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Evaluation and Analysis of Logistics Efficiency of Agricultural Products in China

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Abstract

This paper uses three-stage DEA and Malmquist model to evaluate and analyze the logistics efficiency of agricultural products in China statically and dynamically from the time trend and regional differences. The results show that at the present stage, the logistics efficiency of agricultural products in China is mainly restricted by the efficiency of scale; environmental variables play a different role in promoting the logistics efficiency of agricultural products; from a static point of view, the logistics efficiency of agricultural products in 31 provinces and cities in China is generally low and there is obvious regional differentiation. From the perspective of spatial distribution, the logistics efficiency of agricultural products in China generally shows the distribution characteristics of low in the east and high in the middle; from a dynamic point of view, the logistics efficiency of agricultural products in China shows an overall upward trend, and technological progress promotes the development of total factor productivity of agricultural logistics. On this basis, combined with the current actual situation of the development of agricultural product logistics in China, this paper puts forward relevant suggestions to further improve the efficiency of agricultural product logistics in China.

Subject Areas

Business Management

Keywords

Agricultural Products, China, Logistics Efficiency, Three-Stage DEA, Malmquist Model

1. Introduction

Agriculture has always been an important supporting industry of China's national economy. As a traditional agricultural country, China's rich output of agricultural products can effectively drive economic growth by meeting the market demand for domestic agricultural products and export trade. Since the "three rural" issues were put forward in 2005, the focus of the work of the Party Central Committee and the State Council has gradually shifted to solving the "three rural" issues. With the gradual promotion of agricultural science and technology, the quality and output of China's agricultural products have been greatly improved. At the same time, with the release of the guiding opinions on Further Strengthening the construction of the agricultural product market system, the problem of supply shortage has been gradually alleviated and the agricultural product market has been effectively rectified. However, due to the particularity of perishable, difficult packaging and low added value of agricultural products, it is impossible to ensure the safe and efficient transfer of agricultural products from the production place to consumers, resulting in the relative disconnection between the production and sales of agricultural products, which has an adverse impact on the development of a rural real economy. The convening of the Fifth Plenary Session of the 19th CPC Central Committee in 2020 makes promoting agricultural development a key task of governments at all levels and relevant departments. In the agricultural and rural development plan of the 14th five-year plan, it is clearly proposed to increase investment in storage and preservation of cold chain logistics facilities.

Logistics is the product of economic development. With the continuous advancement of logistics modernization, logistics has penetrated all walks of life, and the operation modes of many industries are inseparable from logistics. As an important branch of the logistics industry, agricultural product logistics plays an important role in promoting rural economic development and improving farmers' income. As a large traditional agricultural country, China's annual circulation of agricultural products is very large, and agricultural products logistics has gradually become a powerful help to promote the rural real economy. However, due to the existing problems in the development of China's agricultural products logistics at this stage, China's agricultural products logistics efficiency is relatively low, and there is a serious problem of circulation loss at the same time. According to the relevant data released by the Cold Chain Committee of China Federation of Things in 2019, the circulation loss of agricultural products in China is obvious, including 11% of fruits, 20% of vegetables, 8% of meat, and 10% of aquatic products, while the loss rate of fruits and vegetables in developed countries is controlled below 5%. It is often seen. In recent years, under the background of technological innovation and policy support, the total output of agricultural products has been improving. However, the phenomenon of poor sales of agricultural products is common. Especially after the outbreak of COVID-19 in 2020, traffic was seriously hindered. The turnover of logistics workers was delayed, resulting in the poor logistics and transportation costs of agricultural products, while the supply chain of agricultural products was affected. In many agricultural products markets, the supply is suspended or even suspended. Suppliers cannot deliver agricultural products to customers in time as before, and warehouses are piled up, resulting in serious unsalable. Vigorously developing the logistics of agricultural products is of great significance for improving the quality of agricultural products supply, promoting agricultural development, and promoting the strategy of Rural Revitalization. Because of the existing problems in the development of China's agricultural products logistics and the negative effects brought by COVID-19 to the circulation of agricultural products, it is necessary to study how to raise the efficiency of agricultural product logistics to promote the structural reform of the supply side of agriculture and solve the "three rural issues".

2. Literature Review

Logistics is an important part of supply chain management, and logistics efficiency is an important index to measure the development of logistics. At present, the research on agricultural product logistics by domestic and foreign scholars mainly focuses on the following three aspects.

(1) The importance of agricultural products logistics. Perdana (2012) [1] proposed to vigorously develop the logistics of agricultural products to meet the market demand in time. Alston and Pardey (2014) [2] pointed out that agricultural product logistics can slow down the food shortage and meet the market demand for agricultural products in time. Stahl *et al.* (2015) [3] and Defraeye *et al.* (2015) [4] believe that agricultural product logistics can effectively improve people's quality of life. Since hundreds of millions of agricultural products are lost in China every year during transportation, Liu *et al.* (2019) [5] established a distribution model based on ant colony algorithm to ensure that agricultural products arrive on time. Han *et al.* (2021) [6] believe that cold chain logistics is not only an important link to maintain the quality and safety of fresh agricultural products and reduce losses, but also an important support to increase farmers' income and promote the revitalization of rural industries.

(2) Based on the perspective of the supply chain. Ding Hua (2004) [7] analyzed the logistics supply chain of agricultural products for the first time and put forward relevant improvement measures. Zhang Min (2007) [8] through the analysis of the current situation of agricultural products circulation, it is found that the main reason for the high circulation cost of agricultural products in China is the poor connection of agricultural products supply chain. Wang Yan *et al.* (2008) [9] pointed out the problems existing in China's agricultural product logistics supply chain at the emergence stage and put forward three improvement measures to promote the development of agricultural product logistics. Zhang Qian and Li Chongguang (2008) [10] believe that the agricultural product supply chain is an important part of agricultural product logistics. Han Yongfei (2011) [11], Cheng Chao and Li Bin (2013) [12] put forward relevant suggestions from the perspective of the supply chain to solve the problems encountered in China's agricultural product logistics. Wang Hainan and others (2020) [13] put forward suggestions to promote the development of fresh logistics by studying

the impact of COVID-19 on the fresh supply chain.

(3) From the perspective of efficiency. Li Chuang (2012) [14] put forward relevant suggestions on the development of agricultural products logistics in Henan Province based on DEA empirical results. Ren Yanhong (2012) [15] used the super-efficiency DEA model to evaluate the circulation efficiency of aquatic products. Xu Liang Pei and Li Shuhua (2013) [16] chose the SFA method when studying the impact of the external environment on the logistics efficiency of agricultural products. Zhao Feng and Duan Fengjun (2014) [17] made an empirical analysis of the logistics efficiency of agricultural products with the help of traditional DEA methods. Huang Fuhua and Jiang Xuelin (2017) [18] found that factors such as sales volume, total batch, unsalable volume, and loss will affect the logistics efficiency of fresh agricultural products. Pan *et al.* (2021) [19] analyzed the regional differences and dynamic evolution of China's agricultural product logistics efficiency by using the Malmquist model.

To sum up, domestic scholars began to pay more and more attention to the related research on the logistics efficiency of agricultural products. In terms of the research object of agricultural product logistics efficiency, most scholars only select the agricultural product logistics industry of a province or a region as the research object. Therefore, because of the reality that the research on the overall situation of agricultural product logistics in China is still relatively scarce, this paper takes the agricultural product logistics industry of various provinces and cities in China as the research object. In terms of efficiency measurement methods, because the traditional DEA method cannot exclude the influence of random error and external environment on the empirical results, based on the previous research results, this paper selects the Three-stage DEA nonparametric method to evaluate the logistics efficiency of agricultural products in China, which can ensure the accuracy of the empirical results to a certain extent. At the same time, the nonparametric method avoids the risk of wrong function settings in the parametric method, and its weight is not artificially set, which ensures the objectivity of the evaluation results. In addition, most of the existing kinds of literature only evaluate and analyze the logistics efficiency of agricultural products from static or dynamic. Therefore, combined with the Malmquist index model, this paper can evaluate and analyze the logistics efficiency of agricultural products in China more comprehensively.

3. Research Design

3.1. Three-Stage DEA Model

In this paper, Fried *et al.* [20] are used to construct a three-stage DEA model, and the specific steps are as follows.

3.1.1. Phase I BCC Model

A traditional BCC model based on variable returns to scale is established, as shown in Formula (1).

$$\begin{cases} \min\left[\theta-\varepsilon\left(\hat{e}^T s^- + e^T s^+\right)\right] \\ \sum_{j=1}^{n} X_j\lambda_j + s^- = \theta X_{j0} \\ \sum_{j=1}^{n} Y_j\lambda_j - s^+ = Y_{j0} \\ \sum_{j=1}^{n} \lambda_j = 1 \\ \lambda_j \ge 0, j=1,2,\cdots,n; s^+ \ge 0, s^- \ge 0 \end{cases} \tag{1}$$

Among them, the decision-making unit inputs variables $X_j = \left(x_{1j}, x_{2j}, \cdots, x_{mj}\right)^T$ express; DMU output variables $Y_j = \left(y_{1j}, y_{2j}, \cdots, y_{sj}\right)^T$ express; X_{j0}, Y_{j0} for the first j_0 input and output variables of decision-making units; s^+ and s^- relaxation variables representing output and input respectively; n is the number of decision-making units; λ_j is a decision variable; $\hat{e} = (1,\cdots,1)^T \in E_m$; $\hat{e} = (1,\cdots,1)^T \in E_s$; ε is non-Archimedean infinitesimal; θ, it is used to evaluate the effectiveness compared with 1.

3.1.2. Second Stage SFA Model

Second Stage SFA Model is the comprehensive efficiency value of the decision-making unit firstly, the theoretical model of input relaxation variables and environmental explanatory variables of the agricultural product logistics industry are established, as shown in formula (2).

$$\begin{cases} s_{ij} = f^i\left(z_j, \beta^i\right) + v_{ij} + u_{ij} \\ i=1,2,\cdots,m; j=1,2,\cdots,n \end{cases} \tag{2}$$

In which, $Z_j = \left(z_{1j}, z_{2j}, \cdots, z_{pj}\right)$ express an environmental variable that has an impact on the logistics efficiency of agricultural products, β^i is the parameter vector to be estimated of the environment variable. $f^i(z_j, \beta^i) = z_j\beta^i$ represents the environment variable versus the relaxation variable S_{ij} influence mode of $v_{ij} + u_{ij}$ is a mixed error term, among, v_{ij} is a random error term, assuming that it follows a normal distribution, *i.e.*, $v_{ij} \sim N\left(0, \sigma_{ui}{}^2\right)$, u_{ij} indicates management inefficiency, assuming that it follows a truncated normal distribution, *i.e.*, $u_{ij} \sim N^+\left(u^i, \sigma_{ui}{}^2\right)$, and assume v_{ij} and u_{ij} especially, order $\gamma = \sigma_{ui}{}^2 / \left(\sigma_{ui}{}^2 + \sigma_{vi}{}^2\right)$, for comparison with 1.

Secondly, through the conditional estimation of management inefficiency $\hat{E}\left[u_{ij} \middle| v_{ij} + u_{ij}\right]$, the estimation of random error is obtained:

$$\begin{cases} E\left[v_{ij} \middle| v_{ij} + u_{ij}\right] = s_{ij} - z_j\hat{\beta}^i - \hat{E}\left[u_{ij} \middle| v_{ij} + u_{ij}\right] \\ i=1,2,\cdots,m; j=1,2,\cdots,n \end{cases} \tag{3}$$

Finally, adjust the input of agricultural product logistics industry in different provinces and cities in China:

$$\begin{cases} x_{ij}^* = x_{ij} + \left[\max_j\left\{z_j\hat{\beta}^n\right\} - z_j\hat{\beta}^n\right] + \left[\max_j\left\{\hat{v}_{ij}\right\} - \hat{v}_{ij}\right] \\ i=1,2,\cdots,m; j=1,2,\cdots,n \end{cases} \tag{4}$$

In which, x_{ij}^{*} indicates the adjusted input value of agricultural product logistics industry, x_{ij} indicates the initial input value of agricultural product logistics industry, β^{n} is the estimated value of the environmental variable parameter. $\left[Max_j\left\{z_j\hat{\beta}\right\}-z_j\hat{\beta}^{n}\right]$ represents that all different provinces and cities in China have the same environmental constraints, $\left[\max_j\left\{\hat{v}_{ij}\right\}-\hat{v}_{ij}\right]$. It represents that the agricultural product logistics industry in different provinces and cities in China is in the same natural state.

3.1.3. The Third Stage BCC Model

The adjusted agricultural product logistics input value in the second stage is used to replace the original input value and combined with the original agricultural product logistics output data, it is brought back into the BCC model for a solution.

3.2. Malmquist Index Model

Malmquist index is often used to measure the change of total factor productivity (TFP) of decision-making units with multiple input and output variables in multiple periods. In this paper, the input and output data of agricultural products logistics obtained in the third stage are substituted into Malmquist model, and the ratio of distance function is used to measure the efficiency of input and output. The calculation formula is as follows (5):

$$
\begin{aligned}
TFP &= M\left(x^{t+1},y^{t+1},x^{t},y^{t}\right)\\
&=\frac{D^{t}\left(x^{t},y^{t}\right)}{D^{t+1}\left(x^{t+1},y^{t+1}\right)}\times\left[\frac{D^{t+1}\left(x^{t},y^{t}\right)}{D^{t}\left(x^{t+1},y^{t+1}\right)}\times\frac{D^{t+1}\left(x^{t+1},y^{t+1}\right)}{D^{t}\left(x^{t},y^{t}\right)}\right]^{\frac{1}{2}}\\
&= EC\times TC
\end{aligned}
\tag{5}
$$

Among them, the distance function of the decision-making unit in the t period is expressed by $DT\ (XT,\ YT)$, and the distance function in $T+1$ period is expressed by $DT\ (XT+1,\ YT+1)$. The approximation between the decision-making unit and the production frontier is expressed by the technical efficiency change index (EC), and the technical change is expressed by the technical progress change index (TC). When $TFP > 1$, it indicates that the logistics efficiency of agricultural products is increasing in a specific period. When $TFP < 1$, it shows that the logistics efficiency of agricultural products shows a downward trend in a specific period.

3.3. Index Selection and Data Source

This paper takes China's agricultural product logistics industry as the research object, takes the agricultural product logistics industry of each province and city as a decision-making unit, obtains relevant data from China Statistical Yearbook 2011-2020 and the statistical yearbook 2011-2020 of each province and city according to the existing research results, and constructs the input-output index system of the agricultural product logistics industry as shown in **Table 1**.

Table 1. Input-output index system of agricultural product logistics industry.

Indicator type	Indicator name	Index meaning
Input index	Number of agricultural products logistics employees/person	Government support
	Fixed investment in agricultural products logistics industry/100 million yuan	Indicates capital investment
	Traffic route mileage/km	Scale input
Output indicators	Added-value of agricultural products logistics industry/100 million yuan	Direct output representing economic benefits
Environment variable	Economic development level	Reflect local economic development
	Scientific and technological development level	Reflect local economic development
	Government support	Reflect the local government's support for agricultural product logistics

(1) Input indicators. This paper refers G. Stigler (2021)'s research which mainly considers the human, financial and scale investment, and selects three indicators: the number of employees in agricultural products logistics, the fixed investment in agricultural products logistics and the mileage of transportation lines. Since there is no unified standard for dividing the logistics industry at home and abroad, and agricultural product logistics is only a branch of the logistics industry, there is a lack of special statistical indicators in the evaluation of agricultural product logistics efficiency. For this, many scholars have adopted a simple alternative treatment method. For example, in terms of human and financial investment indicators, most research literature selects transportation The number of employees and fixed investment in warehousing and postal services is directly used as labor and capital investment in the agricultural product logistics industry. This approach seems simple, but there is a large distortion problem. Referring to the practices of Cheng Shuqiang and Liu Yanan [21], this paper first selects the number of employees in transportation, warehousing, and postal services as the number of employees in the whole logistics industry, then multiply by the proportion of residents' food consumption in total consumption (c), and the new value will approximately represent the number of agricultural product logistics employees. Similarly, the fixed investment in transportation, warehousing, and postal services shall be treated accordingly. In addition, considering the impact of the time value of money, the comparable price conversion shall be carried out with 2009 as the base period. The proportion of residents' food consumption in total consumption is calculated as follows:

$$C = c_1 * c_2 * e \quad (6)$$

Among them, c_1 is the final consumption rate, c_2 is the resident consumption rate, and e is the Engel coefficient (replaced by the national average level).

(2) Output indicators. This paper selects the added value of the agricultural product logistics industry as the output index because the added value can better reflect the net income output brought by the input factors of agricultural product logistics over a while. Similarly, the added value of transportation, warehousing and postal industry is selected, and then multiplied by the proportion of residents' food consumption in the total consumption (c), the new value will approximately represent the added value of the agricultural product logistics industry, and the comparable price conversion is carried out based on 2009.

(3) Environment variables. The logistics efficiency of agricultural products in China is not only affected by the internal development of the industry, but also by the external environmental factors of the industry. Considering that the environmental variables must be able to affect the logistics efficiency, but will not be subject to the subjective control of samples in the short term and the availability of data, this paper selects the level of economic development The level of scientific and Technological Development and the strength of government support are three environmental variables, in which the level of economic development is reflected by the GDP of each region (based on 2009, the comparable price is treated according to the GDP deflator); The level of scientific and technological development is reflected by the proportion of scientific and technological expenditure in the total local financial expenditure; Government support is reflected by the proportion of transportation expenditure in total financial expenditure.

4. Empirical Analysis

4.1. Comprehensive Efficiency of Agricultural Product Logistics in China before Adjustment

The input-output data of China's agricultural products logistics industry from 2010 to 2019 are substituted into the BCC model based on the variable return to scale, and the comprehensive efficiency of China's agricultural products logistics is obtained by using deap2.1 software, as shown in Table 2.

Table 2. Comprehensive efficiency of agricultural product logistics in China before adjustment.

Region	2010Y	2011Y	2012Y	2013Y	2014Y	2015Y	2016Y	2017Y	2018Y	2019Y	Mean V
Beijing	0.794	0.952	0.612	0.742	0.685	0.965	1.000	0.756	0.747	0.540	0.779
Tianjin	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Hebei	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Shanghai	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Jiangsu	1.000	1.000	1.000	1.000	0.942	0.957	0.984	0.890	0.951	0.886	0.961
Zhejiang	0.724	0.673	0.659	0.700	0.753	0.774	0.833	0.818	0.796	0.791	0.752
Fujian	0.789	0.683	0.737	0.676	0.778	0.920	1.000	1.000	1.000	0.754	0.834
Shandong	1.000	0.971	0.900	0.953	0.836	0.749	0.790	0.795	0.823	0.834	0.865

Continued

Guangdong	0.705	0.723	0.785	0.708	0.765	0.775	0.861	0.687	0.693	0.671	0.737
Hainan	0.435	0.688	0.539	0.397	0.465	0.427	0.425	0.457	0.552	0.609	0.499
Shanxi	0.529	0.491	0.496	0.664	0.697	0.756	0.750	1.000	1.000	0.896	0.728
Anhui	0.725	0.731	0.647	0.589	0.562	0.496	0.446	0.412	0.487	0.872	0.597
Jiangxi	0.600	0.640	0.777	0.879	0.751	0.686	0.649	0.702	0.730	0.850	0.726
Henan	0.725	0.682	0.713	0.707	0.861	0.739	0.753	1.000	0.671	0.774	0.763
Hubei	0.539	0.508	0.469	0.509	0.516	0.469	0.449	0.408	0.465	0.679	0.501
Hunan	0.584	0.521	0.583	0.733	0.724	0.651	0.684	0.620	0.692	0.583	0.638
Inner Mongolia	0.781	0.749	0.774	0.841	0.822	1.000	0.681	0.645	0.898	0.920	0.811
Guangxi	0.434	0.450	0.422	0.478	0.473	0.501	0.535	0.529	0.544	0.452	0.482
Chongqing	0.445	0.403	0.396	0.401	0.463	0.435	0.451	0.407	0.448	0.428	0.428
Sichuan	0.367	0.333	0.332	0.281	0.312	0.358	0.441	0.398	0.471	0.432	0.373
Guizhou	0.742	0.716	0.832	0.793	0.880	0.773	0.997	0.855	0.930	0.508	0.803
Yunnan	0.207	0.183	0.212	0.207	0.204	0.183	0.230	0.199	0.223	0.643	0.249
Xizang	0.372	0.423	0.484	0.462	0.415	0.333	0.441	0.373	0.326	0.172	0.380
Shaanxi	0.422	0.393	0.454	0.494	0.511	0.406	0.402	0.352	0.375	0.422	0.423
Gansu	0.716	0.639	0.598	0.532	0.298	0.282	0.256	0.244	0.290	0.379	0.423
Qinghai	0.297	0.290	0.234	0.213	0.241	0.224	0.268	0.215	0.290	0.268	0.254
Ningxia	0.821	0.950	1.000	0.908	0.753	0.667	0.678	0.527	0.580	0.698	0.758
Xizang	0.360	0.381	0.476	0.505	0.501	0.444	0.544	0.389	0.602	0.688	0.489
Liaoning	0.635	0.734	0.738	0.666	0.707	1.000	1.000	1.000	1.000	1.000	0.848
Jilin	0.436	0.487	0.491	0.551	0.532	0.462	0.422	0.409	0.506	0.433	0.473
Heilongjiang	0.388	0.547	0.638	0.697	0.648	0.536	0.504	0.443	0.531	0.333	0.527
Population	0.631	0.643	0.645	0.654	0.648	0.644	0.660	0.630	0.665	0.662	0.648

Without considering the interference of environmental variables and random factors, the overall efficiency of China's agricultural product logistics changed between [0.630, 0.665] from 2010 to 2019, showing a continuous upward and downward trend, but none of them reached 1. DEA was not effective. The decline was more obvious in 2017. 2017 is an important year for China to deepen the structural reform of the grain supply side. Modern grain logistics and supply chain began to integrate. However, due to the new stage of development and the objective situation of random errors in empirical results, the low efficiency was more obvious in that year. However, with the gradual strengthening of grain logistics and supply chain, the logistics efficiency of agricultural products increased significantly in 2018. Tianjin, Hebei, and Shanghai have achieved DEA effectiveness from 2010 to 2019; Although Jiangsu did not reach the efficiency frontier from 2014 to 2019, it was on the edge of DEA effectiveness; Liaoning's comprehensive efficiency increased or decreased by about 0.7 from 2010 to 2014, and then achieved DEA effectiveness from 2015 to 2019; from 2010 to 2014, Fujian experienced two trends of the first decrease and then increase, and the comprehensive efficiency remained increasing, reaching 1 in 2016-2018 and dropping to 0.754 in 2019; from 2010 to 2019, Beijing, Shandong, Shanxi, Henan, Inner Mongolia, and Ningxia achieved DEA efficiency only in 1 - 2 years; The comprehensive efficiency of other provinces and cities showed a trend of increase or decrease from 2010 to 2019, but did not reach the efficiency frontier. Overall, the logistics efficiency of agricultural products in China is not high, and there are problems of slow growth or even negative growth. Therefore, improving the logistics efficiency of agricultural products is an important task for China's agricultural development in the future.

4.2. SFA Regression Analysis

Using frontier 4.1 software, the external environmental factors such as economic development level, scientific and technological development level, and government support are regarded as independent variables, and the relaxation variables of agricultural product logistics employees, agricultural product logistics fixed investment, and traffic line mileage are regarded as dependent variables for regression analysis. According to the regression results in Table 3, the three unilateral likelihood ratio test statistics LR are greater than the test value of mixed chi-square distribution, indicating that it is necessary to conduct SFA analysis.

Table 3. SFA regression results in the second stage.

	Slack variable of agricultural product logistics employees	Slack variable of fixed investment in agricultural product logistics	Traffic route mileage Relaxation variable
Constant term	-1640.98^{*}	9.11	32835.33^{***}
Economic development level	-0.14^{***}	0.00003	0.15
Scientific and technological development level	36826.13^{***}	−193.49	-1763200.00^{***}
Government support	15445.52^{***}	−36.75	-134037.60^{***}
δ^2	162990070.00^{***}	9729.68^{***}	8074106700.00^{***}
γ	0.84^{***}	0.96^{***}	0.94^{***}
LR	261.64^{***}	477.44^{***}	466.44^{***}

Notes: *, **, *** respectively expressed in 10%, 5%, 1% significant level; δ^2 represents variance; γ indicates the proportion of management ineffective variance in the total variance; LR is the one-sided likelihood ratio test statistic.

(1) Economic development level. SFA regression results show that the regression coefficient between the environmental variable and the relaxation variable of agricultural product logistics employees is negative, indicating that the increase of regional GDP will attract more labor force, which is conducive to reducing the input redundancy of young agricultural product logistics employees, promoting the effective utilization of this resource, and improving the efficiency of agricultural product logistics; the regression coefficients of the environmental variable, the relaxation variable of fixed investment in agricultural products logistics and the relaxation variable of traffic line mileage are positive, indicating that when the regional GDP increases to a certain extent, the overflow will lead to the input redundancy of fixed investment and traffic line mileage.

(2) Scientific and technological development level. SFA regression results show that the regression coefficient between the environmental variable and the relaxation variable of agricultural product logistics employees is positive, indicating that the improvement of scientific and technological level may lead to the increase of the relaxation variable of agricultural product logistics employees to a certain extent, resulting in the waste of resources; the regression coefficients of the environmental variable, the relaxation variable of fixed investment in agricultural products logistics and the relaxation variable of traffic line mileage are negative, indicating that the higher the level of science and technology, the more it can attract the capital investment of agricultural products logistics industry and reduce the waste of traffic line investment.

(3) Government support. SFA regression results show that the regression coefficient between the environmental variable and the relaxation variable of agricultural product logistics employees is positive, indicating that when the labor input reaches saturation, the improvement of government support will cause a waste of labor resources; the regression coefficients between the environmental variable and the relaxation variables of fixed investment in agricultural products logistics and traffic line mileage are negative, indicating that the government support can promote the attraction of capital investment and the reduction of agricultural products logistics mileage. The higher the level of government support, the more positive the impact on the development of the local agricultural products logistics industry.

4.3. Adjusted Comprehensive Efficiency of Agricultural Product Logistics in China

Utilizing the refined input data from the second phase in conjunction with the original output figures of the agricultural product logistics sector, the deap2.1 software was employed to re-assess the comprehensive efficiency across China's 31 provinces and cities. The findings are presented in **Table 4**. A comparative analysis of the data pre- and post-adjustment reveals that there is a notable variation in the annual efficiency values, underscoring the influence of external environmental factors and random events on the computation of logistics efficiency for agricultural products in China. For instance, the efficiency values for provinces such as Hebei have remained consistently high, suggesting a resilient

Table 4. Comprehensive efficiency of agricultural product logistics in China after adjustment.

Region	2010Y	2011Y	2012Y	2013Y	2014Y	2015Y	2016Y	2017Y	2018Y	2019Y	Mean V
Beijing	0.696	0.784	0.731	0.809	0.752	0.892	0.966	0.854	0.841	0.595	0.792
Tianjin	0.997	0.877	0.881	0.924	0.889	0.834	0.834	0.902	0.879	0.800	0.882
Hebei	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Shanghai	0.902	0.890	0.894	0.939	1.000	1.000	1.000	1.000	1.000	1.000	0.963
Jiangsu	1.000	1.000	1.000	1.000	0.988	1.000	1.000	1.000	1.000	0.950	0.994
Zhejiang	0.755	0.718	0.670	0.734	0.777	0.805	0.856	0.806	0.824	0.749	0.769
Fujian	0.762	0.718	0.756	0.788	0.860	0.954	0.998	0.952	1.000	0.762	0.855
Shandong	1.000	0.990	0.925	0.969	0.924	0.839	0.886	0.850	0.900	0.889	0.917
Guangdong	0.838	0.873	0.917	0.871	0.905	0.850	0.925	0.888	0.886	0.757	0.871
Hainan	0.228	0.278	0.263	0.239	0.292	0.265	0.270	0.332	0.409	0.365	0.294
Eastern Region	0.818	0.813	0.804	0.827	0.839	0.844	0.874	0.858	0.874	0.787	0.834
Shanxi	0.581	0.548	0.561	0.702	0.730	0.773	0.771	1.000	1.000	0.826	0.749
Anhui	0.680	0.674	0.653	0.616	0.606	0.538	0.502	0.465	0.552	0.886	0.617
Jiangxi	0.606	0.619	0.711	0.748	0.732	0.697	0.672	0.749	0.774	0.791	0.710
Henan	0.780	0.744	0.797	0.794	0.942	0.843	0.861	1.000	0.766	0.863	0.839
Hubei	0.608	0.568	0.531	0.571	0.577	0.523	0.529	0.477	0.532	0.758	0.567
Hunan	0.634	0.585	0.649	0.775	0.787	0.710	0.723	0.679	0.747	0.637	0.693
Central region	0.648	0.623	0.650	0.701	0.729	0.681	0.676	0.728	0.729	0.794	0.696
Inner Mongolia	0.771	0.769	0.789	0.857	0.850	1.000	0.735	0.720	0.916	0.854	0.826
Guangxi	0.483	0.493	0.471	0.526	0.522	0.543	0.582	0.578	0.598	0.490	0.529
Chongqing	0.457	0.435	0.437	0.451	0.525	0.490	0.500	0.474	0.503	0.472	0.474
Sichuan	0.410	0.379	0.385	0.326	0.380	0.443	0.524	0.487	0.564	0.494	0.439
Guizhou	0.639	0.646	0.694	0.717	0.761	0.872	0.839	0.781	0.819	0.477	0.725
Yunnan	0.218	0.198	0.235	0.232	0.241	0.252	0.265	0.236	0.259	0.624	0.276
Xizang	0.064	0.056	0.061	0.071	0.076	0.081	0.080	0.068	0.073	0.062	0.069
Shaanxi	0.481	0.446	0.509	0.541	0.576	0.459	0.456	0.408	0.434	0.476	0.479
Gansu	0.483	0.488	0.510	0.489	0.318	0.301	0.277	0.268	0.327	0.387	0.385
Qinghai	0.157	0.146	0.139	0.149	0.147	0.166	0.167	0.141	0.192	0.173	0.158
Ningxia	0.374	0.399	0.427	0.427	0.400	0.369	0.343	0.301	0.309	0.291	0.364
Xinjiang	0.366	0.380	0.474	0.496	0.531	0.480	0.557	0.442	0.652	0.691	0.507
Western Region	0.409	0.403	0.428	0.440	0.444	0.455	0.444	0.409	0.471	0.458	0.436
Liaoning	0.789	0.845	0.864	0.860	0.910	1.000	1.000	1.000	1.000	1.000	0.927
Jilin	0.468	0.512	0.527	0.546	0.555	0.495	0.453	0.451	0.543	0.458	0.501
Heilongjiang	0.444	0.577	0.669	0.686	0.692	0.599	0.571	0.536	0.645	0.389	0.581
Northeast China	0.567	0.645	0.687	0.697	0.719	0.698	0.675	0.662	0.729	0.616	0.669
Population	0.602	0.601	0.617	0.640	0.653	0.648	0.650	0.640	0.676	0.644	0.637

logistics system that is less susceptible to external perturbations. Conversely, provinces that have experienced significant fluctuations in efficiency values, such as Hainan, may be more sensitive to environmental and random factors, including market volatility and unforeseen events like natural disasters. These variations highlight the necessity for a nuanced understanding of the multifaceted elements that contribute to the efficiency of agricultural product logistics. It is imperative for policymakers and industry stakeholders to consider these factors when devising strategies aimed at enhancing logistics efficiency and sustainability.

Before adjustment, the efficiency of China's agricultural products logistics decreased from 2010 to 2013, but maintained a growth trend. From 2019 to 2019, the efficiency of China's agricultural products logistics showed a trend of "V" before and after adjustment. Specifically, Hebei has reached the efficiency frontier for 10 consecutive years from 2010 to 2019, realizing the effective DEA. Shanghai was in a "V" shape from 2010 to 2013 and remained at the forefront of efficiency from 2014 to 2019. Jiangsu slightly deviated from the efficiency frontier in 2014 and 2019, and DEA was effective in other years. Liaoning showed an overall upward trend from 2010 to 2014, and the efficiency remained at 1 from 2015 to 2019. Fujian, Shandong, Shanxi, Henan, Inner Mongolia and other provinces and cities only achieved DEA effectiveness in individual years from 2010 to 2019. Overall, the efficiency of China's agricultural products logistics has gradually increased since 2011. This is because the general office of the State Council issued the opinions on strengthening the construction of fresh agricultural products circulation system that year, which promoted the construction of agricultural products logistics infrastructure. Since then, the State Council has vigorously supported and encouraged the construction of agricultural products market, which has brought a development period to the agricultural products logistics industry. After excluding the influence of external environment and random error, the overall comprehensive efficiency of China's agricultural product logistics changed between [0.601, 0.676] from 2010 to 2019, which failed to achieve DEA effectiveness, indicating that the overall development level of China's agricultural product logistics industry is not high, the infrastructure network is not perfect, the degree of informatization and standardization is low, and the problem of low logistics efficiency is still prominent. From the perspective of regional division, the region with the highest efficiency of agricultural product logistics is the east of China, followed by the central region, the northeast region ranks third, and the western region has the lowest efficiency of agricultural product logistics. It can be seen from **Figure 1** that the comprehensive efficiency of the eastern region has changed significantly before and after adjustment, which was originally in the "m" type change of volatility. After adjustment, the comprehensive efficiency of the eastern region is in a relatively stable state; the change of comprehensive efficiency in Central China and Northeast China is similar to that before adjustment, but the overall efficiency is increased; the overall efficiency of the western region has decreased significantly compared with that before the adjustment. Originally, it fluctuated up and down at 0.5, but now it is between 0.4 - 0.5.

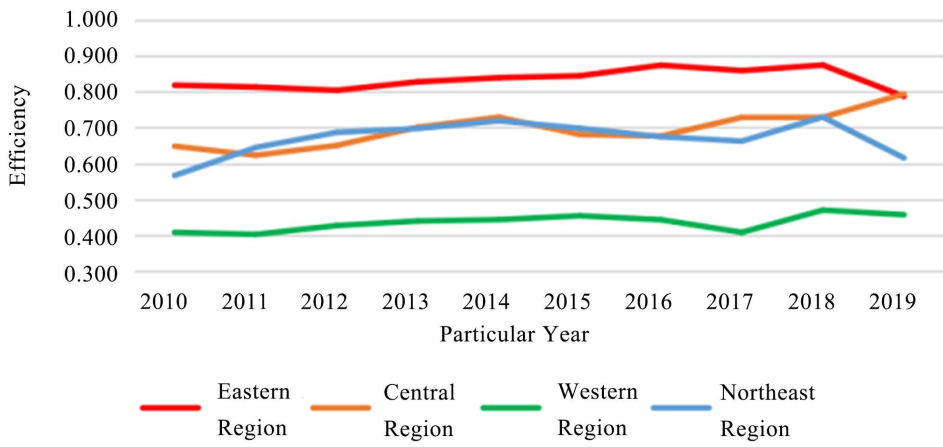

Figure 1. Changes in comprehensive efficiency of agricultural product logistics in the four regions after adjustment.

According to Liu Wei's method of defining the critical value [22], according to Tables 4-6, taking the mean value of pure technical efficiency and scale efficiency (0.858, 0.741) as the critical point, the comprehensive efficiency of agricultural product logistics in 31 provinces and cities in China is divided into four types. The first category is the "high high" type, including 14 provinces and cities such as Beijing, Tianjin, Hebei, Shanghai, Jiangsu, Fujian, Shandong, Guangdong, Shanxi, Jiangxi, Henan, Inner Mongolia, Guizhou and Liaoning. The average values of pure technical efficiency and scale efficiency of these provinces and cities are high, indicating that the development of agricultural product logistics industry in this region is good. However, in addition to Hebei, other provinces and cities still need to significantly improve pure technical efficiency and scale efficiency. The second type is "high-low" type, such as Hainan, Xizang, Qinghai and Ningxia. Its scale efficiency needs to be improved. The development scale of local agricultural product logistics industry should be adjusted in time to improve infrastructure construction. The third category is "low high" type, such as Zhejiang, Anhui, Hubei, Hunan, Sichuan and Heilongjiang. These six provinces can improve the logistics efficiency of agricultural products by improving the logistics technology level and pure technical efficiency. The fourth type is "low low" type, such as Guangxi, Chongqing, Yunnan, Shaanxi, Gansu, Xinjiang and Jilin. The pure technical efficiency and scale efficiency of this type have great room for improvement and need to be greatly improved at the same time. From the average value of comprehensive efficiency, Jiangsu, Hebei and Shanghai ranked among the top three in terms of agricultural product logistics efficiency, and Yunnan, Qinghai and Xizang ranked at the end. Xizang had the lowest value of agricultural product logistics efficiency, which was only 0.069.

According to Table 5, the spatial distribution of China's agricultural product logistics efficiency with the annual average value of 0.637 and DEA effective reference value 1 as the boundary. The adjusted logistics efficiency of China's agricultural products still maintains the distribution characteristics of low east-west and high middle, including Hainan, Anhui, Hubei, Guangxi, Chongqing, Sichuan The comprehensive efficiency of agricultural product logistics in 15 provinces and cities such as Yunnan, Xizang, Shaanxi, Gansu, Qinghai, Ningxia, Xinjiang, Jilin and Heilongjiang is lower than the national average. Compared with the total number of these provinces and cities before the adjustment, there is no change, but Hunan, which was originally lower than the national average, has become Ningxia, indicating that the comprehensive efficiency of agricultural product logistics in Hunan Province is underestimated, Ningxia is overvalued; The comprehensive efficiency of agricultural product logistics in 15 provinces and cities such as Beijing, Tianjin, Zhejiang, Fujian, Guangdong, Shanxi, Jiangxi, Henan, Hunan, Inner Mongolia, Guizhou, Shanghai, Jiangsu, Shandong and Liaoning is higher than the national average, but DEA is still not effective. Compared with before the adjustment, the total number of these provinces and cities has increased by 2. It shows that the comprehensive efficiency of agricultural product logistics in Shanghai and Tianjin is overestimated; only the comprehensive efficiency value of Hebei Province before and after the adjustment has reached 1, which realizes the effective DEA.

Table 5. Average logistics efficiency of agricultural products after adjustment.

Region	Comprehensive efficiency	Pure technical efficiency	Scale efficiency	Ranking	Region	Comprehensive efficiency	Pure technical efficiency	Scale efficiency	Ranking
Beijing	0.792	0.884	0.895	11	Ancient Inner Mongolia	0.826	0.933	0.883	10
Tianjin	0.882	1.000	0.882	6	Guangxi	0.529	0.745	0.710	20
Hebei	1.000	1.000	1.000	1	Chongqing	0.474	0.682	0.697	24
Shanghai	0.963	0.998	0.965	3	Sichuan	0.439	0.537	0.817	25
Jiangsu	0.994	1.000	0.994	2	Guizhou	0.725	0.958	0.753	14
Zhejiang	0.769	0.818	0.940	12	Yunnan	0.276	0.565	0.475	29
Fujian	0.855	0.934	0.913	8	Xizang	0.069	1.000	0.069	31
Shandong	0.917	0.974	0.942	5	Shaanxi	0.479	0.652	0.733	23
Guangdong	0.871	0.961	0.910	7	Gansu	0.385	0.784	0.485	26
Hainan	0.294	0.998	0.295	28	Qinghai	0.158	0.934	0.169	30
Shanxi	0.749	0.878	0.846	13	Ningxia	0.364	1.000	0.364	27
Anhui	0.617	0.788	0.781	17	Xinjiang	0.507	0.796	0.633	21
Jiangxi	0.710	0.918	0.773	15	Liaoning	0.927	0.950	0.974	4
Henan	0.839	0.886	0.947	9	Jilin	0.501	0.786	0.637	22
Hubei	0.567	0.655	0.866	19	Heilongjiang	0.581	0.774	0.747	18
Hunan	0.693	0.795	0.870	16	Mean value	0.637	0.858	0.741	

4.4. Dynamic Analysis on Innovation Efficiency of the Pharmaceutical Manufacturing Industry in China

Using DEAP2.1 software and Malmquist model, the original output data of agricultural product logistics industry from 2010 to 2019 and the input data of agricultural product logistics industry adjusted in the second stage are substituted to obtain Table 6.

(1) Time trend: As can be seen from Table 6, the average total factor productivity of China's agricultural product logistics industry is 1.014, with a growth rate of 1.4%. From 2010 to 2019, China's agricultural product logistics efficiency showed an overall upward trend, mainly due to the introduction of a series of policies and guidance to encourage and support agricultural development and agricultural product market construction since 2010, as well as the continuous innovation and introduction of agricultural product logistics technology. From the decomposition index of total factor productivity, the average technical efficiency is 1.005, the growth rate is 0.5%, and the average change of technological progress is 1.009, the growth rate is 0.9%, indicating that the improvement of total factor productivity of agricultural product logistics in China mainly benefits from technological progress. The reason is that in recent years, provinces and cities in China have focused on the introduction and development of new logistics technologies, this has led to the improvement of technological progress index, but the low growth rate of technical efficiency also reflects the insufficient application of new logistics technology in agricultural products logistics at the emerging stage, and there are defects in agricultural products logistics management. From 2010 to 2019, the average pure technical efficiency of agricultural

Table 6. Malmquist efficiency of agricultural products logistics in China from 2010 to 2019.

Particular year	Technical efficiency	Changes in technological progress	Pure technical efficiency	Scale efficiency	Total factor productivity
2010-2011	1.018	1.131	0.977	1.042	1.151
2011-2012	1.007	1.076	1.012	0.995	1.084
2012-2013	1.010	0.864	1.027	0.984	0.872
2013-2014	0.992	0.951	1.017	0.975	0.944
2014-2015	0.973	1.008	1.005	0.969	0.981
2015-2016	1.035	0.968	1.028	1.007	1.002
2016-2017	0.936	1.130	0.959	0.977	1.058
2017-2018	1.082	0.985	1.043	1.038	1.066
2018-2019	0.997	0.996	1.028	0.970	0.993
Mean value	1.005	1.009	1.010	0.995	1.014

product logistics was 1.01, with a growth rate of 1%, while the average scale efficiency of agricultural product logistics was 0.995, with a growth rate of −0.5%, indicating that the improvement of China's agricultural product logistics technical efficiency benefited from the promotion of pure technical efficiency. According to the relevant data in **Tables 4-7**, draw the broken line chart of total factor productivity and its decomposition index of agricultural products logistics. It can be seen from **Figure 2** that the change trend of total factor productivity of agricultural products logistics in China is similar to that of technological progress change index, indicating that there is a certain correlation between agricultural products logistics efficiency and technological progress change index. Therefore, in order to effectively improve the efficiency of agricultural products logistics in China. In the future, the logistics industry should actively develop and introduce new agricultural product logistics technologies. From 2010 to 2013, the logistics efficiency of China's agricultural products has been in a downward trend, and even reached the lowest point in 2013, only 0.872. This is because 2012 is a year when China's economy has changed from "depression" to "recovery". Agricultural development is affected by macroeconomic tightening, resulting in large fluctuations in the price of agricultural products and an impact on the agricultural product market. The original advantages of logistics technology have also been exhausted, resulting in a significant reduction in the logistics efficiency of agricultural products from 2012 to 2013. From 2013 to 2018, the logistics efficiency of agricultural products was gradually improved. This is because after the logistics of agricultural products was included in the 12th Five Year Plan, local governments increased their support for resource investment in the circulation of agricultural products, so that the construction of logistics infrastructure of agricultural products was firmly guaranteed, thus promoting the significant improvement of logistics efficiency of agricultural products.

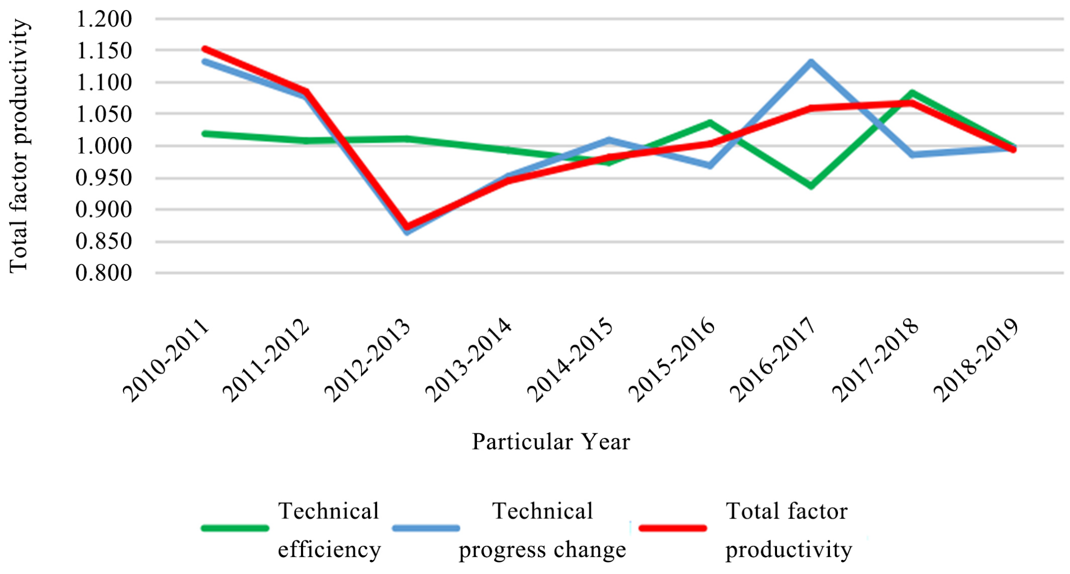

Figure 2. Changes of total factor productivity and its decomposition index of agricultural product logistics.

Table 7. Change trend of logistics efficiency of agricultural products in China from 2010 to 2019.

Region	Technical efficiency	Changes in technological progress	Pure technical efficiency	Scale efficiency	Total factor productivity
Beijing	0.958	1.031	0.985	0.973	0.988
Tianjin	1.000	0.993	1.000	1.000	0.993
Hebei	1.000	1.021	1.000	1.000	1.021
Shanghai	1.000	1.021	1.000	1.000	1.021
Jiangsu	0.987	0.994	1.000	0.987	0.981
Zhejiang	1.010	0.995	1.014	0.996	1.005
Fujian	0.995	1.010	0.995	1.000	1.005
Shandong	0.980	0.992	1.000	0.980	0.972
Guangdong	0.994	1.003	1.011	0.984	0.997
Hainan	1.038	0.993	0.977	1.062	1.031
Eastern Region	0.996	1.005	0.998	0.998	1.001
Shanxi	1.060	1.010	1.060	1.001	1.070
Anhui	1.021	0.995	1.016	1.005	1.015
Jiangxi	1.039	1.008	1.036	1.003	1.048
Henan	1.007	1.003	1.012	0.995	1.010
Hubei	1.026	0.996	1.026	1.000	1.021
Hunan	1.000	1.007	1.002	0.998	1.007
Central region	1.026	1.003	1.025	1.000	1.029
Inner Mongolia	1.018	1.017	1.019	0.999	1.035
Guangxi	1.004	1.003	1.021	0.984	1.007
Chongqing	0.996	0.997	1.005	0.991	0.993
Sichuan	1.018	1.037	1.022	0.996	1.056
Guizhou	0.959	1.039	0.977	0.981	0.996
Yunnan	1.135	1.022	1.126	1.008	1.160
Xizang	0.918	1.042	1.000	0.918	0.957
Shaanxi	1.000	0.992	1.000	1.000	0.992
Gansu	0.932	0.998	0.937	0.995	0.930
Qinghai	0.988	1.017	0.983	1.005	1.006
Ningxia	0.982	0.991	1.000	0.982	0.973
Xinjiang	1.074	1.002	1.065	1.009	1.076
Western Region	1.002	1.013	1.013	0.989	1.015
Liaoning	1.052	1.054	1.051	1.001	1.108
Jilin	0.999	0.988	1.004	0.995	0.988
Heilongjiang	0.983	1.010	0.988	0.995	0.993
Northeast China	1.011	1.017	1.014	0.997	1.030
Mean value	1.005	1.009	1.010	0.995	1.014

(2) Regional differences: The changes of agricultural product logistics efficiency and its decomposition index in various regions of China are sorted out in Table 7 to compare the spatial differences of agricultural product logistics efficiency in the east, middle, west and northeast regions. It can be seen from Table 7 that the total factor productivity of agricultural product logistics in the four regions of east, middle, west and northeast is greater than 1, indicating that China's overall agricultural product logistics efficiency is improving, but in contrast, the east < west < central < northeast. Specifically, the technical efficiency of Beijing, Jiangsu, Shandong, Fujian, Guangdong and other regions is less than 1, indicating that the logistics management level of agricultural products has decreased, resulting in the overall technical efficiency value of the eastern region is only 0.996. Although the application of advanced logistics technology makes its technical progress change index reach 1.005, which barely makes up for the deficiency of the former, however, the total factor productivity is only 1.001, approximately 1, indicating that the logistics efficiency in the eastern region is in a stable state. One belt, one road, is the main reason for the development of logistics industry in the western region. Because of its special geographical location, the logistics infrastructure construction is relatively weak, and the logistics efficiency of agricultural products is relatively low. With the introduction of advanced logistics technology and the improvement of management level, the change index of technical efficiency and technological progress in the western region has exceeded 1, resulting in the total factor productivity of agricultural product logistics reaching 1.015, which makes the efficiency of agricultural product logistics in the western region show an increasing trend. The central region has a vast territory, rich natural resources, obvious location advantages, convenient transportation and certain basic logistics facilities. Its logistics management level has been steadily improved, and its technical efficiency has reached 1.026, which is the highest among the four regions. However, there is a large room for improvement in the application of advanced logistics technology. The three northeastern provinces have a good climate and agricultural product planting environment, rich output of agricultural products, and convenient land and water transportation, which is conducive to the development of agricultural product logistics industry. With the application of advanced logistics technology and the improvement of management level, the technical efficiency and technology change index exceed 1, and finally, the total factor productivity reaches 1.03, the logistics efficiency of agricultural products in Northeast China shows an increasing trend.

5. Research Conclusions and Policy Recommendations

Based on the empirical results of the analysis of China's agricultural product logistics efficiency and influencing factors, this paper draws the following conclusions:

(1) The existence of environmental variables and random factors leads to the

underestimation of the pure technical efficiency of China's agricultural product logistics and the overestimation of scale efficiency. At this stage, China's agricultural product logistics efficiency is mainly subject to scale efficiency.

(2) Environmental variables play different roles in promoting the efficiency of agricultural product logistics. Although the improvement of scientific and technological development level reduces the investment redundancy of infrastructure construction, it plays a promoting role in attracting capital investment and increasing infrastructure construction; the improvement of government support can reduce factor redundancy, help enterprises reduce operating costs and standardize market order, to improve logistics efficiency; on the whole, the level of regional economic development helps to reduce input redundancy and improve the comprehensive efficiency of logistics.

(3) From a static point of view, the logistics efficiency of agricultural products in 31 provinces and cities in China is generally low, and there are obvious regional differences. After excluding the influence of external environmental factors and random errors, only Hebei Province has reached the efficiency frontier for 10 consecutive years, and other provinces and cities are weak DEA effective or DEA ineffective, and the efficiency value is uneven. From the perspective of spatial distribution, the logistics efficiency of agricultural products in China generally presents the distribution characteristics of low east-west and high middle. The logistics efficiency of agricultural products in the eastern region is the highest, followed by the central region, the northeast region is the third, and the logistics efficiency of agricultural products in the western region is the lowest.

(4) From a dynamic point of view, the overall efficiency of agricultural product logistics in China shows an upward trend, and technological progress drives the development of total factor productivity of agricultural product logistics. Although the low growth rate of technical efficiency reflects the current deficiencies in the application and management of new logistics technologies in China, at this stage, China still has the problems of weak logistics infrastructure and lack of professional logistics talents, with the continuous promotion of agricultural supply-side reform, the agricultural product logistics industry relies on the continuous and strong support of national policies. In recent years, China's provinces and cities have focused on the introduction and development of new logistics technologies to promote the development of agricultural products logistics, which has driven the improvement of technological progress index. Therefore, Chin's overall agricultural products logistics efficiency is improving, but in contrast, the east < west < central < northeast.

Based on the above research conclusions and the actual situation of China's agricultural product logistics development, this paper puts forward the following suggestions:

(1) Strengthen the construction of transportation infrastructure. From the empirical analysis results, the low scale efficiency is the main reason for the low efficiency of China's agricultural products logistics, which shows that China's rural logistics infrastructure is not perfect at this stage, and there are still prob-

lems such as low utilization rate of agricultural products transportation equipment, high transportation cost and large loss. Therefore, strengthening the construction of agricultural product logistics infrastructure is an urgent task to improve the efficiency of agricultural product logistics. Road transportation is the most important mode of logistics transportation of agricultural products. At present, many rural areas in China do not have developed logistics and transportation networks, and some remote mountainous areas do not even have roads that can be accessed by cars, resulting in a large number of agricultural products that cannot be transported out in time, resulting in great waste. Therefore, the government should increase investment in rural road construction. At the same time, gradually improve the logistics and transportation network system of urban roads and railways, and improve the utilization rate of existing agricultural product logistics infrastructure resources; secondly, because of the characteristics that agricultural products are easy to break and corrode, we must increase the investment in agricultural products storage and speed up the development of cold chain logistics, to reduce the losses of agricultural products in packaging, transportation and storage; In addition, provinces and cities should reasonably plan the distribution centers and distribution points of agricultural products logistics, especially in areas where the logistics efficiency of agricultural products needs to be improved, such as Yunnan, Xizang and Qinghai, we need to actively promote the construction of agricultural products logistics parks and agricultural products wholesale markets.

(2) Promote the innovation and application of logistics technology. According to Malmquist's dynamic analysis results, the change in total factor productivity of agricultural product logistics is mainly affected by technological changes, which shows that logistics technology plays an important role in the development of agricultural products. Therefore, we need to pay attention to improving the scientific and technological innovation and application ability of agricultural product logistics technology. The government should fully mobilize the enthusiasm of logistics enterprises for technological innovation, set up special support funds to reward agricultural product logistics technological innovation units and individuals, provide logistics enterprises with a good technological innovation environment, improve the technological innovation competitiveness of logistics enterprises, and encourage logistics enterprises to learn foreign advanced logistics technology, promote the construction of Agricultural Product Logistics Enterprise Incubation Park, to improve the independent R & D ability of agricultural product logistics enterprises. In terms of logistics enterprises, they should set up a separate technology R & D department to cultivate middle and senior logistics professionals and shorten the cycle of studying new logistics technologies. At the same time, they should pay attention to the exchange and project cooperation among enterprises, universities and scientific research institutes, and jointly explore and study the technical problems faced by agricultural product logistics in practical life, and how to apply the relevant theories of logistics

management to the process of agricultural product logistics management. In addition, logistics enterprises should enhance contact and cooperation to avoid the repeated waste of new technology R & D resources.

(3) Promote the informatization of agricultural products logistics. In today's era, the development of all walks of life is inseparable from the support of information technology. Information, as an important link in the agricultural product supply chain, is closely related to the logistics efficiency of agricultural products. A high level of information construction can actively promote the logistics efficiency of agricultural products. In the future, the development of agricultural product logistics should pay more attention to improving the information level. First of all, the government should increase investment in internet construction and gradually improve internet penetration, especially in rural areas and the western region limited by geographical and spatial location. Secondly, we should establish a positive and effective overall planning and coordination system, accelerate the construction of agricultural product logistics information platform, and ensure the timeliness of agricultural product transportation status and agricultural product market supply and demand information feedback. Finally, to ensure the effective management and control of agricultural products during production, circulation and storage, we should vigorously develop and promote logistics information technologies such as RFID, EDI and POS, track and supervise agricultural products in the supply chain in real-time, and ensure that the information of agricultural products in all links of the supply chain is fully shared.

(4) Improve the logistics guarantee system of agricultural products. According to the Malmquist dynamic analysis of China's agricultural product logistics efficiency, the development of China's agricultural product logistics is not yet stable. Therefore, it is necessary to improve the guarantee system of agricultural product logistics, and establish and improve relevant laws, regulations and rules. At the same time, it is necessary to establish a special agricultural product logistics management department to continuously promote the long-term and stable development of the logistics industry; secondly, we should strengthen the punishment of vicious competitive strength and advocate creating a fair, open and Fair logistics competition atmosphere; finally, strengthen legislative protection measures, strengthen supervision, ensure the legitimacy of transaction behavior, and accelerate the pace of promoting the standardization of agricultural product logistics market, to realize the sustainable development of agricultural product logistics.

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Conflicts of Interest

The authors declare no conflicts of interest.

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