Benefits Distribution in Logistics Finance with the Consideration of Risk Factor in Shapley Model

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***Abstract*—The emergence of logistic finance provides a chance for small and medium sized enterprises, logistic companies and financial instruments to reach a win-win situation. However, with the rapid development of logistic finance model, former distribution methods are no more suitable, but leading to unstable cooperate relationships even the breakdown of cooperation. As a result, how to divide the profit properly is the crucial problem we are facing. The method proposed in this article is based on Shapley value model and using risk factor as adjustment tools. By combining the adjustment factor with Shapley value model, a new distribution version is designed. This new model takes the motivation of enterprises into consideration, which is a factor ignored by original model. Furthermore, the cases are provided in the article to prove the application effect of this modified model.**

Keywords-logistics finance, benefit distribution, Shapley value method

I. INTRODUCTION

As a new arisen third-party logistics services product, logistics finance can provide a platform for the business cooperation of financial companies, logistics enterprises and financing enterprises to achieve the win-win effect. Financial companies can attract more customers, expand their business in conjunction with decreased lending risks and improved earning ratio, and solve the logistics bottleneck problem in the business of mortgage loan. Logistics enterprises can improve their standard of integration services, boost the competitiveness and add high value-added service features. Small and medium-sized enterprises can expand financing channels, bring the time being idle raw materials and finished products back into active use and optimize enterprise resources.

However, the logistics finance in our country develops relatively late, and faces many problems, like imperfect business system and unreasonable distribution scheme. Although many cooperation modes like warehouse receipt, chattel mortgage, confirming storage and financing warehouse derived from the original mode, the problem of unreasonable distribution has not been resolved. The fundamental objective among main bodies is gaining competitive advantage and getting more benefits. If one of the participants holds the opinion that the distribution mode is unfair, the alliance would be affected, even collapsed in some severe cases. So, how to build a reasonable benefit distribution mechanism is the key to ensure the sustainable and efficient operation of logistics finance.

II. LITERATURE REVIEW

Shapley[1] proposed the profit distribution model of n numbers, which is an earlier method researching from quantitative aspects. Werner and Roman, He and Welrand[2,3] proved that the main reason of cooperation rupture is the unreasonable profit distribution. Ilaria and Pierpaolo[4] analyzed three stage supply chain revenue sharing contract from the Angle of the intermediate product of supply chain transfer pricing and indicated that cooperative mechanism can lead all the decision makers reach channel coordination, but they did not determine the distribution coefficient of enterprises with adjacent nodes. David-D-Vanhoose and John-V-Duca[5] considered that the cut-throat competition of merchandise sales and poor financial flows are the preconditions of cooperation between financing enterprises and logistics enterprises. Small and medium-sized enterprises need new revenue stream badly. Karl Morasch[6] achieved revenue sharing by using ‘trust—agency’ incentive model, and determined the allocation ratio among members of the cooperation. Ilaria and PierPaolo[7] constructed a revenue-sharing model based on cooperation contract, achieving reasonable distribution of benefit by changing parameters of contract. Zheng Xin, Zhu Xiaoxi and Ma Weimin[8] Verify the feasibility of using Shapley value method based on the contribution rate to distribute profit in manufacturing industry and logistics industry. Zhang Handong,Yan Zhong and Fang Dachun[9] combined ANP and Shapley value method and advanced an improved alliance benefit allocation policy. Ye Huaizhen and Hu Yijie[10] researched the principle of benefit distribution in supply chain cooperation and put forward a benefit distribution model based on contribution to the project and risk compensation.

In this paper, a new model based on the classical Shapley value method is proposed, in which the risk factors and innovation factors are comprehensively considered. And this model made sure that every participant can take more benefit than not collaborating, which ensured the initiative of the participants, making sure the relationship stable and permanent.

III. SHAPLEY MODEL

Assuming set I={1,2,3,...,n}, for each subset S of I, there is a real function V(s), satisfying condition:

$$v(\Phi) = 0 \quad (1)$$

$$v(s_1 \bigcup s_2) \geq v(s_1) + v(s_2), s_1 \bigcap s_2 = \Phi$$

Then we call [I,V] as Cooperative Game of n participants, v is the characteristic function of this game.

Using xito indicate the deserved benefit from the maximal cooperation benefit v(I) of participant i. Using x=(x1, x2, …, xn) to indicate the distribution based on the cooperation I. To achieve success of the cooperation, the following conditions must be met.

$$\sum_{i=1}^{n} x_i = v(\text{I}) \quad (2)$$

$$x_i \geq v(\text{i}), \; i = 1, 2, \cdots\cdots \text{n}$$

Using Φ (v) to indicate the distribution of participant i based on the cooperation I, then the Shapley value of every members can be indicated by

$$\Phi(\text{v}) = (\varphi_1(v), \varphi_2(v), \cdots\cdots \varphi_{\text{n}}(v)) \quad (3)$$

and

$$\varphi_i(v) = \sum_{s \in S_i} w(|s|)[v(\text{s}) - v(\text{s}\backslash \text{i})] \quad (4)$$

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

Si represents all the subsets in I which include member i. |S| is the number of elements in sub S. w(|s|) is a weighting factor. v(s) is the benefit of subset s. v(s/i) is the benefit of sub s expect element member i.

Shapley value method can be explained as a probability. Supposed that all the members forming alliances casually and all the probabilities are equal to 1/n!. And using v(s)-v(s-i) to indicate the contribution of member i if i forming an alliance s with previous (|s|-1) members. There are (|s|-1)!(n-|s|)! kinds of probabilities for the arrangement of s-i and n-s, which means the probability for each situation is (|s|-1)!(n-|s|)!/n!. According to this interpretation, the expected value of contribution of member i is exactly Shapley value. The detailed calculation is listed in table 1. The sum of the terminal row is the benefit of member i, which is indicated by Φ i(v).

TABLE I. CALCULATION OFSHAPLYVALUE

S	{i}	{i,B}
$v(\text{s})$	π_i	π_S
$v(\text{s}\backslash \text{i})$	0	π_B
$v(\text{s}) - v(\text{s}\backslash \text{i})$	π_i	$\pi_S - \pi_B$
$\lvert s \rvert$	1	$\lvert s \rvert$
$w(\lvert s \rvert)$	$\frac{1}{n}$	$\frac{(\text{n}-\lvert s \rvert)!(\lvert s \rvert-1)!}{n!}$
$w(\lvert s \rvert)[v(\text{s}) - v(\text{s}\backslash \text{i})]$	$\frac{\pi_i}{n}$	$\frac{(\text{n}-\lvert s \rvert)!(\lvert s \rvert-1)!}{n!}(\pi_S - \pi_B)$

IV. ADJUSTMENT ON THE BENEFIT DISTRIBUTION

The procedure of construct a new Shapley value method modified by risk factor is as shown below:

- Make a list of all the considerable risk factors, denoted by j (j=1,2,3,……,m).
- Using expert evaluation method to evaluate the magnitude of every risk factors. Assigning Sij into j to represent the magnitude of risk j for member i.
- Install a weight wj according to the impact of risk factors, making sure that 0≤wj≤1 and ∑wj=1.
- Calculate the risk factor ri of member i:

$$r_i = \sum_{j=1}^{m} w_j S_{ij} \quad (5)$$

- Unitary processing of ri :

$$r_i' = \frac{r_i}{\sum_{i=1}^{n} r_i} \quad (6)$$

So the ultimate risk factor can be defined as $(r_i' - \frac{1}{n})$. Then the benefit distribution can be adjusted:

$$\varphi_i'(\text{v}) = \varphi_i(\text{v}) + (r_i' - \frac{1}{n})v(\text{I}) \quad (7)$$

If $r_i' > \frac{1}{n}$, member i bears a higher risk compared to the average level, so we can use $(r_i' - \frac{1}{n})v(I)$ to make a compensation. So it goes with the low risk members [10]. But it is possible gaining a lower benefit than noncooperation for the low risk bearing companies, which means these companies have low willingness to cooperate and the cooperation is easy to break up. When it comes to logistics finance, this problem is more dramatic because banks usually bear lower risk and seize the initiative.

In order to solve the problem, we introduce Φ(s) into the method to represent the value added after the formation of alliance:

$$\varphi(\mathrm{S}) = \mathrm{v}(\mathrm{S}) - \sum v(\mathrm{i}) \qquad (8)$$

The adjusted calculation of Shapley value is as follows:

TABLE II. SHAPLEY VALUE WITH RISK FACTORS

S	{i}	{i,B}
$v(\mathrm{s})$	π_i	π_S
$v(\mathrm{s} \setminus \mathrm{i})$	0	π_B
$v(\mathrm{s}) - v(\mathrm{s} \setminus \mathrm{i})$	π_i	$\pi_S - \pi_B$
$\mathrm{v(s)} - \mathrm{v(s \setminus i)} + (r_i^{'} - \frac{1}{n}) * \varphi(\mathrm{S})$	π_i	$\pi_S - \pi_B + (r_i^{'} - \frac{1}{n}) * \varphi(\mathrm{S})$
$\lvert s \rvert$	1	$\lvert s \rvert$
$w(\lvert s \rvert)$	$\frac{1}{n}$	$\frac{(\mathrm{n} - \lvert s \rvert)!(\lvert s \rvert - 1)!}{n!}$
$w(\lvert s \rvert)[v(\mathrm{s}) - v(\mathrm{s} \setminus \mathrm{i})]$	$\frac{\pi_i}{n}$	$\frac{(\mathrm{n} - \lvert s \rvert)!(\lvert s \rvert - 1)!}{n!}(\pi_S - \pi_B + (r_i^{'} - \frac{1}{n}) * \varphi(\mathrm{S})$

For the sake of comprehension, an example is given. Assuming that there are three members A, B, C cooperating in the logistics finance. Using V to represent the benefit for the cooperation portfolio. Specific numbers is in the table 3.

TABLE III. THE BENEFIT FOR COOPERATION PORTFOLIO

V(A)	V(B)	V(C)	V(A+B)	V(A+C)	V(B+C)	V(A+B+C)
30	40	50	80	95	110	150

In the table, V(A), V(B), V(C) separately represent the singular benefit for company A, B, C; V(A+B), V(A+C), V(B+C) separately represent the benefit for 2-member's alliance and the third one is uninfluenced; V(A+B+C) represent the gross benefit for the 3-member's alliance.

The risk of A, B, C companies can be reached by expert evaluation method or other feasible methods, we don't introduce techniques for specific work. Giving the risk factors for A, B, C is 30, 40 and 50. The adjusted risk factor for A is shown in table 4.

TABLE IV. THE NORMALIZED RISK FACTOR FOR MEMBER A

A	A+B	A+C	A+B+C
1	3/7	3/8	1/4

The prime Shapley value and the adjusted Shapley value can be calculated. The results are listed in table 5.

Using the information of table 5, we can calculate $\phi_A(V)$ =37.5 and adjusted $\phi'_A(V)$ =36.23. In the same way we can calculate the benefit distribution for B and C, as shown in table 6 to table 8.

TABLE V. COMPARISON OF SHAPLEY VALUE FOR A

S	A	A+B	A+C	A+B+C
$v(\mathrm{s})$	30	80	95	150
$v(\mathrm{s} \setminus \mathrm{i})$	0	40	50	110
$v(\mathrm{s}) - v(\mathrm{s} \setminus \mathrm{i})$	30	40	45	40
$\varphi(\mathrm{S})$	0	10	15	30
$\mathrm{v(s)} - \mathrm{v(s \setminus i)} + (r_i^{'} - \frac{1}{n}) * \varphi(\mathrm{S})$	30	275/7	345/8	37.5
$\lvert s \rvert$	1	2	2	3
$w(\lvert s \rvert)$	1/3	1/6	1/6	1/3
$w(\lvert s \rvert)[v(\mathrm{s}) - v(\mathrm{s} \setminus \mathrm{i})]$	10	20/3	15/2	40/3
$w(\lvert s \rvert)[v(\mathrm{s}) - v(\mathrm{s} \setminus \mathrm{i}) + (r_i^{'} - \frac{1}{n}) * \varphi(\mathrm{S})]$	10	275/42	115/16	12.5

TABLE VI. NORMALIZED RISK FACTOR FOR B

B	B+A	B+C	B+A+C
1	4/7	4/9	1/3

TABLE VII. COMPARISON OF SHAPLEY VALUE FOR B

S	B	B+A	B+C	B+A+C
$v(\mathrm{s})$	40	80	110	150
$v(\mathrm{s} \setminus \mathrm{i})$	0	30	50	95
$v(\mathrm{s}) - v(\mathrm{s} \setminus \mathrm{i})$	40	50	60	55
$\varphi(\mathrm{S})$	0	10	20	30
$\mathrm{v(s)} - \mathrm{v(s \setminus i)} + (r_i^{'} - \frac{1}{n}) * \varphi(\mathrm{S})$	40	355/7	530/9	55
$\lvert s \rvert$	1	2	2	3
$w(\lvert s \rvert)$	1/3	1/6	1/6	1/3
$w(\lvert s \rvert)[v(\mathrm{s}) - v(\mathrm{s} \setminus \mathrm{i})]$	40/3	25/3	10	55/3
$w(\lvert s \rvert)[v(\mathrm{s}) - v(\mathrm{s} \setminus \mathrm{i}) + (r_i^{'} - \frac{1}{n}) * \varphi(\mathrm{S})]$	40/3	355/42	265/27	55/3

TABLE VIII. NORMALIZED RISK FACTOR FOR C

C	C+A	C+B	C+A+B
1	5/8	5/9	5/12

From above tables, we can calculate that $\varphi_B(\mathrm{v})$ =50 and adjusted $\varphi_B^{'}(\mathrm{v})$=49.93; $\varphi_C(\mathrm{v})$=62.5 and adjusted $\varphi_C^{'}(\mathrm{v})$=63.83.

The fact that different participants have different risk level is considered in the adjusted Shapley method, making sure that high-risk company get high yield. Member A takes the lowest risk, so its benefit is turned down most drastically. Member C bears the highest risk, so it gains compensation. Although member B has average level of risk, but when it only cooperate with A or C, the proportion of risk bearing is changed, so its benefit changed in this model. What's more, this method solves the problem of lower risked company dropped out.

TABLE IX. COMPARISON OF SHAPLEY VALUE FOR C

S	B	B+A	B+C	B+A+C
$v(s)$	40	80	110	150
$v(s\backslash i)$	0	30	50	95
$v(s)-v(s\backslash i)$	40	50	60	55
$\varphi(S)$	0	10	20	30
$v(s)-v(s\backslash i)+(r_i^{'}-\frac{1}{n})*\varphi(S)$	40	355/7	530/9	55
$\lvert s\rvert$	1	2	2	3
$w(\lvert s\rvert)$	1/3	1/6	1/6	1/3
$w(\lvert s\rvert)[v(s)-v(s\backslash i)]$	40/3	25/3	10	55/3
$w(\lvert s\rvert)[v(s)-v(s\backslash i)+(r_i^{'}-\frac{1}{n})*\varphi(S)]$	40/3	355/42	265/27	55/3

V. CONCLUSION

This study adds risk factor into Shapley value model, constructing a new benefit distribution method. The results show that benefit distribution is related to the degree of risk contribution. With a proper range of adjustment, the calculation result can be improved in new model.

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REFERENCES

[1] M. Maschler, B. Peleg, L. Shapley, "Geometric Properties of the Kernal, Nucleolus, and Related Solution Concepts", Mathematics of Operational Research, vol. 4, 1979, pp. 303-338

[2] H. Werner, S. Roman, "Success factors of strategic alliance in small and medium-sized enterprise: an empirical survey", Long Range Planning, vol. 34, 2001, pp.357-381.

[3] L. He, J. Walrand, "Pricing and revenue sharing strategies for internet service provider", IEEE Journal on Selected Areas in Communications, vol. 24, 2006, pp.942-951.

[4] C. Vidal, M. Goetschalckx, "Strategic production distribution models: A critical review with emphasis on global supply chain models", European of Operational Research, vol.98, 1997, pp.1-18.

[5] K. Moraseh, "Strategic alliances as Stackelberg cartels-concept and equilibrium alliance structure", Int. J. Industrial Organization, vol. 18, 2000, pp.257-278.

[6] I. Giannoeearo, P. Paolo, P. dolfo, "Supply chain coordination by revenue sharing contracts", Int. J. Production economies, vol. 89, 2004, pp.131-139.

[7] X. Zheng, X. Zhu, W. Ma, "Revenue Distribution Model of Three Echelon Closed-loop Supply Chain Based on Shapley-value", Operations Research & Management Science, vol. 20, 2011, pp. 17-22.

[8] H. Zhang, Z. Yan, D. Fang, "Strategies of profit allocation in enterprises' dynamic alliance value based on Shapley applying ANP", J. of System Engineering, vol. 24, 2009, pp.205-211.

[9] H. Ye, Y. Hu, "Research on Benefit Allocation among Cooperative Partners in Supply Chain", J. of Southwest Jiaotong University, vol. 39, 2004, pp.30-33.