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Research on Performance Evaluation of Green Supply Chain of Agricultural Products Based on G1-Entropy Weight Method

Dechuan Geng*, Huixia Zhu, Shuliang Chen
School of Economics and Management, Liaoning University of Technology, Jinzhou, Liaoning, 121001, China
**corresponding author*

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Abstract: With the continuous improvement of consumers' demand for green quality of products, it is necessary to strengthen the green supply chain management of agricultural products to reduce the useless consumption of resources and environmental pollution losses. Taking the green supply chain of agricultural products as the research object, this study constructs the performance evaluation index system from five aspects: financial performance, innovation performance, supply chain operation performance, green performance and social performance. Then based on the G1 and entropy weight method, the combination weighting performance evaluation with the minimum sum of squares deviation is used. The empirical research shows that supply chain operation performance factor and green performance factor play a leading role in the performance evaluation framework of agricultural green supply chain. In terms of decomposition, it is necessary to focus on the brand size, inventory capacity, response time, environmental reputation and resource utilization efficiency of agricultural products. It also proves that this method is feasible.

1. Introduction

Agriculture is the foundation of the national economy and plays an important role in stabilizing the development of social economy. In recent years, the supply chain of agricultural products has developed rapidly, but there are also many problems, which consume a lot of agricultural resources in the production process and fail to achieve the optimal allocation of resources. The use of pesticides and the accumulation of waste have also caused environmental pollution and brought immeasurable losses [1]. With the popularization of green concept, people have higher and higher requirements for the quality of agricultural products, and gradually realize the green supply chain management of agricultural products, and control the various environmental and resource utilization problems caused by the production, transportation, sales and inventory of agricultural products [2]. In order to understand the development status of each node in the supply chain, it is necessary to carry out reasonable performance evaluation. It is an important information feedback link and a key link in the process of green supply chain management. Reasonable and effective evaluation of green supply chain performance of agricultural products can provide corresponding reference for the green supply chain management of each node subject, so as to better realize the optimization of resource allocation and the minimization of environmental loss cost [3]. Therefore, taking the green supply chain as the innovation breakthrough point of the extensive development of traditional agriculture and studying the performance evaluation of the green supply chain of agricultural products can suit the remedy to the case, improve its ability to continuously improve and break through itself, and realize the high-quality development of agriculture and the improvement of overall performance.

Research on the performance evaluation of green supply chain of agricultural products has been widely concerned by scholars from different levels. Zheng (2022) carried out performance evaluation analysis combined with other factors such as environmental friendliness, and believed that the focus should be on collaborative ability and green environmental protection effect [4]. Based on the characteristics of agricultural products, Wang et al. (2020) constructed the supply chain performance evaluation index of green agricultural products, and evaluated it by grey clustering and fuzzy comprehensive evaluation [5]. Chen et al. (2018) established a reasonable and effective index system according to the basic principles of comprehensiveness and feasibility to solve the problems of excess, cumbersome links and wide distribution of agricultural products logistics enterprises [6]. Cao et al. (2017) used PCA to reduce the dimension, constructed the index system including economy, innovation and environment, and used the DEA model to evaluate the performance of the green supply chain of agricultural products in Shandong Province, and found that there were problems such as waste of resources and lack of innovation [7]. Zhou et al. (2016) took the agricultural products cold chain logistics company as the evaluation target, and established the corresponding green supply chain performance evaluation framework for the problems of nonstandard and extensive industrial development, which provided some reference for the cold chain logistics industry [8]. Other scholars from the supply chain risk management research, Li et al. (2016) studied how to deal with emergencies in the green supply chain of agricultural products, put forward the procedures for collaborative processing, and concluded that multi-agent technology was used to build a platform [9].

Literature review shows that the research mainly focuses on the index system construction of green supply chain of agricultural products and the use of performance evaluation methods. Under this premise, based on the green concept and the characteristics of agricultural products, this study constructs the performance evaluation index system of agricultural products green supply chain. Taking 14 cities in Liaoning Province as the research scope, on the basis of G1 and entropy weight method, the combination weighting method with the minimum deviation square sum is used to evaluate the performance, and the corresponding performance improvement suggestions are put forward, which provides some reference for the improvement of supply chain performance in the field of green agricultural products.

2. Performance Evaluation Index System and Evaluation Method

2.1. Construction of Performance Evaluation Index System for Green Supply Chain of Agricultural Products

On the basis of combing the above literature research results [1-9] and combining with the suggestions of experts in the field of agricultural products, based on the principles of systematic, scientific and practical, the representative performance influencing factors are selected, and the performance evaluation index system of agricultural products green supply chain is constructed, including five first-level indicators and 21 second-level indicators of financial performance, innovation performance, supply chain operation performance, green performance and social performance, in order to comprehensively and objectively evaluate the performance of agricultural products green supply chain, as shown in Table 1.

Table 1: Performance evaluation index system of green supply chain of agricultural products.

first grade index	second index	index type
financial performance	profitability	positive index
	capital turnover rate	positive index
	debt paying ability	positive index
	total supply chain cost	negative index
innovation performance	application quantity of new technology for agricultural products	positive index
	brand size of agricultural products	positive index
	new product sales income ratio	positive index
	staff training effect	positive index
supply chain operation performance	information processing efficiency	positive index
	inventory capacity	positive index
	logistics transportation efficiency	positive index
	response time	negative index
	customer satisfaction	positive index
green performance	total emission of three wastes	negative index
	resource efficiency	positive index
	waste utilization rate	positive index
	environmental protection reputation	positive index
	investment in pollution control	positive index
social performance	employee welfare security	positive index
	incidence of safety accidents	negative index
	green public welfare activities	positive index

2.2. Determination Method of Index Weight

G1 method and entropy weight method are used to determine the subjective weight and objective weight of each index, and then the combination weight value of each index is determined based on the combination weight method of the minimum deviation square sum [10], which reflects the real value of each index more reasonably and avoids the deviation problem of a single subjective and objective weighting method.

2.2.1. G1 Method

G1 method is a qualitative comparison of indicators, and then quantitative assignment of indicators. The specific steps are as follows:

(1) Determine the order relationship

According to the relevant literature and expert evaluation, the relative value of different indicators is compared, and the order relationship between indicators x_j is given: $x_1 > x_2 > \ldots\ldots > x_m$.

(2) Rational assignment

Experts judge according to the rational assignment reference table in Table 2, and calculate the rational assignment between indicators x_j and x_{j-1} according to the value between indicators, as follows (1).

$$r_j = w_{j-1} / w_j \tag{1}$$

The reference value of rational assignment is shown in Table 2.

Table 2: Reference table of rational assignment.

r_j	meaning
1.0	x_j and x_{j-1} are equally important
1.2	x_{j-1} is slightly more important than x_j
1.4	x_{j-1} is Significantly more important than x_j
1.6	x_{j-1} is strongly more important than x_j
1.8	x_{j-1} is extremely more important than x_j

(3) Index weight solution

According to rational assignment r_j, the weight w_j of the j-th index can be calculated, as shown in formula (2). Then according to the weight w_j to solve the remaining index weight value, as shown in formula (3).

$$w_j = (1+\sum_{k=2}^{m}\prod_{i=k}^{m} r_i)^{-1} \tag{2}$$

$$w_{k-1} = r_k w_k, k = j, j-1, ...3, 2 \tag{3}$$

Among them, $\sum_{k=2}^{m}\prod_{i=k}^{m} r_i = r_2 r_3 r_4 + r_3 r_4 + r_4$.

(4) Weight vector solution

By solving the vector constituted by the weight of evaluation index, w_j^z value can be obtained from Equation (4).

$$w_j^z = (w_1, w_2, w_3, w_4)^T * (w_1^*, w_2^*, w_3^*, w_4^*) \tag{4}$$

Among them, (w_1, w_2, w_3, w_4) is the weight vector of the overall objective level to the first level indicator level, and $(w_1^*, w_2^*, w_3^*, w_4^*)$ is the weight vector of the first level indicator level to the second level indicator level.

2.2.2. Entropy Weight Method

Entropy method is based on the entropy value of an index to determine the degree of change of an index. The greater the change is, the greater the effect on the evaluation results is. The specific calculation process is as follows:

(1) Determine the proportion of features

Let x_{ij} denote the score of the j-th indicator of the i-th scheme, and P_{ij} denote the characteristic proportion of the j-th indicator of the i-th scheme, then P_{ij} is:

$$P_{ij} = \frac{x_{ij}}{\sum_{i=1}^{n} x_{ij}} \tag{5}$$

(2) Determine the entropy value

The entropy e_j of the j-th indicator is:

$$e_j = -\frac{1}{\ln n}\sum_{j=1}^{n} P_{ij}\ln(P_{ij}) \tag{6}$$

(3) Determine index weight vector w_j^s

$$w_j^s = \frac{1-e_j}{n-\sum_{j=1}^{n} e_j} \tag{7}$$

2.2.3. Combination Weighting with Minimum Sum of Deviation Squares

(1) Determination of combination weight

Set W_j^{**} to represent the combination of subjective weight w_j^z and objective weight w_j^s, the formula is as follows:

$$W_j^{**} = \beta w_j^z + (1-\beta) w_j^s \tag{8}$$

β represents the proportion of subjective weights.

Establish a model for minimizing the sum of squares of deviations, as shown in formula (9):

$$\min z = \sum_{j=1}^{m} \left[\left(W_j^{**} - w_j^z \right)^2 + \left(W_j^{**} - w_j^s \right)^2 \right] \tag{9}$$

Insert formula (8) into formula (9) can get:

$$\min z = \sum_{j=1}^{m} \left(w_j^z - w_j^s \right)^2 \left[(\beta-1)^2 + \beta^2 \right] \tag{10}$$

Derivation β of formula (10), let the first derivative be zero and get β=0.5, so the combined weight expression is:

$$W_j^{**} = 0.5 w_j^z + 0.5 w_j^s \tag{11}$$

The deviation square sum of subjective weight w_j^z of G1 method and objective weight w_j^s of entropy weight method with combination weight reaches the minimum, and the combination weight is more reasonable.

(2) Comprehensive evaluation score of indicators

P_i is the comprehensive evaluation score of system *i*, and the formula is as follows:

$$P_i = \sum_{j=1}^{n} p_{ij} W_j^{**} \tag{12}$$

3. Empirical Study

Liaoning Province is an important export province of agricultural products in China. In recent years, a series of agricultural development policies have made great growth in agricultural production in Liaoning Province. In order to achieve the high-quality development of agricultural products supply chain in Liaoning Province, change the mode, and accelerate the construction of agricultural products green supply chain system, the combination weighting method with the minimum sum of squares deviation is applied to the performance evaluation of agricultural products green supply chain in the region for empirical research.

3.1. Performance Evaluation of Green Supply Chain of Agricultural Products in Liaoning Province

The evaluation objects of this study are 14 cities in Liaoning Province: Shenyang, Dalian, Anshan, Fushun, Benxi, Dandong, Jinzhou, Yingkou, Fuxin, Liaoyang, Panjin, Tieling, Chaoyang and

Huludao.

(1) Performance indicators score

On the basis of the existing research results in the field of green supply chain performance evaluation of agricultural products [3-9], based on the actual development of green supply chain of agricultural products in Liaoning Province, and combined with relevant experts in the field of logistics and agriculture, 14 cities in Liaoning Province were scored.

(2) Determine the index weight

1) The indexes are sorted by relevant experts to determine the order relationship and rationally assign values. The subjective weights of each index are calculated according to Equations (2) to (4). The weight values obtained by G1 method are shown in Table 3.

2) Substituting the performance index score data into Equations (5) to (7) to calculate the objective weight value of each index. The weight value obtained by the entropy method is shown in Table 3.

3) The subjective weight of G1 method and the objective weight of entropy method (12), and the combined weight value is obtained, as shown in Table 3.

Table 3: Weight of performance evaluation index.

first grade index	second index	G1 method	Entropy method	Combination weight
financial performance	profitability	0.0347	0.0367	0.0357
	capital turnover rate	0.0465	0.0424	0.0444
	debt paying ability	0.0506	0.0600	0.0553
	total supply chain cost	0.0640	0.0415	0.0528
innovation performance	application quantity of new technology for agricultural products	0.0405	0.0412	0.0409
	brand size of agricultural products	0.0662	0.0889	0.0776
	new product sales income ratio	0.0474	0.0484	0.0479
	staff training effect	0.0560	0.0507	0.0533
supply chain operation performance	information processing efficiency	0.0297	0.0189	0.0243
	inventory capacity	0.0763	0.0590	0.0676
	logistics transportation efficiency	0.0470	0.0248	0.0359
	response time	0.0554	0.0689	0.0621
	customer satisfaction	0.0619	0.0406	0.0513
green performance	total emission of three wastes	0.0482	0.0396	0.0439
	resource efficiency	0.0495	0.0642	0.0569
	waste utilization rate	0.0317	0.0567	0.0442
	environmental protection reputation	0.0501	0.0726	0.0614
	investment in pollution control	0.0349	0.0337	0.0343
social performance	employee welfare security	0.0224	0.0131	0.0178
	incidence of safety accidents	0.0517	0.0508	0.0513
	green public welfare activities	0.0351	0.0472	0.0411

(3) Performance evaluation score

The performance evaluation scores of 14 cities can be obtained by substituting Table 3 weight value and standard score data (12). Scores and ranking results as shown in Table 4:

Table 4: Performance evaluation score and ranking.

city	performance evaluation score	ranking of performance results
Shenyang	0.714	2
Dalian	0.733	1
Anshan	0.553	10
Fushun	0.444	13
Benxi	0.409	14
Dandong	0.586	8
Jinzhou	0.669	3
Yingkou	0.577	9

Fuxin	0.605	7
Liaoyang	0.450	12
Panjin	0.480	11
Tieling	0.615	5
Chaoyang	0.654	4
Huludao	0.614	6

3.2. Statistical Analysis

According to the combined weight results of Table 3, it can be seen that in the first level index, the largest combined weight value is the supply chain operation performance, the value is 0.2412; the value of green performance is 0.2407; then is the innovation performance, the value is 0.2197; finally, financial performance and social performance, the values were 0.1882 and 0.1102, social performance accounted for the smallest. Thus, supply chain operation performance factor and green performance factor play a leading role in the performance evaluation framework of agricultural green supply chain. The environment faced by the green supply chain of agricultural products is complex and changeable. The supply chain itself needs to continue to operate, improve the efficiency of information processing, and adopt more advanced information technology means to analyze the authenticity and effectiveness of surrounding information. At the same time, it is also necessary to optimize the logistics path, improve the efficiency of logistics transportation, and indirectly affect customer satisfaction and service response time. Supply chain inventory capacity determines the acceptance and transshipment capacity of agricultural products. The green performance factor is a necessary factor for the performance management of the green supply chain of agricultural products. The utilization efficiency of resources affects the production of wastewater, exhaust gas and solid waste in the supply chain. The higher the efficiency is, the lower the emission of three wastes is. Environmental pollution control input should also have a certain proportion in the total input of the supply chain, which is the requirement of building a high-quality supply chain. In the secondary indicators, the brand size of agricultural products is 0.0776, and the weight is the largest; secondly, the inventory capacity is 0.0676; then is the response time, environmental reputation and resource utilization efficiency. In detail, these factors are the main factors affecting the performance of the green supply chain of agricultural products, which need to focus on development and breakthrough, and then improve the overall performance of the supply chain.

According to the performance evaluation score and ranking of Table 4, it can be seen that the city with the highest performance level of agricultural green supply chain is Dalian, which is 0.733. Then there are six cities whose performance evaluation scores are higher than0.6: Shenyang, Jinzhou, Chaoyang, Tieling, Huludao and Fuxin, which are 0.714, 0.669, 0.654, 0.615, 0.614 and 0.605 respectively. These cities have high performance in Liaoning Province, which provides reference for the improvement of performance in other cities.

4. Conclusion

Based on the concept of green and the characteristics of agricultural products, this study constructs the performance evaluation index system of agricultural products green supply chain, which provides reference for the selection of existing performance evaluation indexes. At the same time, the combination weight of G1 method and entropy method is used to evaluate the performance of agricultural products green supply chain, which provides new ideas for the improvement of the performance level of agricultural products green supply chain in various regions. The main conclusions are as follows:

(1) This study constructs the performance evaluation index system of green supply chain of agricultural products, including five first-level indicators of financial performance, innovation

performance, supply chain operation performance, green performance and social performance and 21 second-level indicators. The weight of performance indicators is determined by the combination weighting of the minimum sum of squares of deviations of G1 method and entropy method, which effectively avoids the limitations of single weighting and reflects the experience judgment and subjective preference of experts while reflecting the changes of objective conditions. The combination weighting value is more reasonable.

(2) Empirical analysis shows that among the first-level indicators, supply chain operation performance factor and green performance factor play a dominant role in the performance evaluation framework of agricultural green supply chain, which are 0.2412 and 0.2407, respectively. Among the secondary indicators, the brand size of agricultural products is 0.0776, with the largest weight; secondly, the inventory capacity is 0.0676; then is the response time, environmental reputation and resource utilization efficiency. The analysis results can provide reference for the improvement of performance factors in the region, focus on prevention and development, and make decisions more accurate.

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