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Simulation of Benefit Distribution Strategies Based on Game Theory in the Dairy Industry Chain

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ABSTRACT

Through the examination and calculation of each link of the dairy industry chain, we analyze the benefit distribution pattern of the dairy industry chain and highlight the necessity of optimizing the benefit distribution strategy of the dairy industry chain. The Shapley value method of the equilibrium of interests in game theory is chosen to study the benefit distribution strategy of each subject in the dairy industry chain under the cooperative game, and the model is revised by using the input factor, the risk factor and the correction factor, so as to further improve the rationality of the benefit distribution strategy. The research data were obtained by visiting the dairy industry chain in Xilingol League through field investigation, and the modified Shapley values of the herdsmen, middlemen, milk processors and retailers were finally obtained as 3976.43 yuan, 3839.31 yuan, 4175.53 yuan, and 3977.47 yuan after the modeling calculation, respectively. The comprehensive cost profit margin of each subject after correction is 2.17%, 1.82%, 7.43%, 7.68%, respectively, and herdsmen and milk processors are compensated in the benefit distribution strategy of this paper, and the amount of benefit distribution and the comprehensive profit margin of all the subjects in the dairy industry chain have been improved compared with that before the cooperation.

Keywords: game theory, Shapley value method, correction factor, comprehensive cost profit margin, dairy industry chain

1. Introduction

With the overall development of China's economy, the living standards of urban and rural residents have been continuously improved, the residents of the food expenditure, nutrition and dietary structure has undergone significant changes, people's attention to nutritional health and food safety has exceeded the history of any period [1-3]. Milk consumption is increasing day by day, has become one of the residents of the three meals necessary food, dairy farming and milk processing industry has also been rapid development, dairy processing industry output value in the proportion of the gross national product continues to rise, has been less than one-thousandth of the initial period of reform

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and opening up to the current nearly six-thousandths of a per cent [4-6]. However, in recent years, with the rapid development of science and technology, science and technology in the field of milk processing and dairy farming has been greatly popularised, and a variety of advanced technologies have been rapidly promoted and applied in the milk industry, which has greatly facilitated the development of China's dairy industry, which has become a pillar industry of the national economy in some regions [7-8]. However, from a national perspective, affected by regional land resources, market resources and other factors, China's dairy industry, whether it is the regional layout structure, production and processing structure or consumption structure, compared with developed countries, there are still many problems [9-10].

The issue of interests is a basic problem involving human socio-economic activities and life. All social relations of people are based on interest relations [11-12]. At present, the contract system is the main form of dairy industrialisation in Hohhot. In fact, in the contract system, the relationship of interests between the subjects, i.e., the enterprise and the dairy farmers as well as the dairy stations, is a typical non-cooperative game [13-14]. From the point of view of game theory, under the current contract system, the enterprise wants to obtain the maximum profit and the dairy farmers pursue the highest income between the two goals are bound to produce contradictions, at the same time, there are supervision difficulties between the enterprise and the private dairy station, so that the interests of the enterprise and the dairy farmers and the dairy station in the interests of the game relationship. The existing contractual system hinders the process of dairy industrialisation, and it is necessary to optimise the institutional arrangement and construct a new type of institutional arrangement [15-17]. Then, how to design an institutional arrangement, so that enterprises, dairy farmers and dairy stations and other subjects to find a balance or become a community with the same interests, so as to make them harmonious in the interests of each other and create a more reasonable institutional environment is worth in-depth study. Institutional innovation is a key factor in the success or failure of dairy industrialisation, and efficient institutional arrangement is the core issue of dairy development. The optimisation of existing institutional arrangements and the construction of new institutional arrangements have the following dual theoretical and practical significance [18-21].

This paper selects the organization mode of dairy industry chain of traditional market transaction by sorting out the existing literature and visiting and researching the situation. Using the data obtained from visits and surveys in Xilingol League, the empirical analysis is conducted to study the cost-benefit situation of the dairy industry chain in Xilingol League in terms of herdsmen, intermediate producers, milk processing enterprises and retailers. Considering the time cycle factor, the comprehensive cost profit margin is introduced to calculate the profit margin of each subject under the time cycle as a benchmark, in order to evaluate the benefit distribution pattern of the dairy industry chain in Xilingol League. Aiming at the problems in the distribution pattern, this paper adopts the cooperative game to adjust the benefit distribution strategy, and selects the Shapley value method of benefit equilibrium to preliminarily calculate the benefits that can be gained by cooperation between subjects. Four subjects such as herdsmen are arranged and combined according to different cooperation patterns, calculate their Shapley values respectively, and determine the input, risk and correction factors using fuzzy comprehensive evaluation and other methods. The final calculation model was used to obtain the benefit distribution amount and the comprehensive cost profit margin of the dairy industry chain among the herdsmen, intermediaries, milk processing enterprises and retailers.

2. Analysis of the pattern of benefit distribution in the dairy industry chain

By combing the existing literature and visiting the research situation, it can be seen that the organization mode of the dairy industry chain is mainly divided into the traditional market transaction mode, the company + cooperatives + herdsmen mode and the company + herdsmen mode of three [22], this paper selects the traditional market transaction mode as the main object of study.

2.1. Cost and Benefit Analysis of Various Links in the Dairy Industry Chain

2.1.1. Data sources. Xilingol League is one of the typical grassland pastoral areas in China and also one of the major milk producing areas, so this paper selects Xilingol League as the main research area.2022 In May, the research team of this paper traveled to Xilinhot City, Abaga Banner, and Zhenlan Banner once to conduct a field research on the main stakeholders of the dairy industry chain, which included: 302 herding households, 18 milk intermediaries, 13 milk processing enterprises, and 18 milk retailers. According to the research data, the dairy industry chain at this stage is still dominated by the traditional market transaction mode, therefore, this study selects the traditional "herdsmen + middlemen + milk processing enterprises + sellers" industry chain mode as the research object, and researches the issue of dairy industry chain benefit distribution strategy in grassland pastoral areas.

2.1.2. Cost-benefit analysis of the dairy farming chain. According to the research, it can be seen that the breeding of dairy cows in pastoral areas is mainly self-breeding and does not involve the purchase of young animals, and due to the limitations of relevant policies and external factors such as weather, most of the feeding methods are half-housed and half-grazed, and the cows are mainly fed on pasture and purchased forage and fodder. Generally speaking, milk sold in pastoral areas is mainly produced by cows 15 days after giving birth, and the average period of cow calving is about 300 days. Most herdsmen choose to sell their milk to door-to-door middlemen because of their remote location and high transportation costs. According to the visit and research, it can be seen that the costs that herdsmen need to bear for dairy cow breeding are mainly feed costs, hired labor, repair and maintenance costs, veterinary medicine costs, breeding costs, livestock insurance costs, fuel and power costs, pasture leasing and depreciation, and the specific results are shown in Fig. 1, in which P1-P9 denote the feed costs and other various cost items, respectively. According to the data in the figure, it can be seen that the cost of forage is mainly the average feed cost of 303.87 yuan during the period of pregnancy and lactation of the cow, and the average feed cost of 68.24 yuan during the period of milk production of the cow.In 2020, the price of fresh milk is about 3.79 yuan/kg, the average milk production per cow is 1034.83 kg/year, and the average milk production income per cow is about 3922.01 yuan/year, and the breeding total cost was 561.44 yuan, and the net profit per cow was 3360.57 yuan. According to Figure 1, feed cost accounted for the largest share of the total farming cost, which was about 66.28% of the total farming cost, followed by pasture leasing cost and construction and machinery and equipment costs incurred by the dairy cows, which accounted for 6.39% and 9.44% of the total farming cost, respectively.

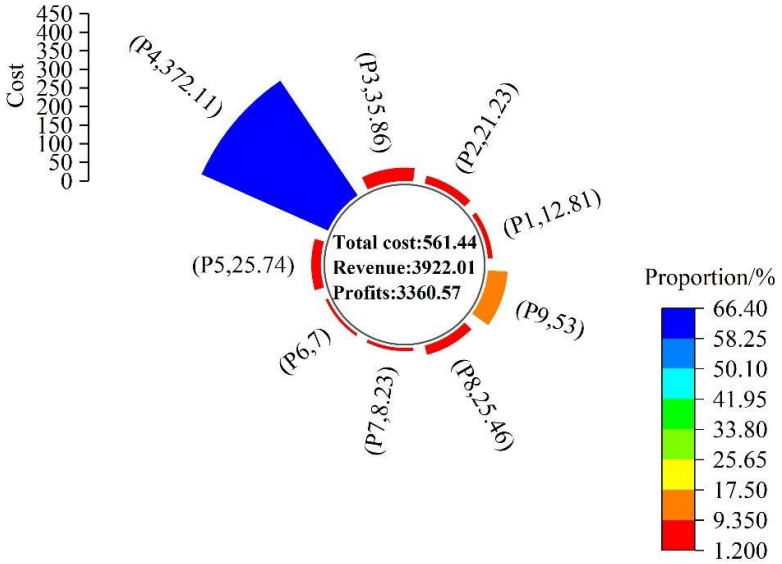

Fig. 1. Analysis of cost-income in breeding link

2.1.3. Cost-benefit Analysis of Milk Intermediary Segments. The costs of the middleman link design mainly include milk purchase costs, labor hire fees, repair and maintenance costs, milk trucks, transportation costs and contact fees, and the main sources of income are milk sales and by-product income to milk processing enterprises. The costs and benefits are shown in Figure 2, where X1-X6 represent the cost items. According to the survey data, the price of milk sold by middlemen in 2021 was 3.98 yuan/kg, and the average milk that each cow could buy was about 1028.64 kg. The selling price of milk produced per cow is 4,093.99 yuan. The price of by-products is about 58 yuan/kg. The total income was 4151.99 yuan, the total operating cost was 1037.69 yuan, and the net profit per cow was about 3114.30 yuan. As can be seen from Figure 2, the main cost that middlemen need to pay to make a profit is the purchase cost of milk, accounting for 98.03%.

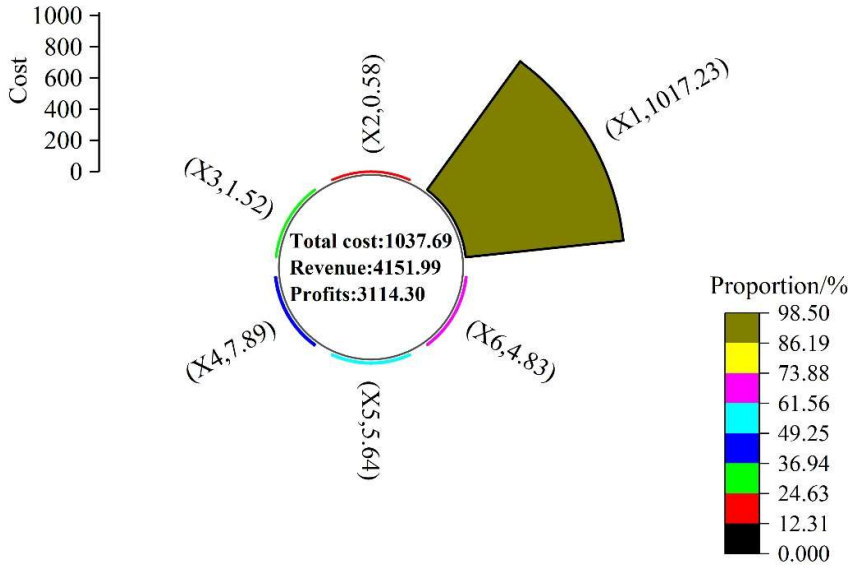

Fig. 2. Cost-income analysis of middlemen

2.1.4. Cost-benefit analysis of milk processing chain. The main costs faced by milk processing enterprises are milk acquisition costs, hired workers' fees, repair and maintenance costs, depreciation of buildings and machinery, packaging costs, quarantine fees and utilities, and the main source of income is the main product of milk and by-products, and the various costs and expenses are shown in Fig. 3, where Y1-Y7 indicate the cost items. According to the research data, in 2021, the average milk processing enterprise sells one cow to produce milk main product income is 4208.74 yuan, the by-product price is about 83 yuan/kg, the total income is 4,291.74 yuan, the total cost of production is 1,192.36 yuan, and the net profit of the milk produced by each cow is 3,099.38 yuan. According to Figure 3, it can be seen that the main component of the total operating cost of milk processing enterprises is still the acquisition cost of milk, which accounts for as much as 88.43%. This is followed by depreciation cost of building and machinery and equipment. It accounts for 4.77% of the total operating costs.

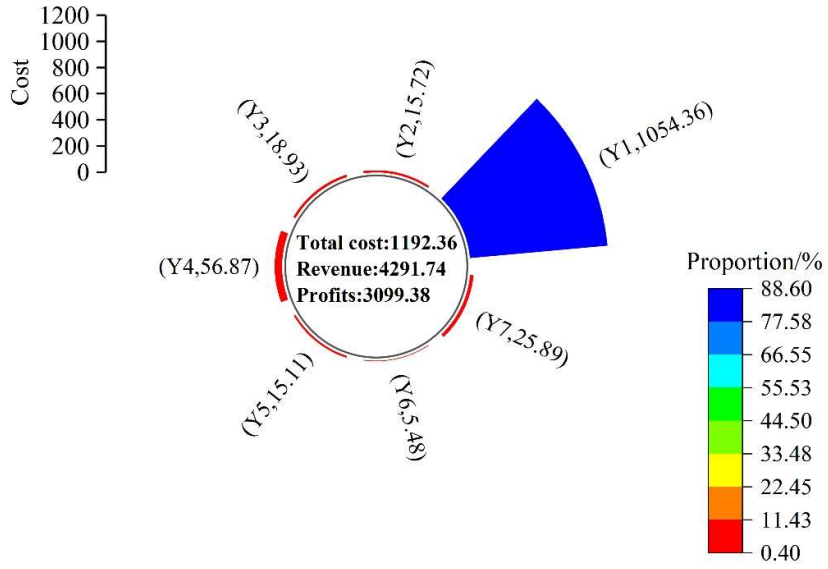

Fig. 3. Analysis of cost-income in milk processing

2.1.5. Cost-benefit Analysis of Milk Retail Segment. The main costs involved in milk retailers include milk purchase costs, labour costs, maintenance and care costs, construction and machinery depreciation, packaging costs, utility bills, and rent or stall fees. The revenue sources can be mainly divided into the sales revenue of the main milk product and the sales revenue of milk by-products, and the specific costs are shown in Figure 4, in which Z1-Z7 represent each cost item. According to the survey data, in 2021, the average income of milk retailers from selling milk produced by one cow was 4,586.83 yuan, the price of by-products was 183 yuan/kg, the total income was 4,769.83 yuan, the total operating cost was 1,385.69 yuan, and the profit of milk produced by each cow was 3,384.14 yuan. As can be seen from Figure 4, like intermediaries and milk processors, the main cost of the retail sector still comes from the purchase cost of milk, accounting for 89.75%.

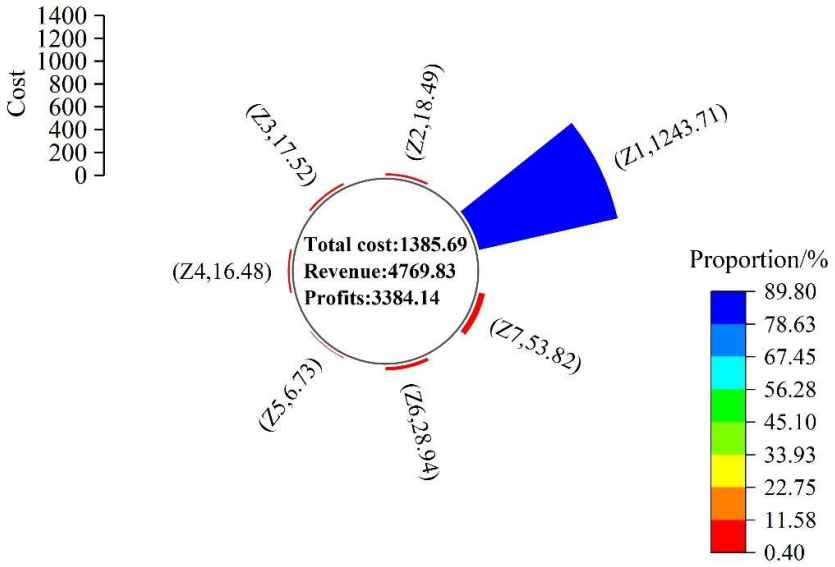

Fig. 4. Cost-income analysis of retail links

2.2. Evaluation of the pattern of benefit distribution in the dairy industry chain

2.2.1. Calculation of consolidated cost margins:

1) Calculation method. Comprehensive cost profit margin takes the unit time cycle as a benchmark,

and measures the profit situation gained by the unit input in this time cycle. Since the breeding cycle in the dairy industry chain is relatively long, while the acquisition, milk processing and retail cycle is relatively short, the comprehensive cost profit margin considering the time cycle is chosen to illustrate the profit situation of each subject. The comprehensive cost profit margin Z_i of each subject in the dairy industry chain can be expressed as follows:

$$Z_i = \frac{L_i - C_i}{C_i(T_i / T_0)} \tag{1}$$

Where L_i is the revenue of each subject, C_i is the total cost of each subject, T_i is the time taken by members of the dairy industry chain to complete the current cycle of operation and production, and T_0 is the shortest time among the subjects of the dairy industry chain. (T_i / T_0) represents the multiple of the time spent by other subjects, and in the final calculation of the comprehensive cost margin, the time cost is included in the comprehensive cost margin by time sharing, i.e. dividing by (T_i / T_0).

2) Analysis of results. Based on the cost-earnings data of the dairy farming link, middleman link, milk processing link and sales link above, according to formula (1), the comprehensive cost profit margins were finally obtained as 1.78%, 1.84%, 5.63% and 7.92%, respectively. Herders are in a disadvantageous position in the whole dairy industry chain due to their longer breeding cycle and higher breeding costs leading to a lower level of profitability. Compared with herdsmen, middlemen have a short operating time, but the cost of milk purchase is too large, so the profit level is not high. Compared to the upstream of the dairy industry chain, milk processors have a higher level of profitability, which is obtained due to their shorter flow cycle, and they are in a relatively higher advantageous position in the whole industry chain. Retailers have higher comprehensive cost profit margins than herdsmen, intermediaries and milk processing enterprises, and are in an advantageous position in the entire dairy industry chain.

2.2.2. Evaluation of benefit distribution patterns. Taking dairy farmers as the starting point of the production process, in 2021, the total cost of farmers from the breeding of dairy cows to the sale of milk will be 561.44 yuan, the total sales revenue will be 3922.01 yuan, and the net profit will be 3360.57 yuan. The total cost of milk intermediaries from the purchase of milk to the sale of milk was 1037.69 yuan, the total sales revenue was 4151.99 yuan, and the net profit was 3114.30 yuan. The total cost of milk processing enterprises to purchase milk and processing was 1192.36 yuan, the sales revenue of milk products was 4291.74 yuan, and the net profit was 3099.38 yuan. The total retail cost of milk was 1385.69 yuan, the sales revenue was 4769.83 yuan, and the net profit was 3384.14 yuan. Figure 5 shows the distribution of profits from milk in the four main links of farming, intermediary, processing and retail. In 2021, the total profit of milk produced by a dairy cow in the four links of breeding, middleman, milk processing and retail is 12,958.39 yuan. Therefore, considering the time period factor, this paper introduces the comprehensive cost profit margin, and obtains the profit margins of each entity are 1.78%, 1.81%, 5.63% and 6.92%, respectively.

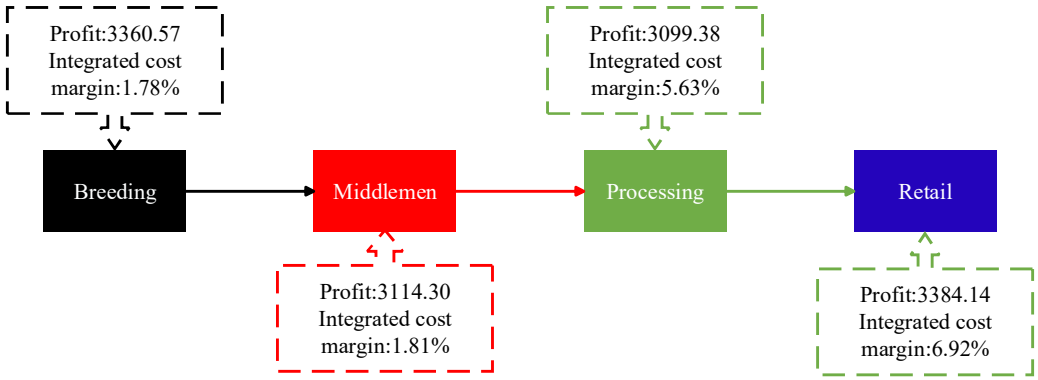

Fig. 5. Benefit distribution of the milk industry chain

As the dairy industry chain is long and involves many links, and milk production and operation has a certain degree of complexity, it is difficult to quantify or standardize the criteria for evaluating whether the pattern of benefit distribution is reasonable. However, the return on benefits in any one of the distribution links is related to the cost inputs and risks borne by the main production and operation. In terms of the four main links of the dairy industry chain, the milk retailing link has the highest cost, followed by the milk processing and middlemen links, and finally the farming link. In terms of risk taking, the farming link faces market and disease risks, and has a long farming cycle, slow capital turnover and no ability to withstand risks, so the farming link faces the greatest risks. Milk processing intense market competition also exists a greater risk. The retail segment can choose to withdraw and switch to other products when facing risks, so the retail segment bears the least risk.

3. Benefit-sharing strategies based on cooperative games

3.1. Research methodology

3.1.1. Shapley value approach to the equilibrium of interest. The study mainly considers the distribution of benefits in the four main links of the dairy industry chain, namely, farming, middlemen, milk processing, and retailing, and the corresponding subjects are dairy farmers, middlemen, milk processors, and retailers, which are denoted as set $I=\{1,2,3,4\}$, with n to denote the number of subjects involved in the cooperation, with v to denote the characteristic function of the countermeasure, and the cooperation countermeasure as $[I,v]$, with s to denote the cooperation of one of the n people cooperated in the cooperation, and with $v(s)$ to denote the cooperation of the s benefit, $s\in n$, with X_i denoting the i th subject among all subjects of cooperation from the maximum benefit $v(I)$ of cooperation, and $x=(x_1,x_2,x_3)$ for the distribution benefit of the cooperation countermeasure on the basis of cooperation I.

On the basis of the success of industrial chain cooperation, the distribution of benefits should satisfy the following 3 conditions:

1) The maximum benefit of the cooperation as a whole is equal to the sum of the benefits obtained by each participant, reflecting the overall rationality, which is expressed by formula (2):

$$\sum_{i=1}^{n} X_i = v(I) \tag{2}$$

2) For the interior of the cooperative whole, there exists a Pareto-optimal allocation rule, where each participating member is allocated a benefit from the benefits of the cooperative whole that is greater than or equal to the benefit that would have been obtained from operating alone without the cooperative, as expressed in equation (3):

$$X_i \ldots v(i), i = 1,2,3,4 \tag{3}$$

3) The sum of the benefits received by cooperative members under the overall cooperative alliance should be better than the benefits received by them in the sub-alliances so as to maintain the stability of the cooperation, which is expressed by formula (4):

$$\sum_{i \in s} X_i \geq v(s) \tag{4}$$

In the Shapley value method [23], the distribution of benefits obtained by the cooperating parties in the cooperation becomes the Shapley value and is recorded as:

$$\Phi(v) = \left[\varphi_1(v), \varphi_2(v), \cdots, \varphi_n(v)\right] \tag{5}$$

$$\varphi_i(v) \sum_{i=1}^{n} w(|s|)\left[v(s) - v(s/i)\right], i = 1,2,3 \tag{6}$$

$$w(|s|) = \frac{(n-|s|)!}{n!}(|s|-1) \tag{7}$$

Where: s represents the subset included in set I, $v(s)$ represents the benefit obtained in the state of set s, represents the number of subjects involved in the cooperation in subset s, $w(|s|)$ represents the weighting factor, and $v(s/i)$ is the benefit excluding participant i in subset s.

3.1.2. Modification of model results:

1) Calculation of input factors. Assuming that there is a total of n cooperator in the industrial chain cooperation, and the number of input factors is m, using a_{ij} to represent the actual market value of the factor j invested by the cooperator i, and using k_j to represent the importance coefficient of the invested factor in the value creation of the industrial chain, then the value of inputs to the industrial chain by the cooperator i can be expressed as:

$$P_i = \sum_{j=1}^{m} a_{ij} k_j \tag{8}$$

The proportion of each partner's input to the total input is then expressed as:

$$P_i^1 = \sum_{j=1}^{m} a_{ij} k_j \Big/ \sum_{i=1}^{n} \sum_{j=1}^{m} a_{ij} k_j \tag{9}$$

2) Calculation of risk factor. Let i represent the partner, with j representing the risk, w_{ij} represents the jth risk assumed by the partner i, where $i = 1,2,\cdots,n$; $j = 1,2,3$. A combination of fuzzy comprehensive evaluation method and hierarchical analysis is used to determine the value of w_{ij}. Assuming that there are k experts who judge the risk, and the weighting factor is expressed by α, the risk assumed by the partner i is judged to be expressed by formula (10):

$$A_{k\times 3}^i = \begin{pmatrix} a_{11}^i & a_{12}^i & a_{13}^i \\ a_{21}^i & a_{22}^i & a_{23}^i \\ \vdots & \vdots & \vdots \\ a_{b1}^i & a_{k2}^i & a_{i3}^i \end{pmatrix} \tag{10}$$

The three elements of each row of the matrix in Equation (10) are independent of each other, i.e., the sum of the elements of each row is not 1. $w_i = (w_{i1}, w_{i2}, w_{i3}) = \alpha A_{k\times 3}^i$ is the risk matrix of cooperator i, then the risk factor of cooperator i is $r_i = \prod_{j=1}^{3}(1 - w_{ij})$, and the risk factor of cooperator i in the

industry chain cooperation is expressed as:

$$P_i^2 = P_i^1 r_i \Big/ \sum_{i=1}^{n} P_i^1 r_i \tag{11}$$

3) Calculation of correction factor. Since both the risk factor and input factor have a positive influence on the distribution of benefits, in order to facilitate the calculation, the two factors can be integrated into a single factor to express, i.e., P_i^1 and P_i^2 are unified into a single factor λ_i, which represents the position of the i th participant in the industrial chain cooperation, and α and $1-\alpha$ are derived by fuzzy comprehensive evaluation method to represent the degree of influence of the resources and risks on the distribution of benefits of all parties in the industrial chain cooperation, respectively [24], and the factor is calculated by using linear programming to derive λ_i:

$$\lambda_i = \alpha P_i^1 + (1-\alpha) P_i^2 \tag{12}$$

Where: $0 \le \lambda_i \le 1$, $\sum_{i=1}^{n} \lambda_i = 1$.

The final modified benefit distribution proceeds are expressed in equation (13) as:

$$\varphi_i'(v) = \varphi_i(v) + (\lambda_i - \frac{1}{n}) \times [V(I) - V(n)] \tag{13}$$

3.2. Game simulation results

3.2.1. Profits in different states of cooperation. From the above analysis, it can be seen that when they operate independently, the profits obtained by herdsmen, middlemen, milk processing enterprises and retailers on a dairy cow are 3360.57 yuan, 3114.30 yuan, 3099.38 yuan and 3384.14 yuan respectively. When economic entities cooperate in pairs, according to the calculation method of benefit distribution: when herdsmen cooperate with middlemen, the repair and maintenance costs, depreciation and transportation costs of middlemen's transport vehicles will be reduced, and the contact fee can also be avoided, and the common profit of the two is 6503.72 yuan. According to the survey and investigation, when the herdsmen cooperate with milk processing enterprises, the government generally takes the lead in providing herdsmen with improved breeding, disease diagnosis and treatment services, and the herdsmen can save veterinary medical expenses, breeding fees and insurance premiums, and the common profit of the two is 6893.58 yuan. When the herdsman cooperates with the retailer, it is impossible to realize the direct conversion of dairy cows to milk, and the benefit of cooperation remains unchanged, and the profit of the cooperation between the two is 6744.71 yuan. When the middleman cooperates with the milk processing enterprise, the middleman's repair and maintenance costs, depreciation, and transportation costs will be reduced, and the joint profit of the two is 6384.29 yuan. When the middleman and the retailer cooperate is unable to realize the direct conversion of cows to milk, the benefits of cooperation or not remain unchanged, and the common profit of the two cooperation is 6498.44 yuan. When the milk processing enterprise cooperates with the retailer, the retailer can save the corresponding packaging fee, and the labor cost is also reduced, and the profit of the two is 6571.36 yuan. When the three economic entities cooperate, according to the above-mentioned cooperation between the two countries, it can be seen that the common profit of the cooperation between herdsmen and middlemen and milk processing enterprises is 9748.92 yuan, the common profit of herdsmen and middlemen and retailers is 9887.86 yuan, the common profit of herdsmen, milk processing enterprises and retailers is 9981.32 yuan, and the common profit of middlemen, milk processing enterprises and retailers is 9839.61 yuan. When the four economic agents work together, the profit of herdsmen and middlemen, milk processing enterprises and retailers is 15,073.82 yuan.

According to the Shapley value method, the process of calculating the distribution of benefits among

herders, middlemen, milk processing enterprises, and retailers is shown in Tables 1-Table 4. In the table, H denotes the herder household, M denotes the middleman, E denotes the enterprise, and R denotes the retailer. According to the model can get the benefit of the herder (yuan): $\varphi_1(v) = 1108.99 + 203.37 + 227.65 + 201.63 + 201.88 + 203.37 + 204.60 + 1727.29 = 4078.78$. Similarly, we can get the middleman's benefit (yuan): $\varphi_2(v) = 1027.72 + 188.59 + 197.09 + 186.86 + 171.32 + 187.99 + 196.10 = 3882.96$. Milk processing enterprise's benefit (yuan): $\varphi_3(v) = 1022.80 + 211.98 + 196.20 + 191.23 + 194.71 + 194.20 + 200.47 + 1711.37 = 3922.96$. Retailer's benefit (yuan): $\varphi_4(v) = 1116.77 + 203.05 + 203.05 + 208.32 + 185.26 + 207.32 + 1757.22 = 4084.04$.

Table 1. Benefits of the herdsmen under different cooperation states (yuan·cow^{-1})

Item	$V(S)$	$V(S \mid i)$	$V(S)-V(S \mid i)$	$\mid S \mid$	$W(\mid S \mid)$	$W(\mid S \mid)[V(S)-V(S \mid i)]$
H	3360.57	0	3360.57	1	1/3	1108.99
H+M	6503.72	3114.30	3389.42	2	18/1	203.37
H+E	6893.58	3099.38	3794.2	2	1/18	227.65
H+R	6744.71	3384.14	3360.57	2	1/18	201.63
H+M+E	9748.92	6384.29	3364.63	3	1/18	201.88
H+M+R	9887.86	6498.44	3389.42	3	1/18	203.37
H+E+R	9981.32	6571.36	3409.96	3	1/18	204.6
H+M+E+R	15073.82	9839.61	5234.21	4	1/3	1727.29

Table 2. Benefits of middlemen under different cooperation states (yuan·cow^{-1})

Item	$V(S)$	$V(S \mid i)$	$V(S)-V(S \mid i)$	$\mid S \mid$	$W(\mid S \mid)$	$W(\mid S \mid)[V(S)-V(S \mid i)]$
M	3114.30	0	3114.30	1	1/3	1027.72
H+M	6503.72	3360.57	3143.15	2	18/1	188.59
M+E	6384.29	3099.38	3284.91	2	1/18	197.09
M+R	6498.44	3384.14	3114.3	2	1/18	186.86
H+M+E	9748.92	6893.58	2855.34	3	1/18	171.32
H+M+R	9877.86	6744.71	3133.15	3	1/18	187.99
M+E+R	9839.61	6571.36	3268.25	3	1/18	196.10
H+M+E+R	15073.82	9981.32	5092.5	4	1/3	1680.53

Table 3. Benefits of enterprises under different cooperation states (yuan·cow^{-1})

Item	$V(S)$	$V(S \mid i)$	$V(S)-V(S \mid i)$	$\mid S \mid$	$W(\mid S \mid)$	$W(\mid S \mid)[V(S)-V(S \mid i)]$
E	3099.38	0	3099.38	1	1/3	1022.8
H+E	6893.58	3360.57	3533.01	2	18/1	211.98
M+E	6384.29	3114.30	3269.99	2	1/18	196.2
E+R	6571.36	3384.14	3187.22	2	1/18	191.23
H+M+E	9748.92	6503.72	3245.2	3	1/18	194.71
H+E+R	9981.32	6744.71	3236.61	3	1/18	194.2
M+E+R	9839.61	6498.44	3341.17	3	1/18	200.47
H+M+E+R	15073.82	9887.86	5185.96	4	1/3	1711.37

Table 4. Benefits of retailers under different cooperation states (yuan·cow^{-1})

Item	$V(S)$	$V(S \mid i)$	$V(S)-V(S \mid i)$	$\mid S \mid$	$W(\mid S \mid)$	$W(\mid S \mid)[V(S)-V(S \mid i)]$
R	3384.14	0	3384.14	1	1/3	1116.77
H+R	6744.71	3360.57	3384.14	2	18/1	203.05
M+R	6498.44	3114.30	3384.14	2	1/18	203.05
E+R	6571.36	3099.38	3471.98	2	1/18	208.32
H+M+R	9887.86	6503.72	3384.14	3	1/18	203.05
H+E+R	9981.32	6893.58	3087.74	3	1/18	185.26
M+E+R	9839.61	6384.29	3455.32	3	1/18	207.32
H+M+E+R	15073.82	9748.92	5324.9	4	1/3	1757.22

3.2.2. Revision of the benefit-sharing strategy. According to the size of fixed assets, human capital and patent research and development invested by all parties in the dairy industry chain at the time of cooperation as a proportion of the total input of the dairy industry chain alliance, the input factors of the four parties, namely, herdsmen, intermediaries, milk processors, and retailers, were derived according to the formula as: $P_1^1 = 0.1937, P_2^1 = 0.2193, P_3^1 = 0.3763, P_4^1 = 0.2107$ respectively.

Using the fuzzy comprehensive evaluation method to assign values to the market risk, technology risk, and default risk faced by the four links and finally, respectively, according to the formula to derive the risk factor of the four of the herdsmen, intermediaries, milk processing enterprises, and retailers are: $P_1^2 = 0.2861, P_2^2 = 0.2733, P_3^2 = 0.2349, P_4^2 = 0.2237$.

According to the fuzzy comprehensive evaluation method, the influence coefficients of the input factor and the risk factor on the distribution of benefits are 0.7 and 0.3, respectively, and the correction factor of the model is derived according to the formula $\lambda_1 = 0.2160, \lambda_2 = 0.2355, \lambda_3 = 0.3339, \lambda_4 = 0.2146$.

Calculating the modified Shapley value of each subject can be obtained:

$$\varphi_1'(v) = \varphi_1(v) + (\lambda_1 - \frac{1}{n}) \times [V(I) - V(n)] = 4078.78 +$$
$$(0.2160 - 0.25) \times (15968.74 - 12958.39) = 3976.43$$

$$\varphi_2'(v) = \varphi_2(v) + (\lambda_2 - \frac{1}{n}) \times [V(I) - V(n)] = 3882.96 +$$
$$(0.2355 - 0.25) \times (15968.74 - 12958.39) = 3839.31$$

$$\varphi_3'(v) = \varphi_3(v) + (\lambda_3 - \frac{1}{n}) \times [V(I) - V(n)] = 3922.96 +$$
$$(0.3339 - 0.25) \times (15968.74 - 12958.39) = 4175.53$$

$$\varphi_4'(v) = \varphi_4(v) + (\lambda_4 - \frac{1}{n}) \times [V(I) - V(n)] = 4084.04 +$$
$$(0.2146 - 0.25) \times (15968.74 - 12958.39) = 3977.47$$

According to the formula, after the redistribution using the modified Shapley value method, the milk profits produced by each cow were 3976.43 yuan, 3839.31 yuan, 4175.53 yuan and 3977.47 yuan, respectively. The comprehensive cost profit margins of each entity were 2.17%, 1.82%, 7.43% and 7.68% respectively. Through the calculation results of the modified Shapley value method, it can be seen that under the effect of the correction factor, herdsmen and milk processing enterprises are large-scale, high-input and high-risk. As a result, intermediaries and retailers have been compensated, while the amount of profit distribution and the profit margin on comprehensive costs of intermediaries and retailers due to their low exposure to risk and capital investment have decreased compared with the level of contribution alone, but all parties have improved compared with before the cooperation.

4. Conclusion

This paper obtains the benefit distribution pattern of the dairy industry chain in Xilingol League through the cost-benefit analysis of the herdsmen and other subjects in the dairy industry chain and the calculation of the comprehensive cost profit margin. Based on the Shapley value method in cooperative game theory and its revised model after introducing input factor, risk factor and correction factor to adjust the benefit distribution strategy in the dairy industry chain.

1) When operating alone, the profits obtained by herdsmen, middlemen, milk processing enterprises and retailers are 3360.57 yuan, 3114.30 yuan, 3099.38 yuan and 3384.14 yuan, respectively, and the comprehensive cost margins are 1.78%, 1.81%, 5.63% and 6.92%, respectively. However, in terms of inputs and risk-taking, the farming segment faces market risk and disease risk, and the farming cycle is productive, the capital turnover is slow, and there is no ability to resist risk, and the risk it faces is

the greatest. Therefore, the benefit distribution pattern in the dairy industry chain when operating alone has a big problem and needs to be adjusted.

2) After adopting the cooperative game strategy, the revised Shapley values of the four subjects are 3976.43 yuan, 3839.31 yuan, 4175.53 yuan and 3977.47 yuan, respectively, and the comprehensive cost profit margin becomes 2.17%, 1.82%, 7.43% and 7.68%. Herdsmen and milk processing enterprises were compensated in the adjusted benefit distribution strategy due to their large scale, high input and high risk exposure. The benefit distribution amount and comprehensive cost profit margin of each dairy industry chain subject are increased compared with the pre-cooperation period. It shows that the benefit distribution strategy of dairy industry chain adopted based on game theory in this paper has considerable scientific rationality.

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