The Study of Enterprise Technical Alliance Comprehensive Profit Allocation Based on Orthogonal Projection

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Abstract. We apply orthogonal projection to the profit allocation of a technical alliance based on traditional profit allocation methods, such as Shapely value, minimum core, simplified minimum costs remaining savings, and Nash negotiation methods. This distribution method is based on the weight coefficient of the first four profit allocation projects, and split the four different profit allocation methods into a comprehensive profit distribution plan.

Introduction

Relevant research on technical alliance began in the early 1980s; the initial research mainly focused on the reasons for technology alliance formation, alliance mode motivations, cost–effect analysis, and risk control measures. Teresa [1] proposes a technology alliance strategy model that is derived from the factors that affect alliance cooperation and enhance the competitive advantage and strategic capacity of organizations. Lee [2] argues that the mission of technology innovation alliance is not merely to achieve technological innovation, but also to improve the ability of technology alliance members to achieve technical innovation. Shengdan Chao [3] proposes a profit distribution model for a technology alliance based on the improved Shapely value method. Local and foreign scholars have successfully investigated technological innovation alliances using instability analysis, performance analysis, risk analysis, and interest distribution method; however, these scholars have not formed a systematic understanding of the form and interest distribution of league organizations.

Distribution method for technology alliance interests

Shapely value method

The basic idea of Shapely value is that the cost that participant i should bear or the benefit that participant i should gain is equal to the average marginal contribution of each league that the participants take part in. Shapely value is the unique solution that meets the four properties of anonymity, effectiveness, additivity, and virtuality. Shapely value shares the major league benefit $v(N)$ according to the following formula[4]:

$$\phi_i(v) = \sum_{S \subseteq N \setminus i} \frac{|s|!(n-|s|-1)!}{n!}(v(S \cup \{i\}) - v(S)), \qquad (1)$$

where s indicates the number of participants in league $v(\phi)=0$.

Minimum core model

The core method uses the optimal distribution of the super concept proposed by Gillies in 1953, and puts forward a cooperative game solution. This method chooses a set of reasonable distributions from the reasonable distribution set of whole rationality and individual rationality, to any union S; they are not controlled by other reasonable distributions, that is, they take the core of the cooperative countermeasures (N,v) as income distribution plan, recorded as $C(v)$.

$$C(v) = \{x \in R^n \mid v(R) - x(R) \le 0 (\forall R \subseteq N), v(N) = x(N)\} \qquad (2)$$

However, the core method has a serious defect; that is, the core of cooperative game (N,v) may be an empty set. Thus, scholars subsequently introduced improvements to the core method, and put forward the minimum core method, weak core method, and proportion core method, among others, to prevent the core of the cooperative game (N,v) from always becoming empty. The structure of these three core methods is similar; hence, we only choose the minimum core method to solve the linear programming problem as follows.

$$\min c$$
$$s.t. \begin{cases} X_i \ge v(i), \forall i \in N \\ \sum_{i \in s} X_i \ge V(S) + c, \forall S \subset N \qquad and \ |S| > 1 \\ \sum_{i \in N} X_i = V(N) \end{cases} \qquad (3)$$

Simplified MCRS model

The calculation of the simplified MCRS model is as follows.

$$\Omega_i = X_{i\,min} + \frac{X_{i\,max} - X_{i\,min}}{\sum_{i \in N}(X_{i\,max} - X_{i\,min})}[V(N) - \sum_{i \in N} X_{i\,min}], \forall_i \in N \qquad (4)$$

Including the ideal interest and deserved interest of each unit as the highest and the lowest interest distribution income, respectively, allows us to obtain,

$$X_{i\,max} = V(N) - V(N-i), \forall i \in N \qquad X_{i\,min} = V(N)_i = X_i.$$

Nash negotiation model

Negotiation is also known as a bargaining game; its core problem is the formulation of a binding contract that deters the negotiating parties and maximizes their profits under the restrictions of the contract. In 1950, Nash put forward a series of negotiation principles, and proved the unique solution in accordance with these principles. The Nash negotiation solution becomes the optimal solution for the maximization problem: $\max(x-a)^h(y-b)^k \ s.t \quad y = f(x)$, including h>0,k>0, and h+k=1.

However, Nash negotiation mainly corresponds to a two-person negotiation; in many cases, the number of participants in a technology innovation alliance is more than two. On the basis of this idea, the Nash negotiation solution extends to a multi-people cooperation game. Thus, the Nash negotiation solution for a multi-objective and multi-people cooperation is $u^* = \varphi(\bar{u}, U)$.

Orthogonal projection method

Based on the orthogonal projection method, this paper proposes a method for determining the optimal weight of different schemes, and the results of various allocation methods compromise a satisfactory profit distribution plan. First, we construct the decision change matrix of the enterprise, and normalize and construct the weighted matrix. Through the positive and negative ideal solutions,

we then calculate the vertical section distance. Finally, we construct the objective function and constraint conditions, and build a model to solve the following:

$$\min z = \sum_{i-1}^{m}\sum_{j=1}^{n} t_{ij} \times h_{j} \qquad (5)$$

$$s.t. \begin{cases} \sum_{j=1}^{n} w_{j} = 1 \\ w_{j} \geq 0, j = 1, 2, \cdots, n \end{cases} \qquad (6)$$

Type (1) is the objective function, which expresses the vertical surface minimum distance as much as possible. Type (2) is the constraint function, which implies that the sum of the weight coefficients of all schemes is 1.

Distribution Simulations of Technology Alliance Interest

This paper hypothesizes that four companies in the technical field have common research and development needs, and this hypothesis is described by cooperation countermeasure theory as $N = \{1, 2, 3, 4\}$. The four enterprises can independently conduct a technical study, or participate in a component technology innovation alliance with other enterprises. When solely undertaking a study, four companies can respectively generate profits of 1,130, 1,760, 2,350, and 870 units. At the same time, if the enterprise solely undertakes a study, it consumes a larger proportion of the total resources, and the technical risk is difficult to predict. The total transaction cost for an enterprise that independently conducts technology innovation is 50; that for two enterprises that cooperate to develop technology is 120; that for three enterprises that cooperate to develop technology is 290; and that for four enterprises in a technology alliance is 570. Enterprises that reach a technology innovation alliance agreement gain an income, that is, market gains minus transaction cost.

Table 1. Results of the four interest distribution methods

Distribution method	Enterprise 1	Enterprise2	Enterprise3	Enterprise4
Shapely method	1519	2130	2628	1227
Minimum core method	1626	2212	2692	974
Simplified MCRS method	1518	2113	2617	1254
Nash negotiation method	1478	2108	2698	1218

Table 1 depicts the differences in the profit allocation schemes of various calculation methods. The Sharply and simplified MCRS methods emphasize fairness, and the pursuit of efficiency is based on justice. Thus, the results of these two methods are relatively balanced, and attention is paid to the weak enterprise. The minimum core and Nash negotiation methods emphasize efficiency and pursue fairness based on efficiency.

Comprehensive Profit Distribution of The Technology Alliance Based on Orthogonal Projection

According to the orthogonal projection method, we calculate the sum of the vertical distance between profit distribution plan and the ideal solution[5]:

$$Z = \sum_{i=1}^{4}\sum_{j=1}^{4} t_{ij} \times h_{j} = 0.00569 w_{1}^{2} + 0.00162 w_{2}^{2} + 0.00045 w_{3}^{2} + 0.01743 w_{4}^{2}.$$

Constructing the objective function and constraint conditions allows us to build the following model:
$$\min Z = \sum_{i=1}^{4}\sum_{j=1}^{4} t_{ij} \times h_j = 0.00569w_1^2 + 0.00162w_2^2 + 0.00045w_3^2 + 0.01743w_4^2$$
Using the model operated in the LINGO

$$s.t.\begin{cases} \sum_{j=1}^{n} w_j = 1 \\ w_j \in (0,1), (j=1,2,3,4) \end{cases}$$

software, we obtain, $w_1 = 0.0572, w_2 = 0.2009, w_3 = 0.7232, w_4 = 0.0187$.

We utilize weight to acquire the vertical surface distance through the following equation:

$$P = t_{ij} \times h_j = \begin{pmatrix} 0.00168w_1^2 + 0.00047w_2^2 + 0.0002w_3^2 + 0.00137w_4^2 \\ 0.00002w_3^2 + 0.01423w_4^2 \\ 0.00169w_1^2 + 0.00056w_2^2 + 0.00023w_3^2 \\ 0.00232w_1^2 + 0.00059w_2^2 + 0.00183w_4^2 \end{pmatrix} = \begin{pmatrix} 0.00013 \\ 0.00001 \\ 0.00015 \\ 0.00003 \end{pmatrix}$$

where P_i refers to how close the distribution plan is to obtain the positive ideal solution. If the value of P_i is smaller, then the alliance enterprises are more satisfied with the profit allocation scheme. With the minimum value of P_i as the object, we obtain the weight vector of the distribution solutions and then normalize the weight vector, $\Omega_i = (0.4, 0.0396, 0.4615, 0.0989)$. The hypothesis for the comprehensive profit distribution plan is $y = (y_1, y_2, y_3, y_4)$. Hence, we calculate the profit allocation scheme of each enterprise, $y = (1519, 2124, 2633, 1229)$.

Conclusion

The orthogonal projection method allows the further exploration of interest distribution in technology alliances; however, this technique does not merely depend on a certain method, but also synthesizes the advantages and characteristics of four methods of interest distribution. This method is applied in enterprise alliances, which improves their satisfaction and meets their stability and development needs. In reality, a method that applies to all types of technological innovation alliances and promotes their long-term stability and coordinated development is lacking. Thus, we should choose a distribution method according to the specific characteristics of the technology innovation alliance. Moreover, in reality, the league constantly undergoes changes and dynamic development. Therefore, the secondary interest distribution is an important aspect of the mechanism of alliance interest distribution that merits future investigation.

References

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