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Risk Assessment of Agricultural Products Supply Chain Based on Combined Weighting of Level Difference Maximization

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Abstract: In the context of the prevalence of novel coronavirus epidemic, effective risk factor assessment of agricultural supply chain and further improvement of supply chain risk management are the key links to stabilize the development of agricultural supply chain. Based on this, taking the potential risk of agricultural product supply chain as the research object, the risk assessment index system of agricultural product supply chain is constructed, and the risk factors of agricultural product supply chain in Northeast China are evaluated by combining a variety of single weighting methods to improve the combination weighting method of level difference maximization. The results show that the combination weighting method of level difference maximization is more reasonable in weight distribution than the single weighting method. On the whole, production risk is the key field of agricultural product supply chain risk management. Among the secondary risk factors, agricultural products refrigeration security, supply and demand uncertainty and product processing quality risk factors are the main factors affecting the risk of agricultural products supply chain.

1. Introduction

At present, the agricultural product market is facing the normalization of epidemic prevention and control, the promotion of double circulation pattern and the new requirements of modern circulation system construction. We need to stabilize and develop the agricultural product supply chain, strengthen the construction of agricultural product supply chain, and promote the innovation of agricultural product supply chain [1]. Agricultural product supply chain is a complex supply chain system, involving rural product production, circulation, sales, services, agricultural material procurement and other business links, as well as agricultural material distributors, manufacturers, farmers and regulatory authorities at all levels [2]. Long industrial chain links and business entities make the agricultural product supply chain more likely to encounter many risks from the macro and micro environment. For example, there are limitations in distribution, scattered business units, extensive business categories, and numerous employees. In view of this, it is necessary to identify and evaluate the risk factors in the agricultural supply chain under the background of the new coronavirus epidemic and the dual-cycle construction, and formulate reasonable and effective risk control measures to improve the risk prevention and control mechanism of the agricultural supply chain.

Compared with other industries, agricultural product supply chain has more opportunities to face risk threats, and many scholars have focused on the key field of agricultural product supply chain risk. Zhang (2022) divided the security risks of agricultural product supply chain into eight types, such as natural disasters and policy intervention, and proposed the corresponding risk response mechanism [1]. In order to make up for the shortcomings of ordinary statistical methods, Xu Peng (2018) evaluated the financial risks of agricultural product supply chain with reference to the characteristics of structural equation model, and proposed risk control measures [3]. Li et al. (2017) used ANP-Fuzzy method to evaluate the risk factors of agricultural products supply chain including planting, circulation and other seven levels [4]. Based on six aspects of biological risk and industry risk, Zhou et al. (2016) constructed the risk index system of poultry supply chain, and used intuitionistic fuzzy analytic hierarchy process to identify and evaluate the risk [5]. Fan et al. (2016) introduced fuzzy multi-attribute method to evaluate the risk of agricultural product supply chain, which reduced the subjectivity of risk assessment [6]. In addition, some scholars analyzed the supply chain risk from the perspective of system simulation. Zhang et al. (2021) divided the supply chain risk of agricultural products from the outside to the inside of the system, and used system dynamics to simulate and analyze the risk factors [7].

Thus, it can be seen that the research on the construction of risk index system and risk factor evaluation method is in the majority. Scholars use subjective, objective weighting method or combination weighting method to evaluate the work, and have made many achievements. But the analysis found that there are some problems: different subjective and objective empowerment will appear index weight bias problem; the rationality and explanation of weight distribution of combination weighting method are weak; in view of this, the application of the combination weighting method of level difference maximization to the risk assessment of agricultural product supply chain can effectively evaluate the importance of risk factors in agricultural product supply chain, provide a reasonable reference for formulating risk prevention measures, and have certain reference significance for improving the risk prevention and control system of agricultural product supply chain.

2. Evaluation Index System and Evaluation Method

2.1. Construction of Risk Index System of Agricultural Products Supply Chain

On the basis of combing the above literature research results [1-7] and combining with expert advice, based on the principles of systematic, scientific and practical, selecting representative risk factors, this study constructs the risk index system of agricultural product supply chain, including four first-level indicators of logistics risk, production risk, information risk and market risk and 15 second-level indicators, in order to comprehensively and objectively evaluate the risk of agricultural product supply chain, as shown in Table 1.

Table 1: Risk index system of agricultural products supply chain.

first grade index	second index
logistics risk	distribution timeliness
	product loss
	refrigeration guarantee of products
production risk	natural disaster
	planting quality
	product processing quality

	risk of pest disease prevention
information risk	information asymmetry
	information lagging
	authenticity of information
market risk	supplier competition
	consumer preference
	fluctuation in prices
	risk of cargo delay
	uncertainty of supply and demand

2.2. Combined Weighting of Level Difference Maximization

At present, the goal of common combination weighting methods such as additive synthesis and multiplicative synthesis is to take into account the advantages of subjective and objective weighting and avoid the disadvantages of different methods leading to different results. However, it is also faced with the problem of insufficient explanation. It cannot be reasonably expressed that this combination weighting method does not have the shortcomings of both, but the advantages [8]? Therefore, this study adopts a more reasonable combination weighting method of level difference maximization, which takes into account the advantages of subjective and objective weighting, and the combination weighting value of the optimal solution is located in the intersection of subjective and objective weighting intervals, which is explanatory and reliable [9]. Moreover, the combination weighting model of level difference maximization takes the maximum variance as the target value, and the obtained combination weight value makes the evaluation results have higher discrimination and better performance.

The specific steps of the combination weighting model of level difference maximization are as follows [10]:

(1) Construction of scoring matrix N

The standard score matrix N is obtained after data processing of a index evaluation of the selected k evaluation objects, as shown below.

$$N=\left[n_{ij}\right]_{a*k}=\begin{bmatrix} n_{11} & n_{12} & \cdots & n_{1k} \\ n_{21} & n_{22} & \cdots & n_{2k} \\ \vdots & \ddots & \ddots & \vdots \\ n_{a1} & n_{a2} & \cdots & n_{ak} \end{bmatrix} \tag{1}$$

Where n_{ij} represents the score of the j-th evaluation object on the i-th index.

(2) Construction of Single Weight Matrix M

Let M be the weight matrix, there are a index, b weighting methods, as follows:

$$M=\left[m_{ij}\right]_{a*b}=\begin{bmatrix} m_{11} & m_{12} & \cdots & m_{1b} \\ m_{21} & m_{22} & \cdots & m_{2b} \\ \vdots & \ddots & \ddots & \vdots \\ m_{a1} & m_{a2} & \cdots & m_{ab} \end{bmatrix} \tag{2}$$

Among them, m_{ij} represents the single weight of the i-th index obtained by the j-th weighting method.

(3) Calculation of reasonable interval of combination weight

Let m_i^- and m_i^+ be the minimum and maximum weights of the i-th indicator, respectively, that is, the reasonable range of combined weights is $\left[m_i^- \quad m_i^+\right]$. Set the combination weight vector $m=(m_1, m_2, \ldots, m_a)$, m_a represents the combined weight value of the a-th indicator.

(4) Construction of variance expression for evaluation results

The variance calculation of the evaluation results is shown in Equation (3), namely:

$$s^2 = \frac{1}{k-1}\sum_{i=1}^{k}\left(mN_i - m\overline{N}\right)^2 = \frac{1}{k-1}\sum_{i=1}^{k} mH_i m^T \tag{3}$$

Among them, $H_i = \left(N_i - \overline{N}\right)\left(N_i - \overline{N}\right)^T, \overline{N} = \left(N_1 + N_2 + ... + N_k\right) / k$.

(5) Construction of the combination weighting model of level difference maximization

$$\begin{aligned} & max \ \frac{1}{k-1}\sum_{i=1}^{k} mH_i m^T \\ & s.t. \begin{cases} \sum_{i=1}^{k} m_i = 1 \\ m_i^- \le m_i \le m_i^+ \end{cases} \end{aligned} \tag{4}$$

Taking s^2 maximum as objective function, weight sum 1 and weight interval as constraints, an optimization model is constructed to solve the optimal combination weight $m = (m_1, m_2, ..., m_a)$.

Finally, combined with the combination weight, the evaluation score results are obtained, as shown in Equation (5):

$$Z = mN = \left(mN_1 \quad mN_2 \quad ... \quad mN_k\right) \tag{5}$$

3. Empirical Study

Northeast China is an important agricultural production area in China. Most regions have developed from self-sufficiency to commodity production, which provides great advantages for the development of agricultural product supply chain in Northeast China. In order to build a more stable and safe supply chain system, the combination weighting method of level difference maximization is applied to the risk assessment of agricultural products supply chain in the region for empirical research.

3.1. Risk Assessment of Agricultural Products Supply Chain in Northeast China

(1) Risk index score

On the basis of the existing research results in the field of agricultural products supply chain risk [2-7], based on the actual development of agricultural products supply chain in the three northeastern provinces, and combined with the relevant experts in the field of logistics and agriculture to score, the results are shown in Table 2 below.

Table 2: Risk index score.

first grade index	second index	risk index score		
		Liaoning province	Jilin province	Heilongjiang province
logistics risk	distribution timeliness	0.7155	0.5367	0.4472
	product loss	0.6285	0.5500	0.5500
	refrigeration guarantee of products	0.4082	0.8165	0.4082
production risk	natural disaster	0.6389	0.5111	0.5750
	planting quality	0.7276	0.4851	0.4851
	product processing quality	0.3333	0.6667	0.6667
	risk of pest disease prevention	0.7071	0.5657	0.4243
information risk	information asymmetry	0.5698	0.6838	0.4558
	information lagging	0.7276	0.4851	0.4851

	authenticity of information	0.5392	0.6470	0.5392
market risk	supplier competition	0.5298	0.6623	0.5298
	consumer preference	0.8018	0.2673	0.5345
	fluctuation in prices	0.4851	0.7276	0.4851
	risk of cargo delay	0.5262	0.6013	0.6013
	uncertainty of supply and demand	0.4558	0.5698	0.6838

(2) Calculation of single weight and Combination weight

The entropy method, G1 method and standard deviation method are used to weight the index, and then the single weight value and Table 2 risk index score data are substituted into the level difference maximization model (4) to solve the combined weight. The obtained weight value is shown in Table 3.

Table 3: Single index weight and Combination weight.

first grade index	second index	entropy method	G1 method	standard deviation method	combination weight
logistics risk	distribution timeliness	0.0572	0.0627	0.0714	0.0714
	product loss	0.0061	0.0228	0.0237	0.0237
	refrigeration guarantee of products	0.1767	0.1116	0.1232	0.1767
production risk	natural disaster	0.0124	0.0372	0.0334	0.0372
	planting quality	0.0588	0.0703	0.0732	0.0732
	product processing quality	0.1311	0.1210	0.1006	0.1311
	risk of pest disease prevention	0.0631	0.0621	0.0739	0.0739
information risk	information asymmetry	0.0403	0.0482	0.0596	0.0596
	information lagging	0.0588	0.0703	0.0732	0.0732
	authenticity of information	0.0115	0.0295	0.0325	0.0181
market risk	supplier competition	0.0174	0.0362	0.0400	0.0174
	consumer preference	0.2616	0.1556	0.1397	0.1397
	fluctuation in prices	0.0588	0.0663	0.0732	0.0588
	risk of cargo delay	0.0057	0.0273	0.0227	0.0057
	uncertainty of supply and demand	0.0403	0.0789	0.0596	0.0403

(3) Calculation variance and Evaluation results

Substituting the score data, single weight and combined weight values into Formula (3), the respective variances are obtained: the entropy method is 0.0017, the G1 method is 0.0009, the standard deviation method is 0.0015, and the combination weighting method of level difference maximization is 0.0018, which verifies the advantages of large discrimination of combined weight.

The risk index score and combined weight value of Table 2 are substituted into formula (5) to solve the risk assessment score of each province: Liaoning Province is 0.5793, Jilin Province is 0.5853, and Heilongjiang Province is 0.5086.

3.2. Statistical Analysis

In terms of risk assessment scores, the northeast three provinces from strong to weak are Jilin Province (0.5853), Liaoning Province (0.5793) and Heilongjiang Province (0.5086). Jilin Province has a huge agricultural market and is also an important logistics center in Northeast China. Under the assistance of information technology, adjust and upgrade the supply chain structure of agricultural products, and actively integrate into the modern circulation system promoted by the state. Followed by Liaoning Province and Heilongjiang Province, is also an important agricultural production base, and actively build a modern circulation system of agricultural products, improve risk prevention and control system, to ensure the smooth operation of the supply chain network.

According to the weight of indicators at all levels, it can be seen that among the first-level risk indicators, the largest weight is production risk, with a value of 0.3154. The weights of logistics risk and market risk are 0.2718 and 0.2619 respectively. The minimum is information risk, with a value of 0.1509. On the whole, the production risk is the key prevention field of supply chain risk management, which is easy to face natural disasters, insect diseases and other risks. It is necessary to focus on ensuring the production safety of agricultural products. Logistics risk and market risk are also key areas in risk management. Among the secondary indicators, the risk of product refrigeration guarantee is the greatest, and the weight is 0.1767; the second is the uncertainty of supply and demand, the weight is 0.1397, the weight of product processing quality is close to 0.1311. In terms of cold storage security, there are some disadvantages in Northeast China, such as less cold storage and preservation facilities for agricultural products, imperfect modern equipment and technology, and lack of professional cold chain logistics talents. In addition, most agricultural products failed to enter the cold storage system, and the full cold chain service coverage was small. In terms of supply and demand uncertainty, affected by the epidemic, the supply of origin and market demand show obvious uncertainty, which cannot realize reasonable resource allocation and cause waste. Product processing quality affects consumers' and purchasers' recognition of agricultural products in Northeast China, and has a great impact on upstream and downstream enterprises of the supply chain. If there are problems, the losses caused cannot be recovered. Therefore, agricultural products cold storage security, supply and demand uncertainty and product processing quality risk factors are the main factors of agricultural supply chain risk management in Northeast China, which cannot be ignored. Finally, the remaining secondary risk factors such as insect disease risk, information lag, planting quality and distribution timeliness should also be included in the risk management of agricultural products and formulate corresponding risk prevention measures.

4. Conclusion

In view of the shortcomings of subjective and objective weighting methods in the traditional risk assessment of agricultural product supply chain, the combination weighting method of level difference maximization is used to evaluate the risk index. The main conclusions are as follows:

(1) The risk index system of agricultural product supply chain is constructed, including logistics risk, production risk, information risk and market risk four first-level indicators and 15 second-level indicators. The weight of risk index is determined by the combination weighting method of level difference maximization, which solves the problem of different weighting methods and the deviation of standard weight. Taking into account the advantages of subjective and objective evaluation methods, the weight distribution is more reasonable and has strong explanatory.

(2) The empirical analysis shows that, from the overall perspective of the agricultural product supply chain, production risk is the key prevention field of supply chain risk management, followed by logistics risk and market risk, and is also the key field of risk management. According to the subdivision of risk factors, among the secondary risk factors, the cold storage security of agricultural products, the uncertainty of supply and demand, and the risk factors of product processing quality are the main factors affecting the risk of agricultural products supply chain. The risks of insect diseases and information lag should also be given a certain degree of attention.

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