Research on Logistics Efficiency of Agricultural Products in Liaoning Province Under the Background of Digital Intelligence—Based on Dea Malmquist Model

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Abstract. The logistics sector is a fundamental, strategic, and leading industry that supports the development of the national economy. High-quality logistics development is a key component of high-quality economic development. This article uses digitization as the research background and uses panel data from 14 cities in Liaoning Province from 2012 to 2021 as the measurement sample. The Malmquist index model and DEA's BCC model are used to calculate the efficiency of agricultural product logistics, and the results are analyzed from both static and dynamic perspectives. The Malmquist index model has been found to have a total factor productivity index that is lower than the provincial average, while the average technical efficiency change index in Liaoning Province can achieve effectiveness. The following development recommendations are made in light of the calculation results: increase the scale of operational and resource investments; build agricultural product logistics network facilities and equipment; strengthen logistics personnel; improve the degree of digitalization of agricultural product logistics; acquire advanced knowledge of digitalization technology; and speed up the development of agricultural product logistics.

Keywords: logistics efficiency; agricultural products; digital intelligence; proposals; DEA

1 Introduction

China is a significant agricultural nation with a sizable volume of agricultural product logistics. The agricultural product logistics market and logistics system are not yet well established, and the logistics infrastructure is comparatively inadequate, which results in low efficiency in agricultural product logistics. This is because Liaoning Province's agricultural products have a relatively low level of logistics technology. This somewhat lessens the market's ability to compete for agricultural products.

In 2009, the idea of smart logistics was initially put forth[1]. As the economy continues to grow steadily, the digital and intelligent development of logistics—such as the use of big data and Internet of Things technologies—becomes more and more

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significant. This helps the logistics business grow. In this paper, the efficiency of agricultural product logistics in Liaoning Province is measured and analyzed from both static and dynamic perspectives using the DEA-BCC model and the DEA-Malmquist index model. The research object is the panel data of 14 cities in Liaoning Province from 2012 to 2021, with a background in digitalization and intelligence. Additionally, it offers specific recommendations and viewpoints for enhancing Liaoning Province's agricultural product logistics efficiency. In addition to steadily increasing the efficiency of agricultural product logistics in Liaoning Province, which has important practical and guiding significance, the aforementioned research is helpful in drawing attention to the digital and intelligent development of agricultural product logistics. It also advances the better development of Liaoning Province's economy and continuously improves the competitiveness of agricultural product logistics in Liaoning Province, both of which have significant practical significance.

2 Review of Relevant Concepts and Literature

As networking, intelligence, and information technology continue to advance, digital and intelligent technologies have been boldly tested in a variety of domains and have produced certain outcomes. Aspects like the intelligent transformation and the rebuilding of the smart logistics model have been examined in several studies on the digital and intelligent transformation of the logistics industry conducted in recent years. There have been a lot of opportunities in rural areas' integrated development over the years. The area where agriculture and logistics meet has new challenges in determining how to significantly increase efficiency, cut costs, and successfully accomplish precise matching between producers and customers.

One area of the logistics sector is the logistics of agricultural products. the actual movement of agricultural material entities and associated data from farmers to consumers in order to satisfy their demands. Considering agricultural output as the goal, agricultural products can be protected and valued through logistics connections like after processing, packaging, storage, transportation, and distribution before ultimately being delivered to customers. Research on the logistics of agricultural products has been performing theoretical investigations into issues and solutions in recent years. Agricultural goods are characterized by their short timeliness and regional concentration. The infrastructure in rural areas is comparatively inadequate when compared to the city. It explains the issues with the current rural logistics operations when combined with the current development trend. and makes logical recommendations based on astute logistics. [2] ; To address the issues with agricultural product cold chain logistics, examine the high-quality development of cold chain logistics, and acquire strategies and tools for high-quality development of cold chain logistics of agricultural products, such as resource reallocation, organizational reconstruction, industry cooperation, [3] In the backdrop of the Internet, Luo Qianfeng and Zhang Lizhen (2021) analyze the cold chain logistics of agricultural products today using big data, create a contemporary information sharing platform using big data technology, create a "personal micro-library" and a "Urban Library," and construct a complete cold chain logistics development model based on big data: network, efficiency, traceability, and stringent requirements. [4].

The major component analysis method, TOPSIS, DEA, and other techniques have been used by many researchers to examine the effectiveness of agricultural product logistics. These techniques serve as a base and source of reference for pertinent departments and units. Ma Jing et al. (2017) employed the major component analysis approach to organize and examine the data in order to determine the elements that influence the green logistics of agricultural products in Liaoning Province; [5] Zhang Lifeng et al. (2020) examined the Northeast China region from 2007 to 2017 using the DEA-MALMQUSIT index model. The effectiveness of regional logistics for agricultural products; [6] Yang Liu and associates (2023) The three-stage DEA model was used to calculate the effectiveness of the cold chain logistics of fresh agricultural products in 14 cities in Liaoning Province, and an appropriate evaluation was carried out. [7] The conclusion is that statistical noise and environmental factors have a greater influence on the overall technological efficiency of fresh agricultural products in 14 cities in Liaoning Province, while the overall technical efficiency of the cold chain logistics of fresh agricultural products in 14 cities is relatively low. However, the overall technological efficiency and scale efficiency across the 14 cities remain noteworthy.

It is evident that there is a wealth of assessment and computation research on the effectiveness of agricultural product logistics. The effectiveness of urban smart logistics in Liaoning Province will be computed and examined in this paper using the DEA-BCC model and the Malmquist index model from both static and dynamic viewpoints in the setting of digital intelligence.

3 Establishing the Data Source and Indication System

3.1 The Indication System's Construction

This article examines the effectiveness of agricultural product logistics throughout the 2012–2021 ten-year period in the context of the 14 cities in Liaoning Province. Three input indicators[8] (agricultural product logistics related fixed asset stock, agricultural product logistics related practitioners, and rural Internet users access number [9]) and one output index (agricultural product logistics GDP) were chosen in order to assess the effectiveness of agricultural product logistics in 14 cities in Liaoning Province in the context of digital intelligence. Particular[10], as seen in Table 1.

Table 1. Variables for input and output

	Name of index data	Code for index data
Input variable	Fixed assets stock associated with the logistics of agricultural products	X_1
	Practitioners involved in agricultural product logistics	X_2
	Number of rural Internet users with access	X_3
Output	GDP from the logistics of agricultural products	Y_1

varia-ble		

Dynamic analysis is conducted by applying the DEA-Malmquist index model. To reflect the changes in technology and scale, the total factor productivity is decomposed. This model can accurately reflect the dynamic changes in efficiency. The distance function is used for calculation to describe the changes in input-output efficiency from period t to t+1, as shown below:

$$M_t(x^t, y^t, x^{t+1}, y^{t+1}) = \frac{D^t(x^{t+1}, y^{t+1})}{D^t(x^t, y^t)},$$
$$M_{t+1}(x^t, y^t, x^{t+1}, y^{t+1}) = \frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^{t+1}(x^t, y^t)} \tag{1}$$

In Formula 1, (x^t, y^t) and (x^{t+1}, y^{t+1}) are respectively used to represent the input and output in period t and period t + 1. The distance functions $D_t(x^t, y^t)$ and $D_t(x^{t+1}, y^{t+1})$ respectively denote the technical efficiency levels in period t and period t+1. By taking the geometric mean of Formula 1 and considering the technical levels of period t and period t+1, the change in total factor productivity (tfpch) can be obtained as follows:

$$tfpch = M_t(x^t, y^t, x^{t+1}, y^{t+1}) = \{[\frac{D^t(x^{t+1}, y^{t+1})}{D^t(x^t, y^t)}] \cdot [\frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^{t+1}(x^t, y^t)}]\}^{\frac{1}{2}} \tag{2}$$

The total factor productivity (tfpch) is refined into the comprehensive technical efficiency change index (effch) and the technological progress index (techch); the comprehensive technical efficiency change index (effch) is further refined into the pure technical efficiency change index (pech) and the scale efficiency change index (sech). (Where "vrs" indicates the variable situation of scale efficiency, and "crs" indicates the constant situation of scale efficiency.) As shown below:

$$\begin{aligned}
&tfpch = effch \times techch \\
&= [\frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^t(x^t, y^t)}] \cdot \{[\frac{D^t(x^t, y^t)}{D^{t+1}(x^t, y^t)}] \cdot [\frac{D^t(x^{t+1}, y^{t+1})}{D^{t+1}(x^t, y^t)}]\}^{\frac{1}{2}} \\
&= pech \times \sec h \times techch \\
&= [\frac{D^{t+1}_{vrs}(x^{t+1}, y^{t+1})}{D^t_{crs}(x^t, y^t)}] \cdot \{[\frac{D^{t+1}_{vrs}(x^{t+1}, y^{t+1}) / D^{t+1}_{crs}(x^{t+1}, y^{t+1})}{D^{t+1}_{vrs}(x^t, y^t) / D^{t+1}_{crs}(x^t, y^t)}] \cdot [\frac{D^t_{vrs}(x^{t+1}, y^{t+1}) / D^t_{crs}(x^{t+1}, y^{t+1})}{D^t_{vrs}(x^t, y^t) / D^t_{crs}(x^t, y^t)}]\}^{\frac{1}{2}} \\
&\cdot \{[\frac{D^t(x^t, y^t)}{D^{t+1}(x^t, y^t)}] \cdot [\frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^{t+1}(x^t, y^t)}]\}^{\frac{1}{2}}
\end{aligned} \tag{3}$$

3.2 Sources of Data

The "Liaoning Statistical Yearbook" and the "Statistical Bulletins on National Economic and Social Development" of the 14 cities in Liaoning Province served as the article's data sources. Considering the advantages and disadvantages of the DEA model comprehensively and to expound the static and dynamic changes of agricultural product logistics efficiency in Liaoning Province more clearly, this study chose the DEA-BCC and Malmquist model. This article employs the transportation and storage, postal, wholesale, retail, lodging, and catering industries as the research object of the logistics industry, referring to the practice of the majority of scholars. using the data selection techniques of researchers Cheng Shuqiang, etc., to more accurately determine the share of agricultural products in the logistics sector. [11] Li Jinhong and so forth. [12] The logistics industry data revealed the factors of residential food consumption and agricultural product characteristics. The final agricultural product logistics variable = x/y×food consumption accounts for the total consumption proportion, which is computed as follows: the total consumption ratio of food consumption = the final consumption rate×the consumption rate of inhabitants×Engel coefficient[13].Some missing data were estimated by interpolation. This study employs the DEAP software to calculate the cross-sectional data of 14 cities in Liaoning Province from 2012 to 2021 as the observation sample.

4 Empirical Findings and Evaluation

4.1 Analysis and Outcomes of the BCC Calculation

Use the DEA-BCC model as a starting point for the research of agricultural product logistics efficiency, then use the DEAP 2.1 program to determine the total technical efficiency value: If the urban unit's comprehensive technical efficiency value is 1, it can be considered relatively efficient. It's not very effective. TE is separated into two categories: scale efficiency (SE) and pure technical efficiency (PTE). To determine if each decision-making unit can efficiently use input items to accomplish output optimization, the pure technical efficiency value, or PTE, is used. Without taking resource size into account, the higher the task efficiency value of the operating efficiency, the better. Due to the general inefficiency of the technology. According to this theory, targeted analysis is predicated on the efficiency and scale efficiency of pure technology since it is mostly due to the inefficiency of the scale or pure technology.

Table 2. BCC model assessment of the agricultural product logistics efficiency in 14 cities in Liaoning Province, 2012–2021

City	TE	PTE	SE	
	Comprehensive technology efficiency	Pure echnical efficiency	Scale efficiency	Scale income type
Shenyang	0.5002	0.460	1.091	irs
Dalian	1.000	1.000	1.000	-
Anshan	0.511	0.663	0.770	irs
Fushun	0.337	0.846	0.398	irs
Benxi	0.357	1.000	0.357	irs
Dandong	0.275	0.791	0.348	irs

Jinzhou	0.456	0.631	0.724	irs
Yingkou	0.270	0.787	0.343	irs
Fuxin	0.318	1.000	0.318	irs
Liaoyang	0.752	1.000	0.752	irs
Panjin	0.375	1.000	0.375	irs
Tieling	0.474	0.888	0.533	irs
Chaoyang	0.763	1.000	0.763	irs
Huludao	0.620	0.869	0.714	irs
Averag value	0.5001	0.852	0.606	-

Overall effectiveness of technology Table 2 shows that only Dalian City is among the 14 cities in Liaoning Province with comprehensive technical efficiency, and the province's average comprehensive technical efficiency is 0.5001, suggesting that the province's agricultural products have poor logistics efficiency; pure technology The average efficiency is 0.852, and six cities—Shenyang, Anshan, Fushun, Dandong, Jinzhou, and Yingkou City—are below this average. This indicates that Liaoning Province will be mindful of future developments. For instance: the efficient use and advancement of associated digital intelligence technologies in the fields of agriculture, fresh-keeping, and immediate delivery of agricultural products; the Internet of Things; and big data;Shenyang City and Dalian City, two cities with a scale of 1, are achieving scale efficiency. Seven of the cities have not attained the scale effect, as evidenced by their scale values being below the average of 0.606. The logistics of the associated agricultural commodity have a comparatively minimal input. Thus, efficient building of infrastructure and equipment for the logistics of agricultural products and personnel, including distribution centers, refrigerated libraries, and insulation libraries, among others.

Liaoning Province does not have a waste of investment in agricultural product logistics, and there is no case in the investment in agricultural product logistics resources, since the decreasing cities are zero from the standpoint of scale compensation. Thirteen cities have scale compensation that increases. It demonstrates how increasing resource investment can further enhance the size of agricultural product logistics in these 13 locations; therefore, in further work, the scale can be attained by increasing operating investment. Only one city's scale has remained constant, indicating that it is at the peak of its manufacturing scale. It can be regarded as developing steadily and steadily in the future.

Table 3. shows how the effectiveness of smart logistics for agricultural products in Liaoning Province changed between 2012 and 2021

Effect Type	Changes and the quantity of cities	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
comprehensive efficiency	TE=1 quantity of cities	1	3	3	4	4	4	4	5	5	5

	average value	0.496	0.827	0.859	0.869	0.870	0.885	0.819	0.849	0.873	0.856
Pure Technical efficiency	PTE=1 quantity of cities	6	4	6	9	6	8	6	6	8	9
	average value	0.852	0.918	0.919	0.940	0.930	0.949	0.915	0.927	0.949	0.906
Scale efficiency	SE=1 quantity of cities	1	3	3	4	4	3	4	5	5	5
	average value	0.596	0.902	0.930	0.923	0.936	0.934	0.896	0.915	0.920	0.939

Table 3 shows the changes in the agricultural product smart logistics efficiency in Liaoning Province. To start, the agricultural product smart logistics efficiency value for Liaoning Province from 2012 to 2021 is 1, attaining an effective number of cities that shows an annual rise. Second, from the perspective of pure technical efficiency PTE values, it is essentially upward; the small number of cities, five, indicates that the efficiency of resource allocation of agricultural goods input resources needs to be further improved. From six in 2012 to nine in 2021, the city of PTE = 1 grew. From a technical standpoint, it is evident that the effectiveness of the intelligent logistics of agricultural products is rising in Liaoning Province; ultimately, although though the scale efficiency SE value varies a little between 2012 and 2021, it still continues to rise steadily. As a result, Table 3 explains why the majority of urban agricultural products in Liaoning Province are not operating at their best efficiency. Liaoning Province still needs to invest more in smart logistics for agriculture and keep improving configuration and planning.

4.2 Results of the Malmquist Index Computation and Analysis of 14 Liaoning Province Cities

The effectiveness of agricultural logistics in 14 cities in Liaoning Province was computed and examined using the DEA-BCC approach mentioned above. However, there were some drawbacks, as the efficiency number that BCC was able to acquire was static. Since the full factor productivity serves as a crucial foundation for accurately capturing the dynamic nature of the industry's development, the Malmquist scale's size efficiency remains constant, and the MALMQUIST index of agricultural product logistics in 14 cities in Liaoning Province from 2012 to 2021 is chosen. Table 4 illustrates the dynamic state of factor productivity and efficiency analysis, including the technical efficiency change index, whole factor productivity change index, and others.

Table 4. based on the DEA-MALMQUIST index 2012–2021 efficiency analysis of 14 cities in Liaoning Province

City	Technical Efficiency Change Index effch	Tech-nical Progress Index techch	Pure tech-nical efficiency change index pech	Flame effi-ciency change in-dex sech	Full factor productiv-ity change index tfpch	Average value
Shenyang	1.096	1.002	1.090	1.005	1.098	1.0582
Dalian	1.000	1.001	1.000	1.000	1.001	1.0004
Anshan	1.078	0.756	1.047	1.029	0.815	0.9450
Fushun	1.126	0.718	1.019	1.105	0.808	0.9552
Benxi	1.110	0.792	1.000	1.110	0.879	0.9782
Dandong	1.076	0.773	0.964	1.117	0.832	0.9524
Jinzhou	1.038	0.764	1.040	0.998	0.793	0.9266
Yingkou	1.103	1.021	0.999	1.103	1.126	1.0704
Fuxin	1.133	0.730	1.000	1.133	0.827	0.9646
Liaoyang	1.032	0.914	1.000	1.032	0.943	0.9842
Panjin	1.092	0.885	0.987	1.107	0.966	1.0074
Tieling	1.087	0.607	1.013	1.072	0.659	0.8876
Chaoyang	0.950	0.779	0.936	1.015	0.740	0.8840
Huludao	1.053	0.776	1.016	1.037	0.817	0.9398
average value	1.068	0.823	1.007	1.061	0.879	0.9681

Table 4 shows that 14 cities in Liaoning Province existed between 2012 and 2021. The province of agricultural product logistics achieved effective indexes such as the scale efficiency change index (SECH), pure technical efficiency change index (PECH), and technical efficiency change index (EFFCH), with respective averages of 1.068, 1.007, and 1.061. According to the aforementioned data, Liaoning Province is experiencing favorable and fair advances in technical efficiency. On the other hand, Liaoning Province's technical progress index (TECHCH) average is 0.823. The province's technical progress index does not meet validity standards and is much below the acceptable number. It demonstrates that Liaoning Province still has a lot of room for growth and development potential. Liaoning Province should raise the level of digital intelligence in agricultural product logistics in future work, continuously improve the promotion management and effective application of their logistics technology, and effectively promote the further development of agricultural product logistics since technology is the first productive force and technological advancement is a crucial component of the effective improvement of agricultural product logistics.

According to Table 4, the average total factor productivity change index (TFPCH) for agricultural product logistics across 14 cities in Liaoning Province in 2012 was 0.879. From a static point of view: The city in Liaoning Province's overall technological efficiency hasn't worked well. The agricultural items produced in the province are From a dynamic standpoint, the level of development between 14 cities is high, but the logistical efficiency is low. While the province's overall technical efficiency has essentially grown, the development degree of agricultural product logistics in 14 cities has fluctuated significantly in recent years; Regarding index decomposition, Liaoning Province's average technological advancement index (TECHCH) is 0.823, while the average technical efficiency changes index (EFFCH) is 1.068. The essence With an average pure technology efficiency index (PECH) value of 1.007, Liaoning Province has a comparatively low degree of agricultural product logistics development when compared to the province as a whole. Therefore, it is imperative that future efforts focus on agricultural product logistics, network facilities and equipment, and related practitioners, and expand the input parts of agricultural product logistics in a timely manner.

From Table 4, observing the data change rate and technological progress rate data of its technical efficiency and technological progress can be observed, and 14 cities in Liaoning Province in Figure 1 can decompose according to the full factor productivity index: The first category is cities where technological efficiency changes and technological progress have increased: Shenyang City, Dalian. In the process of the development of agricultural product logistics, the two cities have a reasonable investment in agricultural product logistics related fixed assets, related practitioners, and the Internet, and are also high in terms of technology and management.

Fig. 1. shows the 14 cities in Liaoning Province based on the whole factor productivity index breakdown.

Yingkou City falls into the second category, which consists of cities with a lower rate of technical efficiency but a higher rate of technological advancement. The active promotion of agricultural product logistics technology, such as the development of the Internet and the development of smart logistics technology, can significantly increase the efficiency of agricultural product logistics. Yingkou City's full factor productivity is 1.126, a positive growth that adequately explains this.

Chaoyang City falls into the third group, which is cities with a rate of decline in technical advancement and changes in technological efficiency. Inadequate innovation capabilities and a comparatively outdated management level characterize the city's agricultural product logistics technology. This is the cause of Chaoyang's agricultural product logistics' declining effectiveness. It demonstrates how poorly Chaoyang City uses logistics resources and technology. As a result, the smart technology of agricultural product logistics must be given prominence. Simultaneously, there is a need to consistently increase the degree and level of management of agricultural product logistics.

Cities in the fourth category—Jinzhou, Anshan, Fushun, Benxi, Liaoyang, Panjin, Dandong, Tieling, Fuxin, and Huludao—have a higher rate of technical efficiency growth but a slower pace of technological advancement. As we hold the majority of these cities in Liaoning Province, we should make efficient use of our resources and accelerate the development of smart technologies for advanced agricultural product logistics, including blockchain, traceability, and the Internet of Things.

As shown in Table 5, cities that achieve DEA efficiency are classified as Class A, those with a comprehensive technical efficiency value lower than the average are classified as Class C, and those with a value higher than the average but not reaching DEA efficiency are classified as Class B cities. The comprehensive technical efficiency of most cities in Liaoning Province has not reached DEA efficiency, indicating that the efficiency of agricultural product logistics in the province is not high. There is still a significant disparity in the development levels among each city. The development level of agricultural product logistics in the 14 cities of Liaoning Province fluctuates greatly. However, the technical efficiency and total factor productivity of the province as a whole showed an upward trend from 2020 to 2021.

Table 5. Divide cities into three groups according to the static analysis of the thorough

Grade	City
Class A	Dalian
Class B	Shenyang, Anshan, Liaoyang, Chaoyang, Huludao
Class C	Fushun, Benxi, Dandong, Jinzhou, Yingkou, Fuxin, Panjin, Tieling

5 Conclusions

In terms of intelligence gathering, it offers prospects and guidance for the province's agricultural product logistics development. It should be able to benefit Liaoning Province's agricultural product logistics growth. The logistics of agricultural products in Liaoning Province must become more efficient, faster, and larger in scope. Therefore, based on the results of the previous calculations, analysis, and conclusions, Liaoning Province needs to increase the number of logistics personnel, build out the infrastructure and equipment for the agricultural product logistics network, increase the amount of money invested in resources and operations, raise the level of digital intelligence in agricultural product logistics, and keep improving their logistics technology. The construction of network facilities and equipment for agricultural product logistics can focus on intelligent warehousing, unmanned distribution, automatic sorting, packaging, loading and unloading, refrigeration and freshness of agricultural products[14].It is essential to support agriculture efficiently and raise the caliber of the related logistics companies. At the same time, the capital and resource investment in this cross -area are increased to make greater output[15]. Liaoning Province will increase the level of digital intelligence of agricultural product logistics and continuously improve logistics technology, it continuously improves existing agricultural product logistics, greatly improves efficiency, and then promotes the large -scale development of the Liaoning province's economy to achieve comprehensive revitalization.

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