Resilience Analysis of Agricultural Supply Chain in Liaoning Province Based on Entropy Weight-TOPSIS Approach

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Abstract. Based on the entropy weight-TOPSIS method, this paper carries out a comprehensive evaluation and analysis of the supply chain toughness of agricultural products in Liaoning Province. An evaluation index system containing production factors, environmental factors, logistics factors and technological factors is constructed, and the entropy weight method is used to determine the weights of each index, and the agricultural supply chain toughness of Liaoning Province is assessed by the TOPSIS method. It was found that the toughness of the agricultural supply chain in Liaoning Province showed an upward trend during 2018-2022. The weights of environmental factors and logistics factors in the evaluation index system are high, which have the greatest impact on the toughness of the agricultural supply chain in Liaoning Province. The influence of production factors is relatively small. In this regard, we should promote the economic development of Liaoning's agricultural industry, support logistics enterprises, and promote the specialization and innovation of agricultural logistics to enhance the resilience and stability of the supply chain. This will promote the sustainable growth of Liaoning's agricultural economy and guarantee national food security. At the same time, it also provides reference for assessing and improving the resilience of agricultural supply chains in other regions.

Keywords: Liaoning Province; agricultural supply chain; supply chain resilience; entropy weight-TOPSIS method;

1 INTRODUCTION

In February 2024, the first document of the central government, "Opinions of the State Council of the Central Committee of the Communist Party of China on Learning and Applying the Experience of the "Thousand Villages Demonstration and Ten Thousand Villages Improvement" Project to Powerfully and Effectively Promote the Comprehensive Revitalization of Rural Areas" was published. This is the 12th central government document focusing on the "three rural areas" since the new era. In this document, the state once again emphasized the issue of food security. It is a top priority to ensure

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national food security. 2023 national grain production hit a record high, providing strong support for the promotion of the economy to continue to rebound and improve. The central No. 1 document emphasizes the "two ensure", which in the first place is to ensure national food security. Looking through the 12 central No.1 documents, the deployment of ensuring national food security and guaranteeing the supply of important agricultural products has been consistent throughout, highlighting the great importance that the party and the state attach to food security [1].

As an important link of agricultural industrialization, the agricultural supply chain is of great significance in guaranteeing national food security and promoting agricultural economic development [2]. International emergencies have continued to occur frequently in recent years, such as the trade war between China and the United States in 2018, the three-year-long outbreak of a new coronavirus in 2019, and the proliferation of extreme weather around the world in 2021, and so on. The emergence of various emergencies has had a great impact on the security of the agricultural supply chain. As of 2020, the total amount of fresh agricultural products in China has reached more than 1.2 billion tons [3], the supply is huge while the consumption of residents is also increasingly huge, and the establishment of a good supply chain resilience can effectively resist the impact of emergencies. Therefore, how to reasonably improve the supply chain resilience management of agricultural products has become a key topic of current research.

Liaoning province is one of the important commodity grain bases in China, and the development of the supply chain of agricultural products in Liaoning is of great significance in realizing the comprehensive revitalization and all-round revitalization of the province as well as the northeast [4]. In recent years, the comprehensive level of agricultural production in Liaoning Province has been improving, and the production of high-quality agricultural products has also made great progress. Liaoning High-Efficiency Agricultural Demonstration Zone has been vigorously developing modern agriculture, producing high-quality fruits and vegetables, and has registered a variety of brands of agricultural products, and many products have been transformed into geographical indications [5]. As a major agricultural province in China, the stability and resilience of the supply chain of agricultural products in Liaoning Province is directly related to the sustainable development of agriculture and social and economic stability of the region [6]. However, with the constant changes of domestic and international market environment and the frequent occurrence of various uncertain emergencies, the agricultural supply chain in Liaoning Province faces many uncertainties and risk challenges, and how to improve the resilience of the supply chain has become an urgent problem.

Therefore, this study comprehensively evaluates and analyzes the resilience of the agricultural supply chain in Liaoning Province based on the entropy weight-TOPSIS method. By constructing a resilience evaluation index system, collecting relevant data, and applying the entropy-weight-TOPSIS method for quantitative evaluation, it aims to reveal the current situation of resilience of the agricultural supply chain in Liaoning Province and its problems, and to provide decision support for improving the resilience and risk coping ability of the supply chain.

2 AGRICULTURAL SUPPLY CHAIN EVALUATION INDEX SYSTEM CONSTRUCTION

In the previous evaluation studies of agricultural supply chain system, the evaluation index system constructed under different research perspectives and research objects are different [7]. When evaluating the supply chain of agricultural products at the provincial level, the source of agricultural production should be considered. Such factors as the production of agricultural products and the current situation of farmers have a positive effect on the resilience of the agricultural supply chain and should not be ignored. In this regard, Xu Wenping [8] synthesized the relevant literature on agricultural supply chain research, and proposed an evaluation index system including production factors for the evaluation of the resilience of the provincial agricultural supply chain. This paper refers to its proposed evaluation index system, combined with the actual situation of the agricultural supply chain in Liaoning Province and the availability of data, and puts forward the evaluation index system of the resilience of the agricultural supply chain in Liaoning Province as shown in the table 1 below.

Table 1. Agricultural supply chain resilience evaluation index system

	Tier 1 indicators	Tier 2 indicators
Agricultural Supply Chain Resilience Evaluation Indicator System	Production factors A1	Cultivated land area B1
		Output of major agricultural products B2
	Environmental factors A2	Employees in primary industry B3
		Gross regional product B4
		Average net income of farmers B5
		Gross value of social consumer goods B6
		Operating cost of service industry B7
	Logistics factor A3	Freight volume B8
		Cargo turnover B9
		Length of Transportation Route B10
	Technology factor A4	Agricultural research and development enterprises B11
		Agricultur0al researchers B12
		Expenditure on scientific research B13

The evaluation index system for the resilience of the agricultural supply chain in Liaoning Province constructed in this paper mainly takes four influencing factors, namely, production factors, environmental factors, logistics factors, and technological factors, as the first-level indicators [9]. Then 13 secondary indicators are selected from the four influencing factors for quantitative analysis. The production factor indicators mainly consider the stability of the production end of the agricultural supply chain, and the resilience of the supply chain to shortages and shortages when the production fluctuates. The environmental factor indicators consider the impact of Liaoning's external environment and consumption capacity on the resilience of the agricultural supply chain. Logistics factor indicators consider the impact of logistics capacity development in Liaoning Province on the resilience of agricultural supply chain. The technical factor indicator considers the effect of scientific research investment, scientific and technological development on the resilience of the agricultural supply chain in Liaoning Province, and the ability to fight against emergencies.

3 ENTROPY WEIGHT-TOPSIS METHOD MODEL CONSTRUCTION

3.1 Entropy Weighting Method to Determine Weights

Entropy weight method is a method of determining weights by using information entropy, which objectively reflects the importance of each indicator in the comprehensive evaluation by analyzing the degree of dispersion of the indicator, and this method can avoid the error of subjective assignment and improve the accuracy and credibility of evaluation. The specific operation steps are as follows:

1. Constructing the evaluation matrix

Build an evaluation matrix containing m years and n evaluation indicators. Construct the standard evaluation matrix formula as shown in (1):

$$B = (b_{ij})_{m\times n} = \begin{bmatrix} b_{11} & b_{12} & \cdots & b_{1n} \\ b_{21} & b_{22} & \cdots & b_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ b_{m1} & b_{m2} & \cdots & b_{mn} \end{bmatrix} \tag{1}$$

2. Data standardization

The raw data unit is not uniform, which will have an impact on the evaluation results. Normalize the raw indicator data. The formula is shown in (2) (3):

$$S_{ij} = \frac{b_{ij} - min(b_{ij})}{max(b_{ij}) - min(b_{ij})} + 0.0001 \tag{2}$$

$$S_{ij} = \frac{max(b_{ij}) - b_{ij}}{max(b_{ij}) - min(b_{ij})} + 0.0001 \tag{3}$$

On this basis, B is transformed into a standardized evaluation matrix S:

$$S = (s_{ij})_{m\times n} = \begin{bmatrix} s_{11} & s_{12} & \cdots & s_{1n} \\ s_{21} & s_{22} & \cdots & s_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ s_{m1} & s_{m2} & \cdots & s_{mn} \end{bmatrix} \tag{4}$$

3. Calculate the entropy value of indicators

Based on the normalized data, the information entropy of each indicator is calculated to reflect its contribution to the decision-making results. The formula is shown in (5):

$$e_i = -\frac{1}{1n}\sum_{i=1}^{n} s_{ij} ln s_{ij} \tag{5}$$

4. Calculate indicator weights

Based on the information entropy, calculate the weight of each indicator, the size of the weight is proportional to the discrete degree of the indicator.

$$w_i = \frac{1-e_i}{m-\sum_{i=1}^{m} e_i} \tag{6}$$

3.2 The TOPSIS Method

TOPSIS method is a commonly used multi-attribute decision analysis method. It evaluates the advantages and disadvantages among the solutions by constructing ideal and negative ideal solutions and calculating the distance between each solution and these two solutions. TOPSIS method can fully utilize the raw data and the results accurately reflect the gaps among the solutions.

In this paper, with the help of entropy right method, we improve the calculation method of positive and negative ideal solutions of traditional TOPSIS, and construct entropy right TOPSIS model to evaluate the resilience of agricultural supply chain. The specific steps are as follows:

1. Construct normalization matrix

After calculating the weights of each index according to the steps of entropy weighting method, construct the normalization matrix T.

$$T = \left(T_{ij}\right)_{m\times n} = \begin{bmatrix} w_1 s_{11} & w_1 s_{12} & \cdots & w_1 s_{1n} \\ w_2 s_{21} & w_2 s_{22} & \cdots & w_2 s_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ w_m s_{m1} & w_m s_{m2} & \cdots & w_m s_{mn} \end{bmatrix} \tag{7}$$

2. Determine the positive and negative ideal solutions

Let P^+ the maximum value of the ith indicator observation data, called the positive ideal solution; P^- indicates the minimum value of the ith indicator observation data, called the negative ideal solution. The formula is shown below:

$$P^+ = (P_1^+, P_2^+, \cdots, P_m^+) = \{maxT_{ij} | i = 1, 2, \cdots, m\} \tag{8}$$

$$P^- = (P_1^-, P_2^-, \cdots, P_m^-) = \{\min T_{ij} | i = 1, 2, \cdots, m\} \tag{9}$$

3. Calculate the distance

Calculate the distance between each evaluation object and the positive ideal solution and the negative ideal solution. D_i^+ is the distance between the ith indicator and P_i^+, and D_i^- is the distance between the ith indicator and P_i^-.

$$D_i^+ = \sqrt{\sum_{i=1}^{m} (T_{ij} - P_i^+)^2} \tag{10}$$

$$D_i^- = \sqrt{\sum_{i=1}^{m} (T_{ij} - P_i^-)^2} \tag{11}$$

4. Calculation of proximity

Calculate the degree of closeness, i.e., the degree of proximity to the ideal solution, based on the distance of each evaluation object from the positive ideal solution and the negative ideal solution.

$$k_i = \frac{D_i^-}{D_i^- + D_i^+} \tag{12}$$

4 EMPIRICAL ANALYSIS OF SUPPLY CHAIN RESILIENCE OF AGRICULT URAL PRODUCTS IN LIAONIN G PROVINCE

4.1 Data Sources

Data collection for the 13 secondary indicators of the above evaluation index system, the research data mainly come from various statistical yearbooks publicly released by the National Bureau of Statistics and the Liaoning Provincial Bureau of Statistics, including the China Statistical Yearbook, Liaoning Statistical Yearbook, China Financial Yearbook, China Tertiary Industry Statistical Yearbook, etc. The research data are mainly from the National Bureau of Statistics and the Liaoning Provincial Bureau of Statistics. As well as Liaoning Provincial National Economic and Social Development Statistical Bulletin, Liaoning Provincial Farmers' Income and Expenditure Research Report and other related materials.

4.2 Determination of Weights

According to the relevant data collected by the evaluation index system, the weight coefficients of each index are obtained as shown in Table 2 by processing them in accordance with formulas (1)-(6) of the entropy weighting method mentioned above.

Table 2. Indicator weightings

Tier 1 indicators	Weighting (%)	Tier 2 indicators	Weighting (%)
Production factors A1	9.199	Cultivated land area B1	4.201
		Output of major agricultural products B2	4.998
Environmental factors A2	39.333	Employees in primary industry B3	6.851
		Gross regional product B4	11.675
		Average net income of farmers B5	6.54
		Gross value of social consumer goods B6	6.515
		Operating Cost of Service Industry B7	7.752
Logistics factor A3	30.71	Freight volume B8	11.509
		Cargo turnover B9	12.888
		Length of transportation routes B10	6.313
Technology factor A4	20.758	Agricultural research and development enterprises B11	7.053
		Agricultural researchers B12	6.892
		Expenditure on scientific research B13	6.813

4.3 Calculation of Closeness and Ranking by TOPSIS Method

According to the results of the entropy weight method, the relative closeness and ranking are calculated according to the formula (7)-(12) of the TOPSIS method mentioned above, and the results are shown in Table 3.

Table 3. TOPSIS calculation results

Year	positive ideal solution distance（D+）	negative ideal solution distance（D-）	relative proximity （k_i）	Ordering
2018	0.71211065	0.64439594	0.47504077	4
2019	0.61394904	0.57920676	0.48544101	3
2020	0.73170155	0.47289972	0.3925778	5
2021	0.63462047	0.63963321	0.50196693	2
2022	0.60241115	0.74214366	0.55196237	1

4.4 Analysis of Results

The results of the weighting of the indicators for the evaluation of the supply chain of agricultural products in Liaoning Province are shown in Table 3. It can be seen from the results of the weighting of the indicators that among all the secondary indicators, the three indicators with the largest weighting are Gross Regional Product , Freight volume and Cargo turnover.

Gross regional product reflects the overall economic level and development situation of Liaoning Province. The provincial economic situation provides a solid guarantee for the smooth operation of the agricultural supply chain, which is conducive to the agricultural supply chain being able to recover to the normal level faster and improve the resilience of the supply chain when it is hit by unexpected events. In view of the specific situation of Liaoning Province, we can start to promote the integrated development of primary, secondary and tertiary industries in rural areas, and promote the extension and specialization of industrial chains. Guide balanced regional development and optimize resource allocation. At the same time, it encourages innovation and entrepreneurship, and promotes the optimization and upgrading of economic structure oriented by market demand [6];

Freight volume and Cargo turnover reflect the logistics carrying and distribution capacity of Liaoning Province. With the continuous improvement of Liaoning's logistics capacity, the resilience of Liaoning's agricultural supply chain has also increased year by year accordingly. Logistics occupies an important position among the components of the agricultural supply chain, and the development of logistics capacity is the basic guarantee of the agricultural supply chain, reflecting the sustainable operation capacity of the supply chain. Therefore, the more inputs, the more it will improve the ability of agricultural supply chain to resist risks.

Among the weight coefficients of all the indicators, the weight of cultivated land area and Output of major agricultural products accounted for the lowest proportion. This indicates that the influence of production factors on the resilience of the agricultural supply chain in Liaoning Province is small, Indicators in this area can be considered later in improving the resilience of the agricultural supply chain in Liaoning Province. Improving the resilience of the agricultural supply chain in Liaoning Province mainly focuses on promoting the regional economic development and improving the regional logistics operation capacity.

From Table 3, from 2018 to 2022, the resilience of the agricultural supply chain in Liaoning Province basically shows a gradual upward trend in the past five years.The resilience level of the agricultural supply chain in Liaoning Province before 2020 continued to rise, and in 2020, there was a small drop due to the sudden impact of the Xinguan epidemic, which was mainly attributed to the slow circulation of agricultural products at that time for the purpose of preventing the epidemic, and it was a fortuitous event. It is fortuitous. After the adjustment of the epidemic prevention policy and the resumption of production, the resilience of Liaoning's agricultural supply chain immediately returned to a steadily increasing level, and continued to rise in 2021-2022, with a significantly accelerated growth trend.

5 CONCLUSION

This paper evaluates the resilience of the agricultural supply chain in Liaoning Province, through combing and analyzing the existing literature related to the agricultural supply chain, constructs the evaluation index system of the agricultural supply chain in Liaoning Province, and constructs the entropy weight-TOPSIS model to evaluate the agricultural supply chain in Liaoning Province, which will help the relevant governmental departments to grasp the development status of the resilience of the supply chain in real time and accurately. The results of this evaluation will help the relevant government departments to accurately grasp the development status of supply chain resilience in real time, promote the development and progress of the agricultural supply chain in Liaoning Province, and better analyze and study the agricultural supply chain in Liaoning Province from the aspect of different influencing factors, which will help to comprehensively analyze the resilience fluctuation of the supply chain of agricultural products in the event of emergencies from multiple perspectives. The specific research findings are summarized as follows:

An evaluation model of the toughness capacity of the agricultural supply chain in Liaoning Province based on the entropy weight-TOPSIS method was constructed, and the time series data of Liaoning Province during the 5-year period of 2018-2022 was used as a sample to conduct empirical analysis, and the results of the study show that the toughness of the agricultural supply chain in Liaoning Province in general shows a rising trend, and the rate of increase gradually accelerates.

The factors that have the greatest influence on the resilience of the agricultural supply chain in Liaoning Province are environmental factors and logistics factors. Enhancing the resilience of the agricultural supply chain in Liaoning Province should start with promoting the local economic development and improving the logistics capacity. The influence of production factors on the resilience is relatively small.

Enhancing the resilience of Liaoning's agricultural supply chain can be done in two ways: one is to promote the economic development of Liaoning's agricultural products industry, drive the economic cycle, improve the vitality of the agricultural products market, and promote the circulation of agricultural products market in the province; the other is to improve the logistics capacity of the province, and to improve the logistics carrying and distributing capacity of Liaoning province. Strengthening logistics infrastructure construction, optimizing the layout of logistics network, promoting the specialization and innovation of agricultural products logistics, improving the provincial logistics capacity and logistics operation efficiency, and thus enhancing the flexibility of agricultural products supply chain.

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