Evaluation of Logistics Efficiency of Paper Skin Walnuts in Northwest China Based on DEA-Malmquist

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In recent years, with the rapid development of the Internet industry, the publicity effect of paperbark walnuts has been substantially increased, and the consumption and demand of paperbark walnuts have been rising, and the output of paperbark walnuts in China has also increased year by year. This paper takes the panel data of the top three prefecture-level cities in each GDP ranking of five provinces in northwest China from 2012 to 2021 as the sample and combines the DEA model with Malmquist to evaluate and analyze the logistics efficiency of paper walnuts in northwest China. It is found that the overall logistics efficiency of paperbark walnuts in Northwest China has been improved in recent years, but there are still areas that need to be improved, such as the factor distribution is not reasonable enough; the logistics efficiency of paperbark walnuts in Northwest China from 2012 to 2021 is in a fluctuating state; the logistics efficiency of paperbark walnuts in Shaanxi Province is better than the other provinces and is in the leading position; the improvement of technological progress has a key role in the total factor productivity improvement. As a result, this paper puts forward five specific suggestions based on the research results to help accelerate the improvement of paper walnut logistics efficiency in Northwest China.

1. Introduction

Paper-skinned walnuts are famous for their paper-thin shells, and the process of removing walnut kernels is much easier than that of ordinary walnuts, which are rich in protein, phosphorus, calcium, and other elements. Northwest China, as a place where paper walnuts are produced in abundance, has seen the development of the paper walnut logistics and transportation industry in recent years, while also facing the serious challenge of modernization and transformation. Therefore, it is necessary to accelerate scientific and technological innovation in the logistics industry, accelerate the efficiency of paperbark walnut logistics, and then improve the revenue of paperbark walnut industry and national economic development. Although the current circulation number of paper walnuts is large, the overall logistics industry has a poor foundation, resulting in high product loss costs and low logistics efficiency in the logistics process. The direct result of low logistics efficiency is serious waste of resources, which not only reduces the market competitiveness of paper skin walnuts, but also hinders the development of national economy and industrial structure upgrading to a certain extent. Therefore, accurately evaluating the logistics efficiency of paper skin walnuts in northwest China and finding its influencing factors will greatly promote the upgrading and development of paper skin walnut industry in northwest China. The global economic development pattern is changing, international economic and trade rules are being questioned, the global economy is not optimistic in the post-epidemic era, and the growth points are harder to find. How to achieve economic growth has become a more complex global issue. China, as the world’s second largest economy and the world’s second largest consumer market, is also a key issue to be addressed: how to promote a strong economic recovery and maintain a high level of public confidence in the state of our economy. The logistics chain plays a relatively good role in achieving supply stability as well as industry chain stability, and has a strong positive effect on the dual domestic and foreign cycle strategy. As a producer of paper walnuts in China,
Northwest China needs to grasp the current opportunities and challenges in order to achieve better development. The production, packaging, storage, transportation, circulation, and handling of agricultural product information is the recycling process of agricultural products, which supports and enhances the value of agricultural products. China is a large agricultural country, the current stage of agricultural products logistics infrastructure is not perfect, and the logistics is unique. According to statistics, China’s agricultural logistics has been hit hard throughout the cycle; therefore, it is urgent to improve the efficiency of China’s agricultural logistics. The “Thirteenth Five-Year Plan” clearly states, “Develop rural e-commerce, actively explore new modes of agricultural logistics, vigorously develop cold chain logistics for agricultural products, build a data sharing platform, and comprehensively promote agricultural modernization.” In addition, the Ministry of Commerce issued in 2015, “stressed the need to establish a comprehensive information platform based on information technology, accelerate the development of rural e-commerce, improve the efficiency of agricultural transport, and should pay more attention to the efficiency of the cycle of agricultural products. Logistics is a key element in the flow of paper walnuts, and studying the efficiency of logistics can make an effective contribution to the sales and transportation of paper walnuts in the region. China’s paperbark walnut light agricultural products flow industry is still in a sustainable development stage, and there are many problems in management and technology that need to be improved. In order to evaluate the logistics performance more comprehensively and accurately, this paper comprehensively discusses the concept and content of logistics efficiency evaluation. The current logistics performance evaluation method is relatively simple, and there is less research on paperbark walnuts in Northwest China. This paper uses DEA model to evaluate the logistics efficiency evaluation of paper skinned walnuts in Northwest China, and presents new ideas for further research on the logistics performance of agricultural products.

2. Research Background

Logistics is the “third source of profit” today. At present, a large number of scholars and experts in the academic field still focus on the analysis of logistics efficiency of traditional products, but there is little research on the evaluation of logistics efficiency of paper skin walnuts. When scholars study logistics efficiency, they mainly focus on the qualitative analysis of the current situation of logistics development and optimization measures and the quantitative analysis of logistics efficiency evaluation and influencing factors.

Regarding the current situation of logistics development and its optimization measures, some scholars have analyzed and compared five types of distribution modes for many types of agricultural products, such as fruits and vegetables, and finally concluded that the product logistics efficiency can be most effectively improved in China’s road freight industry [1]. Some scholars have experimented with various logistics solutions and come up with the best solution for coordinating logistics objectives and circulation processes along the Belt and Road in order to improve logistics efficiency under existing circumstances. They also summarized the problems that China’s logistics industry is facing or will face in the development process after the urbanization phenomenon, and tried to give specific measures to solve them [2]. Some scholars researched and established a gray correlation model of Shandong province region to explore the factors affecting logistics efficiency, and created a relatively effective logistics operation model based on the conclusions [3].

In terms of logistics efficiency evaluation and influencing factors, some scholars used the DEA method to analyze the production areas along the new western land and sea corridor in China, and concluded that the China’s logistics industry should move forward in the direction of intensification and technology development [4]. Some scholars also made a comprehensive evaluation of the logistics efficiency of the pilot cities of the supply chain in the Yangtze River Delta region based on the DEA-PC method [5]. Using the super efficiency model, a complete empirical analysis of logistics efficiency and related influencing factors was made based on the data of agricultural products in China and Mongolia road ports [6]. Some scholars conducted a multi-factor regression analysis on the influencing factors of logistics efficiency in the food industry, followed by relevant comments and suggestions [7]. Some experts and scholars used DEA models in the context of the Yangtze River Delta integration strategy to analyze the differences in logistics efficiency levels between different provinces based on panel data of agricultural products from multiple provinces [8]. Some scholars also used SFA analysis to evaluate logistics efficiency and found that the overall logistics efficiency level in Henan Province was low [9]. Malmquist model was used to analyze and calculate total factor productivity, and through further exploration it was concluded that the technological innovation has an important role in low carbon logistics efficiency [10]. Some scholars also used DEA-Malmquist method to study the changes in logistics efficiency and the reasons for its changes based on China’s logistics panel data, and explored the changes in logistics efficiency after industrial structure upgrading [11].

Based on the existing research results, it can be seen that most of them are mostly logistics efficiency evaluations in agricultural products and foodstuffs, etc., while few logistics efficiency evaluations for paper walnuts in Northwest China have appeared. At present, in many research methods on logistics efficiency, scholars tend to use stochastic frontier method (SFA), gray correlation method, or data envelopment method (DEA), etc., but few experts and scholars consider the process and law of how logistics efficiency changes over time from a dynamic perspective, and do not touch on the deeper reasons of logistics efficiency changes. Based on the above multiple factors, this paper combines DEA model and Malmquist index to analyze the logistics efficiency of paper walnuts in Northwest China from static and dynamic multiple perspectives, respectively, and explore the influencing factors and put forward reasonable suggestions.
3. Research Methods and Materials

3.1. Model Construction and Index Selection

3.1.1. Model Description. (1) DEA Model. The data envelopment analysis method (DEA) uses the principle of optimality to evaluate each decision making unit (DMU) with multiple indicators of input and output, and has been widely used in the research of logistics efficiency measurement. However, the traditional DEA model can only provide a static analysis of logistics efficiency [12].

In 1978, Charles et al. proposed a method to evaluate the effectiveness of similar operations management modules with a large amount of input data, such as data package analysis (DEA). After Charles introduced the first DEA model, DEA models were divided into BC2, FG, and ST models, which describe DEA models with different metrics. Through the unremitting efforts of scholars at home and abroad, DEA methodology has been improved and become a more mature and important method. DEA model is an objective decision model based on relative efficiency, which is one of the most common methods to assess the relative effectiveness of policy modules. It is usually used to assess the relative efficiency of multiple input–output modules and multiple effective decision modules. Using the collected data, a linear method is used to calculate the effective production limit for each decision participant, which is then used as the raw material for analyzing the relative cost-effectiveness of the study population. The relative efficiency of each decision-making body is then reached. Based on the data of the evaluated object, it is evaluated by comparing the difference between the evaluated object and the previous one [13]. The classification of DEA models is shown in Figure 1.

(2) DEA-Malmquist Index Model. Malmquist index was originally proposed by Malmquist as a consumption index classification. The Malmquist index was designed based on a distance function and was first used to measure the performance changes, so the method was not widely used. With the introduction of the DEA model, which describes the relative validity of dynamic simulations, it has attracted the attention of scientists. The DEA-Malmquist index method was designed based on the DEA model and Malmquist index, and the Malmquist index was divided into process efficiency and process variation [14]. Since then, the DEA-Malmquist index method has been increasingly used. The Malmquist index was introduced in 1953, but few empirical studies on this index were conducted in the following years. It took more than four full decades before the Malmquist index was incorporated into the DEA model, bringing the application of the index back into the limelight [15]. The Malmquist index model can measure multiple inputs and outputs in multiple periods at the same time, evaluate the dynamic changes in each decision unit, and also decompose the Malmquist index to precisely determine the main factors causing the changes. In this paper, to study the logistics efficiency of paper walnut in Northwest China, each prefecture-level city selected in the five Northwest provinces is taken as a DMU, and it is assumed that there are n decision units and T units of time, with t and t+1 denoting the current period and the next period, respectively, and \( X_t \) the inputs and outputs of decision unit \( r \) at time \( t \), respectively, denoting the DEA \( D_r^t(X_t^{r,1},Y_t^{r,1}) \) efficiency of the production of decision unit \( r \) in period \( t+1 \) measured by \( t \) as the base period, from which the DEA efficiency is obtained in \( t \) period.

The value of efficiency change from period \( t \) to period \( t+1 \) under the condition of period \( t+1 \) is

\[
M^{t+1} = \frac{D_r^{t+1}(X_r^{t+1},Y_r^{t+1})}{D_r^{t}(X_r^{t},Y_r^{t})} \tag{1}
\]

The Malmquist index, which represents the dynamic change in logistics efficiency from moment \( t \) to \( t+1 \) for each decision unit, i.e., total factor productivity (tfpch), is obtained by calculating the geometric mean of \( \text{tfpch} = M(X',Y',X^{t+1},Y^{t+1}) \)

\[
= \left( M^t \times M^{t+1} \right)^{1/2} = \left[ \frac{D_r^{t}(X_r^{t},Y_r^{t})}{D_r^{t+1}(X_r^{t+1},Y_r^{t+1})} \times \frac{D_r^{t+1}(X_r^{t+1},Y_r^{t+1})}{D_r^{t}(X_r^{t},Y_r^{t})} \right]^{1/2} \tag{2}
\]

It can be seen that total factor productivity (tfpch) can be decomposed into the integrated technical efficiency change index (effch) and the technical progress index (techch). And when the payoff of scale is variable, the effch index can be decomposed into the pure technical efficiency change index (pech) and the scale efficiency change index (sech), i.e.,

\[
\text{effch} = \text{pech} \times \text{sech} \tag{3}
\]

In summary, it is obtained that

\[
\text{tfpch} = \text{effch} \times \text{techch} = \text{pech} \times \text{sech} \times \text{techch} \tag{4}
\]

In this paper, the DEA software is used to calculate the relevant index data, \( \text{tfpch} > 1 \) if, then the logistics efficiency of paper walnut in Northwest China \( \text{tfpch} = 1 \) increases; the efficiency remains \( \text{tfpch} < 1 \) unchanged , the efficiency decreases. And for the four indices obtained, and, effch if pech greater sech than techch 1, it means that the productivity of the decision unit has been improved in the time period, which has a facilitating effect on the efficiency improvement; if the index obtained is less than 1, it means that the
productivity of the decision unit is declining in the time period, which hinders the efficiency improvement.

(3) DEA-Malmquist Stage. DEA methods have obvious advantages when considering the performance evaluation of multi-indicator systems, and they are optimized considering the validity of the evaluation and the lack of evaluation results, and taking into account the differences in the external decision-making environment. The random error in the regression equation is evaluated on the basis of the DEA model and decomposed into statistical error and control efficiency, which achieves the purpose of integrating environmental factors, random error, and control efficiency into the performance analysis framework, and the evaluation results become more weighted [16]. The three stages of the DEA-Malmquist process are shown in Figure 2.

Stage 1. Traditional DEA model: The validity of the decision term is calculated using input and output indicator data. Given that input relaxation cannot be used for efficiency evaluation, the inactive and unconstrained limit method is used to calculate the efficiency in this paper [17].

Phase 2. Establishing the management model: The main purpose of this phase is to adjust the initial input variables so that different decision modules can reflect the actual efficiency gap in a relatively coordinated external environment [18]. First, slack is entered as a variable and environmental elements are selected as independent variables to create the model.

Step 3. Adaptation of the DEA model: Using its own input data instead of the original input data and reassessing it using a non-radiometric, angular approach, the technical efficiency of the rated objects can be reflected more accurately [19].

3.1.2. Index Selection. The selection of the evaluation index system directly determines the later evaluation effect, and in the DEA analysis method, two kinds of data, input and output, are needed. Referring to the selection of indicators in many scholars’ studies on logistics efficiency evaluation, and combining with the research perspective of this paper, the selected indicators and their descriptions are as follows.

(1) Input Indicators. According to the Cobb–Douglas production function, the input factors mainly include technology, labor and capital, etc. However, in the process of logistics performance evaluation and research, the technology factor is often not effectively measured, so only the labor and capital factors are considered. Combined with the availability of data as well as operability, since the data related to the logistics industry cannot be subdivided into paper walnut related, and since transportation, warehousing, and postal industries account for about 85% of the total logistics industry, the data of transportation, warehousing, and postal industries are processed to represent the input–output situation of paper walnut logistics. The input indicators selected in this paper are as follows: one is the number of employees in the paper walnut logistics. The labor input is expressed by multiplying the total number of employees in transportation, storage, and postal industry by a factor $k$, where $k$ is obtained from the product of national consumption ratio, citizen consumption ratio, and Engel’s coefficient to reflect the proportion of the number of employees in paper walnut logistics. Similarly, the capital input is expressed by the amount of investment in fixed assets in paperback walnut logistics. Similarly, the capital input is expressed by the amount of investment in fixed assets in transportation, storage, and postal industry multiplied by the coefficient $k$ to obtain the amount of investment in fixed assets in paperback walnut logistics.

(2) Output Indicators. The output level is mainly considered in terms of social and economic benefits, so two indicators were selected to measure the output in terms of quality and quantity, respectively. One is the value added of paper walnut logistics. The quality of the output is expressed by the value added of the output value of transportation, storage, and postal industry multiplied by the coefficient $k$ to obtain the value added of paper walnut logistics. The reason for choosing the value added is that the value added can eliminate the influence of the total value of the previous period and put the focus on the value-added process. The other is the freight turnover of paperback walnuts. Freight turnover = transport weight × average transport distance, which reflects both the quantity of output and the distance of transport, and better reflects the efficiency of logistics. The indicator data of paperback pecan freight turnover is also obtained according to the treatment of the indicator of the number of employees in paperback pecan logistics.

3.1.3. Data Sources. In order to facilitate the dynamic analysis and research of the real-time changes and conditions of the paper pecan logistics efficiency index in Northwest China, and also considering the difficulty of collecting relevant data accurately, this paper takes the top three prefecture-level cities in Northwest China in terms of GDP ranking in 2019 as the main decision-making units in each of the five provinces and municipalities directly under the central government in Northwest China, and analyzes and compares them in a comprehensive manner. The time period selected is from 2012 to 2021. The data in this paper are obtained from the statistical yearbook of each city in each province from 2013–2022, China Paperback Walnut Market Survey Research and Development Prospect Analysis Report, China Statistical Yearbook and China Logistics Statistical Yearbook.

3.2. Evaluation of Logistics Efficiency

3.2.1. Concept. Logistics efficiency evaluation is defined as the use of relevant performance indicators, standards, and methods, as well as the evaluation system established by relevant institutions, and the acquisition of evaluation results. Logistics efficiency evaluation is defined as "quantifying the efficiency and impact of past actions by collecting, processing, classifying, analyzing, interpreting, and disseminating relevant data, making appropriate decisions and taking appropriate actions" [20]. The logistics efficiency evaluation process is shown in Figure 3.
3.2.2. Content. Logistics efficiency evaluation includes not only pre-monitoring mechanisms, operational activities, and post-evaluation, but also evaluation contents, which must be comprehensive and specific. The performance evaluation varies from discipline to discipline: according to the characteristics of individual disciplines, it can be divided into different aspects of logistics evaluation, including logistics, equipment, and financial evaluation. The evaluation content is also widely used according to the characteristics of the evaluation object, the workflow of the relevant subjects, and the internal and external environment. The contents of logistics efficiency evaluation are shown in Figure 4.

4. Results and Discussion

Based on DEA-Malmquist index model, this paper uses software DEA to measure the change value of logistics efficiency of paper walnuts in northwest China, and the Malmquist index and its decomposition of paper walnut logistics in the five provinces of northwest China from 2012 to 2021 are shown in Tables 1 and 2, respectively.

4.1. Holistic Analysis. From the spatial perspective, except for Shaanxi Province, the decomposition of Malmquist index of logistics efficiency in the other four provinces is similar, and the mean value of total factor productivity in Shaanxi Province and Qinghai Province is higher than the mean value in Northwest China, while the total factor productivity of all five provinces is greater than 1. This indicates that the overall efficiency of paper walnut logistics in the five Northwest provinces has improved between 2012 and 2021, among which Shaanxi and Qinghai province have the most significant improvement.

For the composite technical efficiency change index and scale efficiency change index, only Shaanxi Province is DEA effective, indicating that the logistics organization and management and industrial structure of the other four provinces and the Northwest region as a whole have not been optimized under the existing technical conditions. For the pure technical efficiency change index, all five provinces are DEA invalid, but the total factor productivity of the five northwestern provinces as well as the whole northwestern region is improved, indicating that the regression of integrated technical efficiency, pure technical efficiency, and scale efficiency will have some effect on the total factor productivity but not too significant. The results are shown in Table 1.
For the technological progress index, the average value of the five provinces and the overall average value of the northwest region are greater than 1. The average values of Shaanxi and Qinghai provinces are also greater than the overall average value of the northwest region, indicating that the introduction of new logistics technologies has a catalytic effect on the improvement of overall efficiency, with Shaanxi and Qinghai provinces having the most obvious promotion effect.

From a temporal perspective, the data for each index are shown in Table 2, and the trend of change is shown in Figure 1. It can be seen that the overall changes of each index are more volatile from 2013 to 2015 and 2019 to 2021, while the changes of each index are more stable from 2015 to 2019. The changes of the technological progress index are almost the same as the changes of total factor productivity, which indicates that the Malmquist index is mainly influenced by the technological progress index, and the technological progress has a great role in the improvement of the logistics efficiency of paper-skinned walnuts in Northwest China. Among them, the decline of total factor productivity from 2013 to 2015 is mainly influenced by the negative pull of technology, while the total factor productivity has been improved since 2019 because the five northwestern provinces have promulgated a number of policies to promote the technological development of logistics industry since 2017, as shown in Figure 5.

### Table 2: 2012–2021 indices.

<table>
<thead>
<tr>
<th>Year</th>
<th>Effch</th>
<th>Techch</th>
<th>Pech</th>
<th>Sech</th>
<th>Tfpch</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012–2013</td>
<td>0.920</td>
<td>1.531</td>
<td>0.983</td>
<td>0.936</td>
<td>1.409</td>
</tr>
<tr>
<td>2013–2014</td>
<td>0.928</td>
<td>1.145</td>
<td>0.955</td>
<td>0.972</td>
<td>1.063</td>
</tr>
<tr>
<td>2014–2015</td>
<td>1.029</td>
<td>0.842</td>
<td>1.001</td>
<td>1.028</td>
<td>0.866</td>
</tr>
<tr>
<td>2015–2016</td>
<td>1.056</td>
<td>0.932</td>
<td>0.966</td>
<td>1.093</td>
<td>0.984</td>
</tr>
<tr>
<td>2016–2017</td>
<td>0.944</td>
<td>0.817</td>
<td>0.907</td>
<td>1.041</td>
<td>0.771</td>
</tr>
<tr>
<td>2017–2018</td>
<td>0.941</td>
<td>1.109</td>
<td>1.014</td>
<td>0.928</td>
<td>1.044</td>
</tr>
<tr>
<td>2018–2019</td>
<td>0.795</td>
<td>0.997</td>
<td>0.873</td>
<td>0.911</td>
<td>0.793</td>
</tr>
<tr>
<td>2019–2020</td>
<td>0.883</td>
<td>1.527</td>
<td>0.908</td>
<td>0.972</td>
<td>1.348</td>
</tr>
<tr>
<td>2020–2021</td>
<td>0.993</td>
<td>1.419</td>
<td>1.167</td>
<td>0.851</td>
<td>1.409</td>
</tr>
<tr>
<td>Mean value</td>
<td>0.945</td>
<td>1.146</td>
<td>0.975</td>
<td>0.970</td>
<td>1.078</td>
</tr>
</tbody>
</table>

**Figures:**

- **Figure 5:** Change of each index from 2013 to 2021.

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4.2. Analysis of Variability. In terms of the change of total factor productivity, all three cities in Shaanxi Province are in a state of growth, among which Xi’an has the largest growth rate of about 37.1%, and this rate exceeds the remaining 14 prefecture-level cities including other provinces, making it the fastest growing city in terms of total factor productivity change; Shaanxi Province also has the highest growth rate of total factor productivity among the five northwestern provinces, which is about 18.2%. The total factor productivity of three cities in Gansu Province showed an overall growth trend, but the growth level was not high, about 4.0%, among which the total factor productivity of Lanzhou City increased more, about 15.2%, while the total factor productivity of Tianshui City showed a slight upward trend and the total factor productivity of Qingyang City decreased about 5.3%; the total factor productivity of three cities in Qinghai Province all had more or less growth, among which the total factor productivity of Xining City had the fastest growth of about 9.3%. The average increase of total factor productivity in the three cities of Ningxia Hui Autonomous Region is the smallest among the five provinces, only 2.5%. Except for the change of total factor productivity in Yinchuan City, which increased by 21.9%, the total factor productivity in Shizuishan and Wuzhong City both showed a decreasing trend. The total factor productivity of all three cities in Xinjiang Uygur Autonomous Region increased, with the largest increase of about 10.7% in Aksu and only 0.3% in Changji, basically the same as before. As far as the five provinces in the Northwest region are concerned, Shaanxi Province has the most logistics development potential and advantages, while Ningxia Hui Autonomous Region is the shortcoming of the Northwest region. Shaanxi Province, Gansu Province, Qinghai Province, Ningxia Hui Autonomous Region, and Xinjiang Uygur Autonomous Region total factor productivity growth rate, are shown in Figure 6.

In terms of the change of technological progress rate, among the 15 cities in Northwest China, only four cities, namely, Yulin, Qingyang, Wuzhong, and Changji, have experienced a decline in the rate of technological progress, while the rate of technological progress in the remaining 11 cities has steadily increased, among which Yinchuan has the largest increase of 35.7% and Qingyang has the largest decrease of about 5.7%. It is worth noting that the rate of technological progress and the level of change of total factor productivity are basically the same, which indicates that the development of scientific and technological innovation is the key to the progress of logistics industry as shown in Figure 7.

In terms of the change of comprehensive technical efficiency, Shaanxi Province’s comprehensive technical efficiency is the only province whose average value is on an increasing trend. The average comprehensive technical efficiency index of the remaining four provinces in Northwest China is below 1, and the degree of decline is obvious, among which the average comprehensive technical efficiency of Qinghai Province has dropped the most, by about 9.5%. Broken down into cities, except for Xi’an, Yulin, and Changji...
In this paper, the total factor productivity of 15 cities in five provinces in the Northwest region Figure 9 is decomposed as shown, producing four major categories of cities.

The first category, i.e., cities where both the rate of technological progress and comprehensive technical efficiency have increased, such as Xi'an; this indicates that the input of each factor in the paper pecan logistics industry in Xi'an is more reasonable, and the overall industry has high logistics technology and leading management level. In recent years, Xi'an has focused on developing the economic market, responded to the national policy, and actively encouraged the logistics development of the production and planting industry, which has led to a leap forward in the level of paperbark pecan logistics in the city. The second category, namely, cities with rising comprehensive technical efficiency but declining technological progress rate, such as Yulin and Changji City; this category of cities at present, the most important need is to maintain their great advantage of effective resource utilization and pay attention to the leading role of technological innovation. The third category, i.e., cities with rising rate of technological progress but declining comprehensive technical efficiency, such as Xining, Yinchuan, and many other cities, indicates that these cities need to maintain the introduction of advanced technology based on efforts to promote the improvement of the management level and the efficiency of the distribution of production factors, and to promote the optimal allocation of paper skin walnut logistics resources. The fourth category, i.e., cities with declining overall technical efficiency and technological progress rate, such as Wuzhong; these cities lack the development and research of paperbark pecan logistics technology, and also have low technological innovation capability, and are cities with low overall logistics efficiency and in urgent need of improvement and development.

4.3. Research Conclusions and Policy Recommendations

4.3.1. Research Conclusions. Based on the DEA-Malmquist index model, this paper measured the logistics efficiency of paper walnut in Northwest China from 2012 to –2021, and analyzed the reasons for the changes through index decomposition, and obtained the following main conclusions. The logistics efficiency of paperbark walnuts in Northwest China from 2012 to 2021 is improved in fluctuation, and the main driving force of which is the progress of technology, while the low level of scale efficiency and logistics industry management hinders the improvement of logistics efficiency to some extent. From the perspective of time, the government’s support and the correct guidance of policies have obvious effects on the progress of logistics efficiency. From the spatial perspective, the logistics efficiency of the five northwestern provinces has been improved, among which the effect of Shaanxi Province is the most significant.

4.3.2. Policy Suggestions. (1) Enhance Technological Innovation Capability to Improve Total Factor Productivity. With the rapid development of modern science and technology, innovation capability has gradually become a key driving
force for the development of various industries in China. The improvement of logistics efficiency of paper walnut in Northwest China cannot be separated from the continuous innovation and development of logistics industry technology. Innovation alliances, as emerging science and technology innovation platforms, are able to integrate technological innovation and results transformation. By creating a logistics innovation alliance for paperbark walnut products, Northwest China can apply scientific research results to logistics technology, accelerate the practice of innovation results, and achieve the ultimate goal of enhancing technological innovation in paperbark walnut logistics. While building an innovation alliance for walnut industry, give full play to the function of market regulation to improve the efficiency of resource allocation. The government should cooperate to do a good job of function transformation, introduce relevant protection policies, and strengthen the supervisory role of the market, so as to

![Figure 8: Average comprehensive technical efficiency index of five provinces.](image1)

![Figure 9: Decomposition of total factor productivity indices of prefecture-level cities in northwest China.](image2)
provide a stable and good objective environment for the logistics efficiency improvement of the walnut industry in Northwest China. Secondly, the emergence of new technologies such as 5G technology can also be used to help optimize the logistics technology of paper-skinned walnuts. Combining the two advantages of ultra-low energy consumption and ultra-high speed, 5G technology can be widely used to develop smart logistics and build out a high-quality logistics system.

(2) Rational Allocation of Resources to Improve Scale and Management Efficiency. The development mode of paper walnut logistics system in Northwest China is crude and the level of decision making and management is low. Although the current stage has not yet shown a big obstacle, in a long-term perspective, this will expand the difficulty of coupling modern technology and logistics industry, causing a double waste of logistics resources and value. Therefore, the northwest region needs to reasonably allocate the many resources of the logistics industry, promote the optimal combination of all influencing factors, promote the scale and specialization of the logistics industry, and improve the comprehensive technical efficiency. To achieve such a transformation, specific measures include: bringing scattered paperbark walnut growers together, launching agricultural cooperation, promoting the scale and intensification of paperbark walnut production, and ultimately achieving the purpose of improving scale efficiency; actively responding to national policies to introduce scientific and technological talents, while formulating a reasonable allocation plan for logistics management personnel, and ultimately achieving the purpose of improving management efficiency.

(3) Optimize the Spatial Layout of Paper Walnut Logistics Industry. At present, the government of Northwest China has issued a number of policies to support the production, planting, and transportation of paper skin walnuts. The logistics practitioners must grasp the advantages of these favorable policies, stabilize the production and transportation chain of paper skin walnuts, expand the circulation market of paper skin walnuts in the country, and help revitalize the economy of Northwest China. Secondly, they should also create and improve new logistics and transportation infrastructure, unify planning and rational layout, further optimize the overall spatial layout of paperbark walnut logistics in the northwest, ensure the normal articulation of all links in the logistics and transportation process, and effectively improve logistics efficiency.

(4) Learning from Excellent Experience and Making Improvements According to Local Conditions. Northwest China is deep inland, due to geographical constraints, it is necessary to strengthen the logistics links and cooperation with the central and eastern regions, and learn from the development experience of cities with high logistics efficiency at home and abroad. The provinces in the northwest region should strengthen logistics cooperation, learn from each other’s excellent experience, reduce logistics technology barriers, narrow the logistics technology gap, and create opportunities for regional economic development. Secondly, based on the existing logistics technology and experience in each province, each province should take into account the actual logistics conditions in the region, transform the experience of other regions reasonably before making use of it, take the essence and remove the dross, and promote the high-speed development of the local paperbark walnut logistics industry.

(5) Create a Logistics Information Technology Platform for Paper Walnuts. Information technology platform is an important cornerstone to support the modern development of logistics nowadays, and the emergence of block chain also provides a brand-new opportunity for the development of information technology platform. Building a logistics information technology platform for paperbark walnuts in Northwest China can share logistics information in real time, track logistics dynamics, and make the logistics industry more standardized and specialized. The Northwest region should strengthen the construction of blockchain more, so that blockchain can be better and faster integrated into the information technology platform of paperbark logistics and make logistics data sharing more secure. Using the information technology platform to integrate the scattered paperbark walnut logistics information and resources can not only effectively reduce paperbark walnut transportation costs, but also improve the logistics rate.

5. Conclusion

Based on the DEA-Malmquist index model, this paper measured the logistics efficiency of paperbark walnuts in Northwest China from 2012 to 2021, and analyzed the reasons for the changes through index decomposition, and obtained the following main conclusions. The logistics efficiency of paperbark walnuts in Northwest China from 2012 to 2021 is improved in fluctuation, and the main driving force of which is the progress of technology, while the low level of scale efficiency and logistics industry management hinders the improvement of logistics efficiency to some extent. From the perspective of time, the government’s support and the correct guidance of policies have obvious effects on the progress of logistics efficiency. From the spatial perspective, the logistics efficiency of all five provinces in Northwest China has improved, with the most significant effect in Shaanxi Province. The following is an outlook on the logistics development of paper walnuts in Northwest China.

(1) the northwest region to promote the application of high-tech in logistics. New and emerging technologies are important for the sustainable development of the logistics industry and can improve the efficiency of the logistics industry. Strengthen the application of advanced new technologies in logistics. Combined with the current development trend of intelligent logistics, no one in the intelligent logistics industry is closely linked to modern logistics to reduce the time and cost caused by human beings. At the same time, to accelerate the practical application of scientific and technological achievements in logistics, improve the efficiency of logistics, and drive the development of regional logistics.
(2) the northwest region to strengthen the national support for regional logistics. Government authorities should take appropriate measures and measures to regulate and support some logistics SMEs, encourage them to establish their own logistics infrastructure, and increase policy support for large regional logistics companies, so that they can: take the lead in establishing industrial mutual aid mechanisms. Communication and cooperation among companies. At the same time, the relevant departments should strengthen the supervision of the logistics market, respond positively to the requirements of the times, continuously optimize and improve the logistics supervision system, and create a good market environment.

(3) promote regional cooperation and the use of geographical advantages. As the main output place of China’s paper walnuts, Northwest China should give play to its regional advantages, strengthen coordination and cooperation with neighboring provinces and cities, develop together with neighboring provinces, build inter-city interconnection platform, strengthen interconnection between cities, realize complementary interests, reasonably allocate logistics resources, improve regional logistics efficiency, and realize high-quality development of regional logistics.

(4) the northwest region to strengthen the development of talent logistics. With the development of the times and the increase in market demand, logistics demand for high-tech talent is also growing. Cultivating complex logistics talents with professional quality and skills is the inevitable development of the times. The combination of industry and education deepens the combination of industry and education, cultivates high quality talents who can apply in the actual work, and improves professional skills and comprehensive quality.

Data Availability
The dataset can be accessed upon request.

Conflicts of Interest
The authors declare that there are no conflicts of interest.

References
