to the consistency of indicators, percentage values are found in the indicators of ideal output and all absolute values are divided by local GDP to relative values. The evaluation index system is shown in Table 2.

3. Empirical Results and Analysis
3.1. Stage I: DEA Calculation Results before the Adjustment. At this stage, the traditional DEA model is used to calculate the comprehensive efficiency of the logistics industry in 31 provinces in China from 2009 to 2018, including integrated technical efficiency (TE), pure technical efficiency (PTE), and scale efficiency (SE). Figure 1 illustrates the broken line chart of logistics efficiency in China in the past ten years from 2009 to 2018. As shown in the figure, TE increased from 0.601 to 0.731 and SE increased from 0.75 to 0.835 in the past ten years in China. The change trends of the two are almost the same. The improvement of TE and SE may be related to the increase in government support for the logistics industry. In 2009, the fixed asset investment in the logistics industry increased from 2327.13 billion yuan to 6357.204 billion yuan in 2018, with an increase of 173%. The average values of TE, PTE, and SE are 0.6819, 0.8413, and 0.8106, respectively. PTE is smaller than SE, but they are very close, similar to the results obtained by Wang et al., who calculated the efficiency of the construction industry [23]. Therefore, the improvement of logistics efficiency in recent years is not only due to the expansion of investment scale but also due to the progress of technology.

2.3. Data Source and Variable Selection
2.3.1. Data Source. According to the consistency and availability of indicators, some areas are still affected by the epidemic, considering China’s outbreak of COVID-19 in late 2019. Due to epidemic control and regional blockade, the evaluation index values of logistics efficiency in some regions cannot be obtained, and even if some values can be obtained, they cannot fully reflect the regional logistics efficiency of the region. Therefore, the regional logistics efficiency input and output data of 31 provinces in China (excluding Hong Kong, Macao, and Taiwan) from 2009 to 2018 are selected as samples in this study. All data come from the statistical yearbook of China’s tertiary industry (2010–2019), China Statistical Yearbook (2010–2019), the official website of the National Bureau of Statistics, and the Wind database.

### Table 1: China’s eight major economic regions.

<table>
<thead>
<tr>
<th>Serial number</th>
<th>Name of the region</th>
<th>Provinces included</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Northeast Region</td>
<td>Liaoning, Jilin, and Heilongjiang</td>
</tr>
<tr>
<td>2</td>
<td>Northwest Region</td>
<td>Gansu, Qinghai, Ningxia, Xinjiang, and Xizang</td>
</tr>
<tr>
<td>3</td>
<td>Southwest Region</td>
<td>Guangxi, Chongqing, Sichuan, Guizhou, and Yunnan</td>
</tr>
<tr>
<td>4</td>
<td>The Middle Reaches of the Yangtze River</td>
<td>Anhui, Jiangxi, Hubei, and Hunan</td>
</tr>
<tr>
<td>5</td>
<td>The Middle Reaches of the Yellow River</td>
<td>Shanxi, Neimenggu, Henan, and Shaanxi</td>
</tr>
<tr>
<td>6</td>
<td>South Coast</td>
<td>Fujian, Guangdong, and Hainan</td>
</tr>
<tr>
<td>7</td>
<td>East Coast</td>
<td>Shanghai, Jiangsu, and Zhejiang</td>
</tr>
<tr>
<td>8</td>
<td>North Coast</td>
<td>Beijing, Tianjin, Hebei, and Shandong</td>
</tr>
</tbody>
</table>

3.2. Stage II: Impacts of External Environmental Factors on Regional Logistics Efficiency. In this part, the input relaxation variables calculated in Stage I are used as the explained variables, and the three external environmental variables of residents’ consumption level (RCL), total retail sales of social consumer goods (TRSSCG), and regional per capita GDP (RPC-GDP) are used as the explanatory variables to establish

\[
\min \left[ \alpha - \varepsilon \left( \sum_{i=1}^{n} S_i^+ + \sum_{j=1}^{k} S_j^- \right) \right]
\]

s.t.

\[
\sum_{i=1}^{n} \xi_i X_j + \lambda_j + S^- = \theta \xi X_j \sum_{j=1}^{n} Y_j \lambda_j - S^+ = Y_j \lambda_j \geq 0, S^-, S^+ \geq 0,
\]

(1)

where \( \theta \) is the effective value of the decision-making unit; \( X \) and \( Y \) represent input vector and output vector, respectively; \( S \) is the relaxation variable; \( j = 1, 2, \ldots, n \) represents the decision-making unit; and \( \lambda \) represents a decision variable.

Stage II (SFA): the SFA model is used to measure the correlation between relaxation and environmental variables, which can eliminate the influence of environmental factors and random interference on the results. The calculation formula is as follows:

\[
S_{ni} = f(Z_i; \beta_n) + V_{ni} + \mu_{ni},
\]

(2)

where \( i = 1, 2, \ldots, n \) refers to a decision-making unit; \( S_{ni} \) represents the relaxation variable of the decision unit; \( f(Z_i; \beta_n) \) indicates environmental factors; \( V_{ni} \) represents random noise; and \( \mu_{ni} \) indicates inefficient management. We use Frontier 4.1 software to calculate the estimated values of parameters \( \beta_n, \delta^{ni}_{vi}, \) and \( \delta^{ni}_{\mu}. \) Then, we further calculate the estimator of \( \mu_{ni}. \) We adjust the logistics investment level through the results of the estimation.

Stage III (DEA model): the data, excluding the interference of random factors in Stage II, are substituted into the DEA model to calculate the real regional logistics efficiency in China.
the regression model. The SFA model can be built using software Frontier 4.1, and the empirical results are shown in Table 3.

As shown in Table 3, all LR parameters meet the significance verification of 1%, which indicates that environmental indicators have great impacts on regional logistics input indicators. Variable $Q^2$ is very high; $c$ is approximately 1, which suggests that the proportion of SFA regression results in the total variance is high. At this time, the redundant result caused by environmental variables is large. Therefore, avoiding the interference of the external environment and random factors through SFA regression is necessary. During the process of studying the impacts of environmental variables on input indicators, we observe the following: (1) when the environmental coefficient is greater than 0, the regional logistics input indicators are positively correlated with environmental variables, that is, reducing output can lead to the decline of logistics efficiency; (2) when the environmental coefficient is less than 0, the regional logistics input index is negatively correlated with the environmental variables and reducing the output can lead to the increase in logistics efficiency. By further analyzing the impacts of regional logistics investment indicators and external environmental factors, the following can be concluded:

(1) RCL: from the results of the regression analysis, we observe the regression coefficient value of relaxation variable: the value of RCL to the average number of employees is positive, the value of RCL to the ratio of fiscal expenditure in local fiscal expenditure is also positive, and both have passed the 1% significance level test. In terms of input relaxation variables, the improvement of RCL can lead to the increase in the average number of employees and the proportion of financial expenditure in local financial expenditure. In other words, the labor force and the resources supported by the government for the logistics industry have not been fully utilized, resulting in the difficulty of improving logistics efficiency.

(2) TRSSCG: from the results of the regression analysis, we find the regression coefficient value of relaxation variable: the value of TRSSCG to the fixed asset investment is positive, the value of TRSSCG to the ratio of fiscal expenditure in local fiscal expenditure is also positive, and both have passed the significance level test of 1%. In terms of input relaxation variables, the increase in TRSSCG also increases the proportion of fixed asset investment and financial expenditure in local financial expenditure, resulting in the waste of funds.

(3) RPC-GDP: from the results of the regression analysis, we observe the regression coefficient value of relaxation variable: the value of regional per capita GDP to the average number of employees is negative, and the value of regional per capita GDP to the proportion of fiscal expenditure in local fiscal expenditure is also negative. The redundancy between regional per capita GDP and "the number of logistics employees and the proportion of financial expenditure in local financial expenditure" is decreasing. Referring to the research of Wang et al., a low redundancy is conducive to the improvement of regional logistics efficiency [24].

From the above regression results, the three selected environmental variables have significant impacts on the different input relaxation variables of logistics efficiency evaluation. Measuring the logistics efficiency of actual provinces on the basis of excluding the influence of external environmental factors is necessary.
<table>
<thead>
<tr>
<th>Relaxation variable</th>
<th>IRV</th>
<th>RCL</th>
<th>TRSSCG</th>
<th>RPC–GDP</th>
<th>Log Likelihood ratio (LR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investment in fixed assets</td>
<td>$-0.232 	imes 10^{-2}$</td>
<td>$0.353 	imes 10^{-3}$</td>
<td>$0.0606 	imes 10^{-3}$</td>
<td>$0.6076 	imes 10^{-3}$</td>
<td>$-0.4776 	imes 10^{-2}$</td>
</tr>
<tr>
<td>Average number of employees</td>
<td>$-0.122 	imes 10^{-1}$</td>
<td>$0.746 	imes 10^{-4}$</td>
<td>$-0.181 	imes 10^{-4}$</td>
<td>$0.810 	imes 10^{-7}$</td>
<td>$-0.898 	imes 10^{-7}$</td>
</tr>
<tr>
<td>Ratio of fiscal expenditure to local fiscal expenditure</td>
<td>$0.101 	imes 10^{-3}$</td>
<td>$0.395 	imes 10^{-7}$</td>
<td>$0.810 	imes 10^{-7}$</td>
<td>$-0.898 	imes 10^{-7}$</td>
<td>$-0.866 	imes 10^{-2}$</td>
</tr>
</tbody>
</table>

*, **, and *** mean significant at the significance level of 1%, 5%, and 10%; T values are in parentheses.
3.3. Stage III: Adjusted Regional Logistics Efficiency. The second-phase adjustment input data are entered into the same model again, and we can obtain the actual logistics efficiency value that is unaffected by external environmental factors and random interference. The adjusted average logistics efficiency is shown in Figure 2. The average values of TE, PTE, and SE are 0.6531, 0.9274, and 0.7043, respectively. Comparing Stage I with Stage III, the mean value of PTE changes from 0.8413 to 0.9274, indicating that the actual PTE value is significantly underestimated. The mean SE value changes from 0.8106 to 0.7043, suggesting that the actual SE value is significantly underestimated. The mean value of TE changes from 0.6819 to 0.7043, revealing that the actual TE value is overestimated. It shows that the impacts of environmental factors on logistics efficiency are obvious, especially on regional logistics efficiency.

3.4. Areas of Logistics Efficiency in China. To further analyze the differences in logistics efficiency in China, three efficiency types of China’s eight economic regions are specifically analyzed, as displayed in Figure 3. The results show that the logistics efficiency value changes clearly from Stage I to Stage III. The logistics efficiency in each region has improved, which suggests that under the influence of environmental factors, the integrated technical efficiency is underestimated. Feng and Li obtained the same answer when they calculated regional construction efficiency; each province has a higher TE in Stage III than in Stage I [25]. We can speculate that external environmental factors indeed have impacts on technological innovation development. Each region is compared as follows:

In Northeast China Region, the logistics efficiency is in the middle level. Liaoning Province has the highest efficiency from the perspective of internal comparison. Its TE value is 2.62 times that of Jilin Province and 1.82 times that of Heilongjiang Province. After the adjustment, the PTE values of the three provinces have improved, but SE has lowered. The PTE variation is the largest, which means that the improvement of logistics efficiency in the Northeast Region is largely affected by PTE.

In Northern Coastal Region, after the adjustment, the TE value of Tianjin has withdrawn from the frontier and its SE has decreased from 0.9799 to 0.8519, with the largest decline. All these changes indicate that the key to the improvement of logistics efficiency in Tianjin lies in SE. We can notice that the logistics efficiency of the Shandong and Hebei provinces in the efficiency frontier has been in an effective state. They are in the leading position in the North Coast Region. Overall, the logistics efficiency of the region only has a little change after the adjustment. Therefore, this area is less affected by environmental factors.

In Middle Reaches of the Yangtze River, Anhui Province has always been at the forefront of logistics efficiency; that is, the logistics industry in Anhui Province has been in an effective state. It can rank first in the Middle Reaches of the Yangtze River. By contrast, Hubei Province has the lowest logistics efficiency. After the adjustment, the logistics efficiency of Hunan, Hubei, and Jiangxi provinces has changed in varying degrees. Among them, the adjustment of TE in Hubei Province has increased from 0.5058 to 0.5745 and PTE has increased from 0.7037 to 0.8647, suggesting that external environmental factors have certain impacts on the logistics efficiency in the Middle Reaches of the Yangtze River.

In Eastern Coastal Region, after the adjustment, the TE of Zhejiang Province has increased from 0.6928 to 0.7906, PTE has increased from 0.7277 to 0.8609, and SE is the lowest, revealing that the TE and PTE of this province are underestimated, while SE is overestimated. Shanghai has been in the front in terms of the efficiency, and Jiangsu Province continues to approach the front of the efficiency, indicating that the two areas are less affected by external environments. Their logistics efficiency is at high levels all the time. In contrast to other regions of the country, the regional logistics efficiency of the Eastern Coastal Region is the highest because the region is the first to implement industrial upgrading transformation plans among all regions.

In Southwest China Region, after the adjustment, Sichuan Province’s logistics efficiency is the highest and its TE has increased from 0.8252 to 0.8554. Meanwhile, Yunnan is the lowest, with a TE < 0.4. Compared with other regions of the country, the logistics efficiency is the lowest in Southwest China. This finding also confirms the results of Liu et al. [26] and Qi et al. [27]. This region has inconvenient transportation, low economic level, and low development level. Although the overall logistics level in this region is continuously rising, it is still far from the Eastern Coastal Region.

In Northwest China Region, Qinghai Province has the greatest change, its TE has decreased from 0.5494 to 0.1441, and SE has decreased nearly three times from
Figure 3: Continued.
0.6028 and 0.1534. All these changes suggest that the logistics efficiency of Qinghai Province is seriously overestimated and the actual logistics efficiency is perhaps even lower. Xizang has the lowest logistics efficiency, and its adjusted TE is only 0.0449. Overall, the level of logistics efficiency in the Northwest Region is low. After the adjustment, the highest TE value in this region is 0.4654 times of that in Xinjiang. However, the logistics efficiency in this region changes the most, indicating that environmental factors have significant impacts on the logistics efficiency in the Northwest Region.

In the Southern Coastal Region, Guangdong Province’s logistics efficiency is the highest, whose TE is 0.9328. Figure 3: Three types of regional logistics efficiency in China’s eight economic regions.
Hainan Province’s logistics efficiency is the lowest. From the perspective of change, Hainan’s TE drops from 0.4378 (before the adjustment) to 0.2524, only 1/2 of the adjustment. The logistics efficiency of Hainan Province is overestimated, which reveals that the difference in the logistics efficiency of the Southern Coastal Region is obvious. The region is also affected by external environmental factors easily.

In Middle Reaches of the Yellow River, before the adjustment, the TE values of Neimenggu and Shaanxi provinces are the same, but after the adjustment, the logistics efficiency of Shaanxi Province becomes higher. The logistics efficiency of Shanxi Province is the highest in the Middle Reaches of the Yellow River and continues to be at the forefront. In general, the logistics efficiency of the region is maintained at a high level and changes slightly. It shows that the overall logistics efficiency in the Middle Reaches of the Yellow River is less affected by environmental factors.

3.5. Spatial Distribution of Regional Logistics Efficiency. As illustrated in Figure 4, the three broken line diagrams of efficiency of the six groups of regional logistics reflect the change trend of efficiency over time. Obvious differences can be found in the logistics efficiency among regions. The reason is mainly due to the different development degrees, geographical locations, and resource endowments of each region. First, we compare Figure 4(a) with Figure 4(b) to see the change in TE value from Stage I to Stage III. In Stage I, the TE value changes greatly year by year; in Stage III, the TE value changes gently year by year, suggesting that the development of China’s logistics industry presents a more stable state. In addition, the TE value of Northwest China in Stage III is significantly lower than that in Stage I, which means that external environmental factors have great impacts on the logistics efficiency of Northwest China. We should eliminate the influence of interference factors to fundamentally improve the logistics efficiency in Northwest China. Second, we compare Figure 4(c) with Figure 4(d) to see the change in PTE value from Stage I to Stage III. The PTE values of the eight regions in Stage III are higher than those in Stage I. After excluding the interference of environmental factors, the PTE values in Southwest and Northeast China increase significantly. It shows that the national actual PTE value is underestimated, but the PTE value in Southwest China still has much room for improvement. To improve the regional logistics efficiency in Southwest China, we should start by improving the technical and innovation levels of the logistics industry in this region. Finally, we compare Figure 4(e) with Figure 4(f) to observe the change in SE value from Stage I to Stage III. The SE values of the eight regions in Stage III are mostly lower than those in Stage I. It reveals that the national actual SE value is overestimated, especially in the Northwest. Therefore, the scale effect of China’s logistics industry still has much room for improvement. The most important point is that the change trend of TE is similar to that of SE, which indicates that the improvement of TE value depends more on the improvement of SE value. To improve China’s regional logistics efficiency, we should give full play to the logistics scale effect of each region and build a number of comprehensive logistics parks and hubs.

Figures 5 and 6 show the PTE and SE strategic coordinates of logistics efficiency of 31 provinces in China before and after adjustment. We construct the coordinate axis with the SE value as the horizontal axis and the PTE value as the vertical axis. Based on the PTE and SE mean, the coordinates are divided into four quadrants: the first quadrant (high-high group), the second quadrant (low-high group), the third quadrant (low-low group), and the fourth quadrant (high-low group). Firstly, affected by external environmental factors, we compare the data results of the first stage with the data results of the third stage: because the actual PTE value is underestimated, the PTE value of many provinces has increased in the third stage, so it has changed from the third and fourth quadrants to the first and second quadrants. Secondly, regardless of the first stage (Figure 5) or third stage (Figure 6), Xinjiang, Heilongjiang, Guangxi, Yunnan, and Jilin are all located in the third quadrant (low-low group). These areas have the lowest logistics efficiency. Among them, Yunnan Province is a plateau area and Guangxi Province is a typical karst landform. Jilin and Heilongjiang have cold and long winters. The special topography and landform restrict the improvement of logistics efficiency in these provinces. Thirdly, eight provinces (municipalities directly under the central government) including Tianjin, Liaoning, Anhui, Shanghai, Guangdong, Shandong, Jiangsu, and Hebei are located in the first quadrant (high-high group) in the first and third stages and most of these provinces are close to coastal areas. This also reflects from the side that the development level of the logistics industry in coastal areas is higher than that in inland areas. Fourthly, four provinces (autonomous regions) including Xizang, Hainan, Qinghai, and Ningxia are in the second quadrant (low-high group) in the first and third stages. This shows that the development bottleneck of the logistics industry in the Northwest Region of China lies in the improvement of SE. The reason is that in Xizang and Qinghai, due to their vast land and sparse population, their logistics infrastructure and equipment are not centralized, and they cannot give full play to the scale effect. Therefore, it is very difficult to improve their logistics efficiency. Finally, in most other regions, after eliminating the interference of external environmental factors, their logistics efficiency has a certain change. Therefore, their quadrant will change accordingly. For example, for inland provinces in central regions such as Hubei and Jiangxi, the PTE value of the third stage has increased significantly. This shows that the actual value of pure technical efficiency of logistics in the urban agglomeration in the Middle Reaches of the Yangtze River is underestimated. Taken together, we find that the logistics efficiency of China’s eight major economic regions has improved to a certain extent after the adjustment (the third stage). There is a certain correlation between the level of economic development and the level of logistics efficiency, but there is no complete positive correlation. In addition, the calculation results of other provinces are different, and targeted measures should be taken.
Figure 4: Continued.
Figure 4: Index decomposition of logistics efficiency in each region from 2009 to 2018 before and after the adjustment.

Figure 5: The SE and PTE strategic coordinates of logistics efficiency of China's 31 provinces in Stage I.
according to local characteristics to promote the healthy and orderly development of the logistics industry.

4. Conclusions and Suggestions

4.1. Conclusions. Through the above empirical analysis, this study analyzes and compares the development efficiency of China’s logistics industry in 31 provinces (cities and districts). Before the adjustment, the average values of TE, PTE, and SE of China’s logistics industry from 2009 to 2018 were 0.6819, 0.8413, and 0.8106, respectively. After the adjustment, the average values of TE, PTE, and SE of China’s logistics industry from 2009 to 2018 were 0.6531, 0.9274, and 0.7043, respectively. We present the following conclusions:

(1) The TE, PTE, and SE values of the eight regions have changed in varying degrees before and after the adjustment, suggesting that China’s regional logistics efficiency is affected by environmental factors and its real logistics efficiency is often distorted.

(2) Comparing Stage I with Stage III, the mean PTE value changes from 0.8413 to 0.9274, revealing that the actual PTE value is significantly underestimated. The mean SE value changes from 0.8106 to 0.7043, suggesting that the actual SE value is significantly overestimated. The mean TE value changes from 0.6819 to 0.6531 indicating that the actual TE value is overestimated. The change trend of TE is the same as that of SE, but opposite to that of PTE. We can know that the SE has more room for improvement compared to PTE.

(3) According to the regression results in Stage II, RCL and TRSSCG have negative impacts on the improvement of China’s regional logistics efficiency. The reason is that the improvement of RCL has a threshold effect on the utilization efficiency of logistics industry resources. When it is lower than the threshold, the utilization efficiency of logistics industry resources will not rise as RCL increases, which directly leads to the difficulty of effectively improving regional logistics efficiency within this range.

(4) From the perspective of space, the development level of the logistics industry has a certain regional agglomeration effect. Regardless of whether environmental interference is excluded or not, an obvious spatial imbalance is observed in the logistics efficiency of various regions in China; moreover, the development level of the logistics industry in coastal areas is significantly higher than that in inland areas. The logistics efficiency of eastern coastal areas (Shanghai, Jiangsu, and Zhejiang province.) and the northern coastal areas (Tianjin, Hebei, and Shandong) is highest, whereas the logistics efficiency of Northwest areas (Gansu, Qinghai, Ningxia, Xinjiang, and Xizang) is lowest. It shows a high pattern in the East and a low pattern in the West.

4.2. Suggestions. Based on the above analysis, we can make the following suggestions:

Firstly, we should eliminate the impacts of environmental factors to accurately identify the real logistics efficiency of each region. Doing so can help us find the weak links of improving logistics efficiency and take different measures for weak links to improve their logistics efficiency.
Secondly, according to the analysis of SFA regression results in the second stage, logistics scale and technical factors play an important role in improving logistics efficiency in China. Therefore, we should give full play to the scale effect of regional logistics and the aggregation effect of logistics facilities and equipment, actively promote technological innovation, and realize the effective allocation of logistics resources. Technology is the way to realize logistics productivity, and innovation is the soul and core of logistics productivity. Relying on technology and innovation, one should accelerate the construction of China’s smart logistics platform, deepen the application and innovation of modern logistics technology, and ultimately promote the improvement of logistics scale effect.

Thirdly, the improvement of RCL has a threshold effect on the utilization efficiency of logistics industry resources. Therefore, we should further increase the degree of opening to the outside world, actively introduce foreign-funded enterprises to inject fresh blood into the development of the local logistics industry, reduce residents’ personal income tax, change residents’ consumption concept from the source, take measures to cultivate new consumption hotspots, and encourage residents’ consumption.

Finally, because the logistics efficiency of eastern coastal areas and the northern coastal areas is highest, the logistics efficiency of Northwest areas is lowest. Therefore, the government should take full account of regional differences and formulate policies for the development of the logistics industry in light of local conditions. For example, the eastern region should rely on its own good logistics industry development foundation, logistics industry communication, transportation, and digital economy, and other modern technology benign interaction, for the development of the logistics industry in other regions as a good example. Northwest China can rely on its own industrial base and increase the logistics industry infrastructure equipment and application technology research and development efforts. By optimizing the spatial distribution of logistics industry and tapping the regional development potential, the gap between regions of logistics industry development level can be gradually narrowed.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

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References


