

ARTICLE

Study On Benefit Distribution of Improved Shapley Value in Fresh Agricultural Cold Chain

Jiayi Ge* Gengjun Gao

Shanghai Maritime University, Institute of logistics science and Engineering, Shanghai, 201200, China

ARTICLE INFO

Article history

Received: 21 August 2020

Accepted: 25 August 2020

Published Online: 31 August 2020

Keywords:

Fresh agricultural
Cold chain
Shapley
Benefit distribution

ABSTRACT

This article studies the problem of fresh agricultural cold chain and constructs a comprehensive benefit distribution model with improved Shapley value. First of all, this article considers the influence of input factors, risk factors, effort level on benefit distribution, and uses the entropy method, the order relationship analysis method to determine the benefit distribution coefficient under each influence factor. Then, this article establishes a comprehensive benefit distribution model, and uses the Topsis method to calculate the weight of each participating enterprise. Finally, the simulation result shows the feasibility and effectiveness of the proposed methods. The profit distribution model in this article takes into account the degree of contribution to participating enterprises to the cooperation and their satisfaction with the benefits distribution, solves the problem of unfair benefits distribution of the fresh agricultural cold chain, and thus promotes the stability of the cooperation among participating enterprises.

1. Introduction

China is a big producer of fresh agricultural products, with about 4 trillion tons of fruits and vegetables entering the market every year. Fresh agricultural products, as an important part of agriculture, are one of the important driving forces for the growth of agricultural economy. However, in recent years, the prices of fruits and vegetables among fresh agricultural products have increased greatly, while the cold chain of fresh agricultural products has an “arch bridge effect”. Members of both ends of the supply chain have low incomes, while the income at the middle link is too high for the unfair distribution of benefits. Due to the strict requirements on transportation conditions of fresh agricultural products, unreasonable profit distribution will lead to negative

cooperation attitude to supply chain members, which will reduce the operation efficiency of the supply chain and the quality of agricultural products, and seriously hinder the development of cold chain of fresh agricultural products. Therefore, how to design a fair and reasonable benefit distribution scheme has become an urgent problem in cold chain of fresh agricultural products.

There are few researches on the distribution of benefits in the cold chain of fresh agricultural products, but many scholars have studied and paid attention to the distribution of benefits in the supply chain of agricultural products. Huang Yong^[1] investigated the data of the pork industry chain in EnShi, Hubei, and analyzed the supply of pork. The income of chain breeding, processing, and sales shows that the income of the sales link is much higher

*Corresponding Author:

Jiayi Ge,

Shanghai Maritime University, Institute of logistics science and Engineering, Shanghai, 201200, China;

Email: 844289208@qq.com

than that of processing and breeding, which greatly affects the stability of the supply chain. Chun Feng et al. [2] analyzed the situation of “low vegetables hurting farmers” and “expensive vegetables hurting the people”, and concluded that the main body of the supply chain will affect the distribution of benefits. The participation of farmers in cooperatives can increase the output and income of agricultural products, while reducing Prices increase overall revenue. Minghua Jin et al. [3] analyzed the benefit distribution of agricultural product supply chain under the background of “New Retail”, and studied the influence of the three aspects of the supply chain’s risk-taking, innovation ability and cooperation degree on benefit distribution. Wenjuan Tu et al. [4] studied the supply chain stability, income, and pricing of agricultural products under different cooperative situations between farmers and agricultural cooperatives from the perspective of supply chain. The above literature discusses the distribution of benefits in the supply chain in terms of pricing, models, and partnerships, but did not involve the decay of agricultural product freshness over time, which affects the income of the supply chain. The freshness of agricultural products is an important factor affecting the sales link and the income of supply chain [5].

In terms of interest distribution method, Shapley value method can give consideration to both “fairness” and “efficiency”, effectively mobilize the enthusiasm of enterprises, and the calculation method is monotonous and operable, so this paper intends to adopt Shapley value method to solve the interest distribution problem of fresh agricultural products cold chain. Representative studies on the application of Shapley value method include: Maersk et al. [6] solved the benefit distribution problem of multi-person cooperation based on Shapley value method. Bahinipati [7] applied Shapley value method to the cooperation field of semiconductor alliance to ensure the fairness of benefit distribution. Jerzy Martyna [8] used the Shapley value to solve the power allocation problem of the secondary users in the Radio Network Alliance, and verified the results with a simulation model to prove the validity of the Shapley value. Although the Shapley value is a relatively common method to solve the problem of income distribution in cooperative games, this method has certain limitations. It ignores the indirect factors that lead to the increase or decrease of income. To solve this problem, many scholars have improved Shapley value. Lilin Diao et al. [9] proposed the multi-weight Shapley value method to solve the benefit distribution. . Baizhou Li et al. [10] improved Shapley by using analytic hierarchy process to determine risk factors, selected innovation factors and risk factors of cooperative enterprises,

and solved the benefit distribution of cooperative enterprises. Weigan Li et al. [11] studied the compensation apportionment of various regions in the basin based on the DEA-Shapley value model, considering the importance of input and output in each region, and using trapezoidal fuzzy numbers to determine the weight coefficients of each region to improve the Shapley value method. Compensation apportionment provides decision-making reference. Xu et al. [12] used the gray correlation method to improve the Shapley value and established a theoretical model of the centralized market revenue distribution mechanism, and solved the benefit distribution of the green supply chain. Yiheng Xi et al. [13] used fuzzy analysis to improve the Shapley value, considering risk, investment and member satisfaction as influencing factors, and constructed a supply chain cooperation benefit distribution model. Through the above-mentioned literature analysis, it is found that the improvement process of the Shapley value method has the shortcomings of strong subjectivity or objectivity, which leads to the problem of indicator weight deviation. On the basis of the above-mentioned research, this article uses a combination of subjective and objective methods to improve the shapley value model, and discusses the distribution of cold chain benefits of fresh agricultural products.

2. Influencing Factors of Cold Chain Profit Distribution of Fresh Agricultural Products

It is difficult to evaluate the contribution of the participating members in the cold chain of fresh agricultural products to the cold chain, and the inapplicability of the benefit distribution method will lead to non-cooperative behavior in the cold chain cooperation of fresh agricultural products and hinder the development of the cold chain of fresh agricultural products. Therefore, by analyzing the characteristics of the cold chain of fresh agricultural products and the principle of benefit distribution, this paper proposes three factors affecting the distribution of benefits of the cold chain of fresh agricultural products.

2.1 Equipment Investment

Investment refers to the commodities or labor used by the enterprise in operation, the long-distance truck transportation, the variety of agricultural products, the strict and harsh transportation environment, and the high requirements on the operating equipment. At the same time, the scale of the cold chain is usually determined by the circulation of agricultural products. All is the investment of cold chain equipment, so equipment investment is an important factor in evaluating the distribution of benefits

of the cold chain of fresh agricultural products.

2.2 Fresh-keeping Effort Level

The level of fresh-keeping effort refers to the degree of active measures taken by participating members to preserve fresh agricultural products. The insurance effort of participating members of the cold chain of fresh agricultural products is also related to market demand and agricultural product pricing^[14]. Different behaviors and cooperative attitudes are also different, and a positive attitude will inevitably increase the benefits of the cold chain of fresh agricultural products^[15]. Therefore, the level of fresh-keeping effort as an influencing factor of benefit distribution can effectively avoid participating in the negative cooperative behavior of enterprises.

2.3 Risk Assumption

In the process of cold chain cooperation for fresh agricul-

tural products, participating companies face the risk of chain disconnection, time risk, production risk, etc. These risks directly affect the operation of the participating companies, resulting in a decrease in market share. In order to reflect the benefit sharing, Risk sharing, the greater the risk the participating companies bear, the greater the distribution of their profits. Therefore, risk-taking is an important factor affecting the distribution of benefits in the cold chain of fresh agricultural products.

3. Problem Definition

In the fresh produce cold chain, the farmer is responsible to order agricultural cooperatives agricultural planting, harvesting and other work; agricultural cooperatives to produce the collection, packaging, storage; supermarket responsible for the procurement, orders, inspection and other tasks, the sales of agricultural products to the market . The cold chain operation mode of fresh agricultural products is shown in Figure 1.

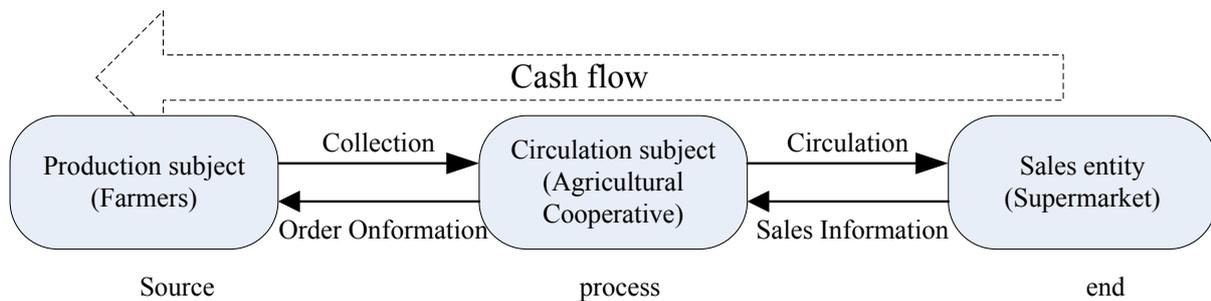


Figure 1. Cold chain operation mode of fresh agricultural products

The cold chain of fresh agricultural products has strict requirements on operating time, temperature control, links and service conditions. The fairness of the benefit distribution of the cold chain of fresh agricultural products directly affects the stability and reliability of the cold chain of fresh agricultural products. Xiaoqing Gan et al.^[16] found that the profit rate of the production link was 10%, the monthly fund return rate was 4%, the circulation link profit rate was 15.06%, the monthly fund return was 99%, and the sales link profit rate was found by investigating the Poyang Lake pig supply chain. 9.8%, and the monthly capital return rate is 146.9%. It can be seen that the upstream nodes that make a large contribution to the supply chain have a lower rate of return, while the middle and downstream nodes that contribute generally to the cooperation have a higher profit. This reduces the enthusiasm of many farmers to cooperate and benefits. Unfair distribution hinders the development of the supply chain. This paper studies the three-level cold chain of

fresh agricultural products, considering the impact of facility investment, preservation efforts, and risk-taking on the benefits of the cold chain of fresh agricultural products, using Shapley value, Topsis and other methods to study the distribution of benefits of the cold chain of fresh agricultural products.

To facilitate modeling, make assumptions:

(1) The participating members of the cold chain of fresh agricultural products are all rationally involved, and each member pursues the maximization of their own interests while participating in cooperation;

(2) The implementation of the cold chain of fresh agricultural products is supported and guaranteed by agreement;

(3) Before the implementation of the cold chain for fresh agricultural products, all parties will make feasibility predictions and cooperate only when it is “profitable”. The distribution benefits of the cold chain for fresh agricultural products have been estimated;

(4) Each member of the cold chain of fresh agricultural products joins the alliance organization randomly, regardless of order;

(5) The cold chain of fresh agricultural products consists of a farmer, an agricultural cooperative, and a seller.

4. Construction of a Cold Chain Benefit distribution model for fresh agricultural products with improved Shapley value

4.1 Shapley

Set $N=\{1,2,\dots,n\}$, for any subset s in set N , there is a corresponding function $V(S)$, and it satisfies:

$$V(\emptyset) = 0 \quad V(S_1 \cup S_2) \geq V(S_1) + V(S_2) \quad (1)$$

and

$$S_1 \cap S_2 = \emptyset \quad (2)$$

Then the benefit distribution determined by the *Shapley* value method means:

$$\phi_i(V) = \sum_{S \in S_i} W(|S|) [V(S) - V(S/i)] \quad i=1, 2, \dots, n \quad (3)$$

$$W(|S|) = \frac{(n-|S|)! (|S|-1)!}{n!} \quad (4)$$

$W(|S|)$ represents the weighting factor. S_i means that the set N contains all the subsets of the member i . $|S|$ represents the number of elements in the subset S . $V(S/i)$ is the income after removing member i from subset S . $\phi(V) = (\phi_1(V), \phi_2(V), \dots, \phi_n(V))$ is the benefit distribution of the cold chain of fresh agricultural products. The premise of the Shapley value method is that all participating members have an equal relationship, but it ignores the behavior of each member that indirectly leads to the increase or decrease of income, and cannot guarantee the fairness of income. Participating members have different investment in facilities and equipment, fresh-keeping efforts, and risk-taking. These factors constitute the bargaining power of participating members in the distribution of cold chain benefits of fresh agricultural products. Therefore, in the cold chain benefit distribution of fresh agricultural products, the above-mentioned influencing factors should be considered to revise the Shapley value of benefit distribution.

4.2 Determination of Influencing Factor Coefficients

4.2.1 Determination of Facility Investment Coefficient

The input factors of facilities and equipment B include the input of transport vehicles x_{1i} , the construction of re-

frigerated warehouses x_{2i} , the maintenance of refrigerated equipment x_{3i} etc. Through the quantitative analysis of each participating member's input of facilities and equipment, the weight of each participating member's input of facilities and equipment w_i^B is determined:

$$w_i^B = \frac{x_{1i} + x_{2i} + x_{3i}}{\sum_{i=1}^3 (x_{1i} + x_{2i} + x_{3i})}, \quad i=1, 2, 3 \quad (5)$$

The correction factor for facility investment is

$$\Delta w_i^B = w_i^B - \frac{1}{n}, \quad \sum_{i=0}^n \Delta w_i^B = 0. \quad \text{When } \Delta w_i^B > 0, \text{ it}$$

means that member i 's investment in the construction of the cold chain of agricultural products is higher than the average value of the overall input. At this time, member i should be given more compensation in the benefit distribution. When $\Delta w_i^B < 0$, the benefits should be reduced.

4.2.2 Determination of the Coefficient of Preservation Effort

When consumers buy agricultural products, they prefer fresh agricultural products. According to the description of the freshness of agricultural products in the literature [17], the freshness of agricultural products is expressed as $\theta_i = \theta_0 e^{-\eta x_{4i}}$. θ_0 indicates the freshness of the agricultural products at the moment they are picked from the orchard, $0 \leq \theta_0 \leq 1$, x_{4i} represents the operating time of each member's agricultural products, and the above function has the following properties:

(1) $\frac{d\theta_i}{dt} < 0$, it means that the freshness of agricultural products decreases with the loss of time;

(2) $\frac{d^2\theta_i}{dt^2} > 0$, it means that the freshness of agricultural products gradually slows down with the change of time.

In order to increase the overall profit and their own profits, each member has made efforts to preserve the freshness of agricultural products according to their own conditions in cooperation. η_0 Indicates the natural attenuation index of agricultural products. After each member adopts the preservation of agricultural products, the attenuation index is $\eta = a\eta_0$. a Indicates the sensitivity coefficient of preservation to the attenuation index, $a \in (0, 1)$. According to literature [18], on the assumption that product input and cost are quadratic function, the fresh-keeping input cost function of each member of the cold chain of fresh agricultural products is defined as $C = ka^2$, $i=1, 2, 3$. k represents the influence coefficient of preservation

efforts on cost, then:

$$\theta_i = \theta_0 e^{\{-[(1-\sqrt{\frac{C_i}{k}})n_0]x_{4i}\}} \quad (6)$$

The weight of the fresh-keeping effort level of each participating member is expressed as:

$$w_i^C = \frac{\theta_i - \theta_{i+1}}{\theta_0 - \theta_e} \quad (7)$$

θ_e indicates the freshness of the supermarket selling agricultural products. The correction coefficient for the preservation effort level is $\Delta w_i^C = w_i^C - \frac{1}{n}$, $\sum_{i=0}^n \Delta w_i^C = 0$. When

$\Delta w_i^C > 0$, it means that member i is actual fresh-keeping effort level is higher than the average value of the overall effort in the operation of the cold chain of fresh produce of agricultural products. At this time, member i should be given more compensation in the distribution of benefits; When $\Delta w_i^C < 0$, the revenue should be reduced to compensate other cooperative members.

4.2.3 Determination of Risk-taking Coefficient

Risk factor D includes time risk x_{5i} , chain break risk x_{6i} and quality risk x_{7i} . Through the quantitative analysis of the risk-taking of each participating member, the measured value of each indicator is standardized to obtain the judgment matrix $R=(r_{ji})_{n \times m}$. This paper uses the entropy method to determine the risk-taking weight of each participating member w_i^D :

$$w_i^D = \frac{1 - E_i^D}{m - \sum E_i^D}, \quad i = (1, 2, \dots, n) \quad (8)$$

$$E_i^D = -\ln(n)^{-1} \sum_{j=1}^m p_{ji} \ln p_{ji}, \quad i = (1, 2, \dots, n), j = (1, 2, \dots, m) \quad (9)$$

$$p_{ji} = \frac{r_{ji}}{\sum_{j=1}^m r_{ji}}, \quad i = (1, 2, \dots, n), j = (1, 2, \dots, m) \quad (10)$$

r_{ji} indicates the normalized data of the measured value of each indicator. p_{ji} indicates the normalized measurement value r_{ji} the probability of being in the i -type index. E_i^D represents the information entropy of each indicator. Then the correction coefficient of risk taking

is $\Delta w_i^D = w_i^D - \frac{1}{n}$, $\sum_{i=0}^n \Delta w_i^D = 0$. When $\Delta w_i^D > 0$, it means that the actual risk taken by member i in the practice of the cold chain of agricultural products is higher than the average value of the overall risk. At this time, member i should be given more risk compensation during

the benefit distribution; when $\Delta w_i^D < 0$, it should be Reduce benefits.

4.2.4 Determination of Relative Coefficients Among Influencing Factors

This paper establishes a set of influencing factors of benefit distribution $X = \{X_1, X_2, \dots, X_m\}$. According to the importance of each indicator, determine the order of the indicators. If X_i is more important than X_k , it is expressed as $X_i > X_k$. The ratio of the relative importance of the evaluation indicators X_{k-1} and X_k by experts is r_k , and the value of r_k is shown in Table 2 [19]. The order relation analysis method is used to determine the relative weight of each influencing factor w_β^z .

Table 2. Attribute comparison judgment table

| r_k | Description |
|-------|---|
| 1.0 | Attribute X_i has the same importance as attribute X_j |
| 1.1 | Attribute X_i is slightly more important than the attribute X_j |
| 1.2 | Attribute X_i is obviously more important than attribute X_j |
| 1.3 | Attribute X_i is more important than attribute X_j |
| 1.4 | Attribute X_i is extremely important than attribute X_j |

$$w_\beta^z = (1 + \sum_{\beta=2}^m \prod_{i=\beta}^m r_i^z)^{-1}, \quad (\beta = m, m-1, \dots, 2) \quad (11)$$

$$r_\beta = \frac{w_{\beta-1}^z}{w_\beta^z}, \quad (\beta = m, m-1, \dots, 2) \quad (12)$$

4.3 Improved Shapley Value of Fresh Produce Cold Chain Benefit Distribution Model

This article constructs the coefficient matrix A through w_β^z and w_i^B , w_i^C , w_i^D . Standardize matrix A to get matrix $B = (b_{ij})_{n \times m}$, b_{ij} is the corresponding element after standardization:

$$b_{ij} = \frac{a_{ij}}{\sqrt{\sum_{i=1}^n (a_{ij})^2}}, \quad j = (1, 2, \dots, m) \quad (13)$$

$$B = (b_{ij})_{n \times m} = \begin{bmatrix} b_{11} & b_{12} & \dots & b_{1m} \\ b_{21} & b_{22} & \dots & b_{2m} \\ \dots & \dots & \dots & \dots \\ b_{n1} & b_{n2} & \dots & b_{nm} \end{bmatrix} \quad (14)$$

Determine absolute ideal solution and negative ideal solution:

$$B^+ = \{(\max b_{ij} | j \in J^+), (\min b_{ij} | j \in J^-)\} = \{b_1^+, b_2^+, \dots, b_m^+\} \quad (15)$$

$$B^- = \{(\min b_{ij} | j \in J^+), (\max b_{ij} | j \in J^-)\} = \{b_1^-, b_2^-, \dots, b_m^-\} \tag{16}$$

$J^+ \cup J^- = J$, J^+ indicates that the larger the value, the better the set of indicators. J^- represents a set of indicators that the larger the value, the worse. This paper selects 1 and 0 as the absolute positive ideal value and the absolute negative ideal value of the positive index^[20].

Determine the Euclidean distance of each participating member to the positive and negative ideal point:

$$d_i^+ = \|b_{ij} - B^+\| = \sqrt{\sum_{j=1}^m w_{\beta}^2 (b_{ij}^+ - b_{ij})^2} \tag{17}$$

$$d_i^- = \|b_{ij} - B^-\| = \sqrt{\sum_{j=1}^m w_{\beta}^2 (b_{ij} - b_{ij}^-)^2} \tag{18}$$

Determine how close each participating member is to the ideal plan, and determine the coefficient w_i :

$$w_i = \frac{d_i^- / (d_i^+ + d_i^-)}{\sum_{i=1}^n [d_i^- / (d_i^+ + d_i^-)]}, i = (1, 2, \dots, n) \tag{19}$$

Then the improved Shapley value of fresh agricultural products cold chain benefit distribution $\phi_i(V)'$:

$$\phi_i(V)' = \sum_{S \in S_i} W(|S|)[V(S) - V(S/i)] + V(N) \times (w_i - \frac{1}{n}) \tag{20}$$

$W(|S|)$ represents the weighting factor. S_i means that the set N contains all the subsets of the member i . $|S|$ represents the number of elements in the subset S . $V(S/i)$ is the income after removing member i from subset S . w_i indicates the improved benefit distribution coefficient. d_i indicates the Euclidean distance of each participating

member to the positive and negative ideal point. $\phi(V) = (\phi_1(V), \phi_2(V), \dots, \phi_n(V))$ is the profit distribution of the cold chain of fresh agricultural products. Whether the improved comprehensive benefit distribution model meets the necessary conditions for cooperation needs to be further verified:

$$\begin{aligned} \sum \phi_i(V)' &= \sum_{S \in S_i} [\sum W(|S|)[V(S) - V(S/i)] + V(N) \times (w_i - \frac{1}{n})] \\ &= \sum \phi_i(V) + \sum [V(N) \times (w_i - \frac{1}{n})] \\ &= \sum \phi_i(V) + V(N) \sum (w_i - \frac{1}{n}) \\ &= \sum \phi_i(V) + V(N) (\sum w_i - \sum \frac{1}{n}) \\ &= \sum \phi_i(V) \\ &= V(N) \end{aligned}$$

5. The Example Simulation

Currently, there are three farmers A, agricultural cooperative B and supermarket C participating in the cold chain of fresh agricultural products. It is known that the profit of farmer A operating alone is 70,000 yuan, the profit of agricultural cooperative B operating alone is 80,000 yuan, the profit of supermarket C operating alone is 50,000 yuan; the profits of the two-two cooperation are $V_{AB}=208,000$ yuan, $V_{BC} = 179$ thousand yuan, $V_{AC} = 151,000$ yuan, and the profit of the three cooperative operations $V_{ABC} = 298,000$ yuan. According to the reference [17] for the value of the relevant parameters and the value basis, this paper sets the initial freshness $\theta_0 = 1$, attenuation index $\eta_0=0.07$, $k=0.5$.

Table 3. Operating situation of each participating member

| Main Body | Cold storage capacity | Refrigerated truck | Refrigerator | Work time | Preservation cost | On-time rate of agricultural products | Equipment failure rate | Agricultural product integrity rate |
|---------------------------|-----------------------|--------------------|--------------|-----------|-------------------|---------------------------------------|------------------------|-------------------------------------|
| Farmer | 2400 | 6 | 30 | 2 | 0.12 | 94 | 95 | 95 |
| Agricultural cooperatives | 2600 | 5 | 40 | 1.5 | 0.11 | 96 | 97 | 93 |
| Supermarket | 1800 | 3 | 20 | 2.5 | 0.13 | 92 | 94 | 96 |

According to formulas (5) ~ (10), the weight of each participating member under different influence factors is as follows:

Table 4. Weights of participating members under different influencing factors

| Influencing factors | Farmer | Agricultural cooperatives | Supermarket |
|------------------------|--------|---------------------------|-------------|
| Equipment investment | 0.3547 | 0.3198 | 0.3255 |
| Freshness effort level | 0.3498 | 0.2908 | 0.3594 |
| Exposures | 0.3601 | 0.3239 | 0.3160 |

According to formulas (11) ~ (12), $r^2 = \frac{y^1}{y^2} = 1.1$, $r^3 = \frac{y^2}{y^3} = 1$, $w_3^z = \frac{1}{1+r^2+r^3+r^3} = 0.3216$; The results are shown in the following table:

Table 5. Relative weights among influencing factors

| Influencing factors | Freshness effort level | Equipment investment | Exposures |
|---------------------|------------------------|----------------------|-----------|
| Relative weight | 0.386 | 0.2924 | 0.3216 |

Construct the coefficient matrix with the weight coefficients in Table 4 and Table 5, and substitute them into equations (15)~(20) to obtain the final benefit distribution result $\phi_i(V)$.

$$\phi_1(V) = \frac{1}{3} \times 25.3 + \frac{1}{6} \times 10.1 + 29.8 \times [0 - \frac{0.1978 / (0.3803 + 0.1978)}{1.9977} - \frac{1}{3}] = 10.41$$

$$\phi_2(V) = \frac{1}{3} \times 29.6 + \frac{1}{6} \times 12.9 + 29.8 \times [\frac{0.1814 / (0.1814 + 0.3971)}{0.9977} - \frac{1}{3}] = 11.45$$

$$\phi_3(V) = \frac{1}{3} \times 14 + \frac{1}{6} \times 18 + 29.8 \times [\frac{0.1968 / (0.1968 + 0.3788)}{0.9977} - \frac{1}{3}] = 7.94$$

The benefit distribution results before and after the Shapley value improvement are shown in the following table:

Table 6. Benefit distribution before and after Shapley value improvement

| | Farmer A | Agricultural cooperatives B | Supermarket C |
|---|----------|-----------------------------|---------------|
| Initial Shapley | 10.12 | 12.02 | 7.66 |
| Initial allocation ratio | 0.34 | 0.40 | 0.26 |
| Facility input correction factor | 0.0214 | -0.0135 | -0.0078 |
| Fresh-keeping effort level correction coefficient | 0.0165 | -0.0425 | 0.0261 |
| Risk-taking correction factor | 0.0268 | -0.0094 | -0.0173 |
| Improved Shapley | 10.41 | 11.45 | 7.94 |
| Improve the allocation ratio | 0.35 | 0.38 | 0.27 |

From the data in the table, it can be seen that there is a significant difference in the income value of each member before and after the Shapley value is improved. From the perspective of facility investment, the correction coefficient of farmers is greater than zero and should be compensated. Compensation should be shared by agricultural cooperatives and supermarkets with less input. From the perspective of fresh-keeping effort level, farmers' fresh-keeping effort level is 2.14% higher than the average, and supermarket fresh-keeping effort level is higher than the average 0.78%. However, the correction coefficient of agricultural cooperatives is less than zero and should be punished to reduce the return value. From the perspective of risk-taking, farmers performed better. The risk of farmers exceeds 2.68% of the average. According to the principle of proportionality between risks and benefits^[13], farmers should get more rewards.

In the initial distribution plan, the benefit distribution coefficients of participating members are 0.34, 0.40, 0.26, while the current benefit distribution coefficients are 0.35, 0.38, 0.27. Compared with the original plan, the benefit distribution coefficients of farmers and supermarkets have increased to varying degrees, while the benefit distribution coefficients of agricultural cooperatives have decreased more. Members with high contribution will receive more profits, in line with the principle of high investment and high return. The improved distribution results not only improve the fairness of the cold chain benefit distribution of fresh agricultural products, but also promote the enthusiasm and stability of cold chain cooperation for fresh agricultural products.

6. Conclusion

This paper studies the profit distribution of fresh agricultural products in the cold chain, constructs a profit distribution model with improved Shapley value, and verifies it through calculation examples. The results show that the use of Shapley value to solve the problem of benefit distribution should fully consider other factors besides marginal contribution. If supply chain companies want to obtain more benefits, they must play a greater role in equipment investment, risk-taking, and fresh-keeping efforts. Although this paper proposes a more reasonable cold chain benefit distribution plan for fresh agricultural products, this paper only studies the profit distribution of the participating companies under different cooperation situations with precise values. The issue of benefit distribution with clear cooperation and ambiguous returns needs further study.

References

- [1] Yong Huang. Research on the profit distribution mechanism of pork supply chain based on Shapley value method[J]. Agricultural Technology Economy, 2017(02): 122-128.
- [2] Chun Feng, Wenda Gao, Qiyang Li, et al. Network coordination and benefit distribution of dual-channel agricultural product supply chain[J]. Jiangsu Agricultural Sciences, 2018, 46(22): 364-368.
- [3] Minghua Jin, Qing Liu. Research on the Benefit Distribution of Agricultural Industry Chain Subjects under the Background of "New Retail"[J]. Academic Exchange, 2019, (5): 104-113.
- [4] Wenjuan Tu, Hui Zhong, Lan Xu. Research on the benefit distribution mechanism of farmers' professional cooperatives based on the perspective of supply chain[J]. Journal of Jiangsu University (Social Science Edition), 2019, 21(04): 67-76.

- [5] Xiaoqiang Cai, Jian Chen, Yongbo Xiao, et al. Optimization and coordination of fresh product supply chains with freshness-keeping effort[J]. *Production and Operations Management*, 2010, 19(3): 261-278.
- [6] Shihua Ma, Peng Wang. The income distribution mechanism among supply chain partners based on Shapley value method[J]. *Industrial Engineering and Management*, 2006, 29(04): 45-49.
- [7] Bahinipati BK, Kanda. A, Deshmukh S. Revenue Sharing in Semiconductor Industry Supply Chain: Cooperative Game Theoretic Approach[J]. *Sadhana*, 2009, 34(3): 501- 527.
- [8] Jerzy Martyna. The Use of Shapley Value to Power Allocation Games in CognitiveRadio Network[M]. *Advanced Research in Applied Artificial Intelligence of the series Lecture Notes in Computer Science*, 2012, 7345: 627-636.
- [9] Lilin Diao, Guilong Zhu, Zhi Xu. Alliance benefit distribution mechanism based on Shapley value of multiple weights[J]. *Industrial Engineering and Management*, 2011, 16(04): 79-84.
- [10] Baizhou Li, Xiaofang Luo. Research on the original innovation income distribution of industry-university-research cooperative enterprises based on the Shapley value method[J]. *Operations Research and Management*, 2013, 22(04): 220-224.
- [11] Weigan Li, Jiancang Xie, Jianxun Li, Hai Shen. A method for apportioning watershed ecological compensation based on improved Shapley value solution[J]. *System Engineering Theory and Practice*, 2013, 33(01): 255-261.
- [12] Zhongwen Xu, Zixuan Peng, Ling Yang, Xudong Chen. An Improved Shapley Value Method for a Green Supply Chain Income Distribution Mechanism[J]. *International Journal of Environmental Research and Public Health*, 2018, 15(09): 1-18
- [13] Yiheng Xi, Yanyuan Cheng. Research on benefit distribution mechanism based on supply chain partnership[J]. *Statistics and Decision*, 2019, 35(05): 59-63.
- [14] Gérard P. Cachon. Supply Chain Coordination with Contracts[J]. *Handbooks in Operations Research and Management Science*, 2003, 11(11): 227-339.
- [15] Terry A. Taylor. Supply Chain Coordination Under Channel Rebates with Sales Effort Effects. 2002, 48(8): 992-1007.
- [16] Xiaoqing Gan, Kuo Gao. Benefit distribution of pig green supply chain in Poyang Lake Ecological Economic Zone[J]. *Journal of Nanchang University (Science Edition)*, 2011, 35(3): 296-301.
- [17] Lei Wang, Bin Dan. A multi-variety ordering model for fresh agricultural products considering the time-varying utility of freshness preservation affecting consumers[J]. *Journal of System Management*, 2013, 22(05): 647-654. KouvelisP,ChambersC,SempleJ.Quality-based competition, profitability, and variable costs[J]. *Management science: Journal of the Institute of Management Sciences*, 2006, 52(12): 1884-1895.
- [18] Xuejun Wang, Yajun Guo. Consistency analysis of judgment matrix based on G1 method[J]. *China Management Science*, 2006(03): 65-70.
- [19] Wei Chen. On the problem of reverse order in the application of TOPSIS method and the method to eliminate it[J]. *Operations Research and Management*, 2005(03): 39-43.