Research on the Profit Allocation of Virtual Enterprise Based on Fuzzy Comprehensive Evaluation

LAN Rongjuan, GUAN Zhongliang
School of Economics and Management, Beijing Jiaotong University, P.R.China,100044

Abstract: Member enterprises engaged in a virtual enterprise are prone to shirk both productive efforts and risks because their efforts are unobservable to any other member enterprises, and so the reasonable mechanism of profit allocating is the major factor which influences the effort extent of each member enterprise, the operating results of Virtual Enterprise, as well as the existence of Virtual Enterprise. Firstly this paper analyses the four principles which should be followed in the course of profit allocating within Virtual Enterprise. On the basis of it, the profit allocation model is proposed, and the quantitatively description on its validity is made. Secondly, taking Virtual Enterprises which are engaged in research and developing work as examples, fuzzy comprehensive analysis method is used to calculate the risk coefficient in the profit allocation model. Finally, calculating example is given to explain the use of the model.

Keywords: Virtual Enterprise, Fuzzy comprehensive evaluation, Profit distribution model, Risk coefficient

1 Introduction

Many enterprises realized that it is difficult to adapt complicated and volatile market environment only relying on their own resources and abilities after 1980’s, and they began valuing cooperative competition based on trust. At the same time, with the rapid development of Information Technique and the globalization of economy, the enterprises alliance appeared. In 1991 Kenneth Preiss, Steven L. Goldman and Roger N. Nagel finished the research paper “21st Century Manufacturing Enterprise Strategy: An Industry-led View”. They put forward the concept of Virtual Enterprise for the first time in the paper. Along with the increase of Virtual Enterprises in the markets, an aggressive research to this was launched, and a lot of research documents were made.

Virtual Enterprise is a kind of temporary organization structure, and its formation is mainly motivated by market opportunity. Its basic spirit lies in breaking down the boundary of traditional enterprises and limited resources. By using an external resources and ability, the partner can expand or extend its function, ability and reach the target which would not be completed just by its own resources or abilities. Fundamentally speaking, Virtual Enterprises are not based on the shares and the administrative relation, but on the contracts. The cooperation of the partners relies on their common benefits. The main purposes which an enterprise participates Virtual Enterprises is to acquire more profit. In the course of cooperation, the colleagues play different roles and carry out different functions. The colleagues have different core competences, different amount of investments and risks. They have different responsibility to reach the common objective of Virtual Enterprise. According to the reciprocity of power and responsibility, the profit must be distributed clearly. Whether the mechanism of profit allocation is reasonable or not will influence the colleagues’ enthusiasm of cooperation. It will also affect the management result and the long-term potentiality of Virtual Enterprise.

2 The basic principles of profit allocation within Virtual Enterprise

In view of the character of Virtual Enterprise, the following principles should be followed.

2.1 Risk and revenue sharing principle

First, It should be considered that the matching between incomes and investments, because the investment which the partner make is irreversible to some extent. The investment should include all the inputs, and a detailed introduction is as follows: starting funds (including the investment beforehand which be used to purchase the research equipment, instruments and patent technique relating to the
business of Virtual Enterprise etc.), human resources costs (including the costs which are used to hire workers related) and financing costs.

Secondly, the matching between incomes and risks should also be considered. The operation mode of the Virtual Enterprise is favorable to decentralize some risks which the partners have in the course of running business independently, but other risks such as cooperation risk coming from the uncertain factors and asymmetrical information among partners are increasing. The amount of profits given to partner should be closely related to the risks that the partner assumes.

### 2.2 Mutual wining principle

To gain some kind of economy or market benefits is the main purpose which the partner joins Virtual Enterprise, so the proportion for profit allocation within Virtual Enterprise should insure that each cooperation colleagues are all profitable. This will assure the mutual trust among partners.

### 2.3 Fair principle

The investment each partner gives to Virtual Enterprise and the contribution each partner makes in Virtual Enterprise are different, so the profits each partner gain should be different. The fair mechanics of profit allocation must assure not only that each partner could gain benefits but also that each partner could gain more benefits on the basis of more contribution.

### 2.4 Stage allocation principle

Stage problem should be considered in the course of establishing profit allocation mechanics. The reasons are as follows:

Firstly, Virtual Enterprise is dynamic. That is, in the course of business running of Virtual Enterprise, it is possible that some old partners will withdraw from Virtual Enterprise, and also it is possible some enterprises will join it.

Secondly, the investments made by the partners usually occur in different stages, not all at once. It is common that the partner will carry on the strategy of investing in different stages in order to protect their core resources and techniques. The amount of investment is related to the game theory results among the partners within the Virtual Enterprise in different stages. Also there are different extent risks the partners should take in different stages, and so the profits must be divided in different stage.

Finally, the profit of Virtual Enterprise is characterized as lagging behind usually. That is, it is difficult that the effectiveness of the investment at present be reflected by the revenue at present.

### 3 Profit allocation model of Virtual Enterprise

#### 3.1 Profit allocation model

Provided that the investments are given at the beginning of each stage and profits are allocated at the end of each stage. We must take time value of capital into account in the course of building model, especially when the Virtual Enterprise exists for a long time. According to the afore-said four principles of profit allocation within the Virtual Enterprise, the model of profit allocation within the Virtual Enterprise is built as follows[3]:

\[
V_{ij} = \alpha_{ij} V_j = \frac{\sum_{k=1}^{n} I_{ik} (F/P, r, j-k+1)}{\sum_{i=1}^{n} \sum_{k=1}^{m} I_{ik} (F/P, r, j-k+1)} V_j
\]

\((i = 1, 2, \ldots, n; j = 1, 2, \ldots, m)\) (1)

In the model, \(V_{ij}\) denotes the profit that partner \(i\) gain during stage \(j\), \(\alpha_{ij}\) denotes the profit coefficient of partner \(i\) during stage \(j\), \(V_j\) denotes the total profit the Virtual Enterprise gain at the end of stage \(j\), \(R_{ij}(0 < R_{ij} < 1)\) denotes the risk coefficient of partner \(i\) during the stage \(j\), \(I_{ik}\) denotes the investment to the Virtual Enterprise that partner \(i\) make at the beginning of stage \(k\).
\( r \) denotes rate of discount. \((F/P, r, j-k+1)\) denotes the final value at the end of stage \( j \) which comes from the investment partner \( i \) makes at the beginning of stage \( k \). The number of partners in the Virtual Enterprise is \( n \), and it is changeable in the course of management of the Virtual Enterprise. 

\( m \) denotes the lifecycle of the Virtual Enterprise.

### 3.2 Effectiveness test on model

It can be proved that the profit allocation model of Virtual Enterprise matches the four principles mentioned above:

① The sum of profit allocation proportions of all the partners within the Virtual Enterprises is one, so the model matches revenue sharing principle. Proved as follows:

\[
\sum_{i=1}^{n} a_{ij} = \sum_{i=1}^{n} \frac{R_{ij} \sum_{k=1}^{j} I_{ik} (F/P, r, j-k+1)}{\sum_{i=1}^{n} \sum_{k=1}^{j} [R_{ij} \sum_{k=1}^{j} I_{ik} (F/P, r, j-k+1)]} = 1
\]

② According to the model, it is impossible that some partners earn while others are at loss. This matches mutual wining principle, proved as follows:

If \( V_{ij} > 0 \), then \( V_{ij} > 0 \), and so \( V_{ij} > 0 \) (\( i \neq i' \))

③ The profit that partner \( i \) gains at the end of stage \( j \) is directly proportional to the total investment that partner \( i \) make at the end of stage \( j \), and is also directly proportional to the risks which partner \( i \) takes during stage \( j \). It can be proved that:

\[
\frac{\partial a_{ij}}{\partial R_{ij}} > 0, \quad \text{and} \quad \frac{\partial a_{ij}}{\partial \sum_{k=1}^{j} I_{ik} (F/P, r, j-k+1)} > 0.
\]

According to the formulas above, we can get the conclusion that the bigger the risks what a partner takes, the more profits it should gain. The more the investments what the partner give to the Virtual Enterprise, the more the profits that the partner should obtain. These testify the fair principle.

④ We must estimate the risk coefficient of each partner in each stage when the model is used. The time value must also be considered. To some extent, the factor of stage has been taken into account in the profit allocation model. This matches stage allocation principle.

### 4 The determination of risk coefficient of the partner

According to the formula (1), we can calculate the profit what each partner can gain at the end of each stage. It is necessary that the risk coefficient be estimated before we use the model of profit allocation.

We will take the research and development (R&D) Virtual Enterprises as examples and use the fuzzy synthetic evaluation model\[(3)\] to study the determination of risk coefficient from qualitative and quantitative angles.

#### 4.1 The designing of evaluation index system of risk coefficient\[(4)\]

The following principles must be followed when we design risk evaluation index system of partners within a Virtual Enterprise:

① Comprehensiveness and integrity

The risks which the partners takes involve many complicated factors, so the evaluation index system should be as complete as possible, especially the main factor shouldn’t be omitted and repeated.

② Scientific property and rationality

Scientific property should be the premise of evaluation index system. In order to make the index...
system reasonable, the number of index must be moderate and the data related must be available.

③Flexibility
Because the market is in a constant state of flux, and the risks are changeable in different Virtual Enterprises, the evaluation index system should be flexibility.
In addition to the principles above, the evaluation index system should also be systematic, operant, and succinct.
According to the designing principles and drawing lessons from past research results[5], We can design the risk index system of R&D Virtual Enterprises. It includes three levels and eleven sub-indexes. The evaluation index system is as particularized at Tab.1 as follows.

<table>
<thead>
<tr>
<th>Tab.1 Risk index system of R&amp;D Virtual Enterprises</th>
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<tr>
<td>general objective level</td>
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<td>the general risk (X)</td>
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</table>

Taking the Virtual Enterprise as a whole, the market risk belongs to exterior risks of system, and technology and cooperation risk belong to interior risks. The technology risk of some partner is related to the difficulty and uncertainty of technique which the partner is in charge of. Though partners take on works related to their core competence, the technology risk exist. The cooperative risk derives from the geographical position difference, cultural difference, managerial difference, and the bad communication among the partners, as well as the bad credits of partners. It will lead to great guls among the partners. Sometimes some partners will withdraw from the Virtual Enterprise, resulting in the disintegrating of the Virtual Enterprise.

4.2 Weight coefficient estimation of risk evaluation index[6]
The trustiness and accuracy of evaluating result are greatly influenced by the weight coefficient estimated. The estimating method includes two kinds, that is subjective and objective determining weights. The main methods include Delphi method, fuzzy determining weights method, analytic hierarchy process(AHP) and main component analysis, and so on. Here the AHP method will be used to determine the weights.
The main steps establishing index weights are as follows:
①Designing the risk evaluation questionnaire. The specialists are invited to evaluate the relative importance of the indexes in pairs at the same layer.
②Designing the judgment matrix. According to the theory of AHP, the paired-comparison judgment matrix can be made as follows: \( A = (\beta_{ij})_{n \times n} \), and it satisfies: \( \beta_{ij} > 0, \beta_{ii} = 1 / \beta_{jj}, \text{and} \beta_{ii} = 1 \).
③Calculating the significance sequence of the indexes at the same layer. Geometric mean method
is used to calculate the maximum eigenvalue, as well as the corresponding feature vector, and \( \lambda_{\text{max}} \) denotes the maximum eigenvalue. The single hierarchical arrangement weights are gotten by normalizing the feature vector.

③ Performing identity checking. A denotes n-order matrix, and \( \beta_{ij} \) is the element in the matrix A. if the elements in the matrix A are characterized by transitivity, then A is an eigenvalue matrix.

The identity ratio can be calculated, that is:

\[
CR = CI / RI
\]

Where \( CI = (\lambda_{\text{max}} - n) / (n - 1) \) denotes identity index. n denotes the order of judgment matrix A. RI is random identity index.

If \( CR < 0.1 \), then the identity of the judgment matrix meets the standard, and the results are reliable, else the judgment matrix should be made again. If \( CR > 0.1 \), then the identity of the judgment matrix meets the standard, and the results are reliable, else the judgment matrix should be made again.

The general weights can be calculated by integrating the single hierarchical arrangement weights. The weights of risks evaluation index system in Tab.1 is described as follows.

The weight set for main factor layer is: \( \omega = (\omega_1, \omega_2, \omega_3) \), and the weight set for sub-factor layers is: \( \omega = (\omega_1, \omega_2, \omega_3) \). Here: \( \sum_{i=1}^{3} \omega_i = 1 \), \( \sum_{i=1}^{m} \omega_{kj} = 1 \), \( \omega_k \geq 0 \).

4.3 Fuzzy synthetic evaluating of risk coefficients for partners within Virtual Enterprises

The main steps are as follows.

① Building the fuzzy sets. The index set on the main factor layer is \( X = (X_1, X_2, X_3) \), and the weight set corresponding is \( \omega = (\omega_1, \omega_2, \omega_3) \), where \( \omega_k \) ( \( k = 1, 2, 3 \)) denotes the weight that index \( X_k \) is in index \( X \), and \( \sum_{k=1}^{3} \omega_k = 1 \). The index set of sub-factor layer is \( X_k = (X_{k1}, X_{k2}, \cdots, X_{km}) \) (In this paper, while \( k = 1 \) or \( 2, \ m = 3 \). and while \( k = 3, \ m = 5 \)). The corresponding weight set is \( \omega = (\omega_{i1}, \omega_{i2}, \cdots, \omega_{im}) \), where \( \omega_{ki} \) ( \( i = 1, 2, \cdots, \ m \)) denotes the weight that index \( X_{ki} \) is in index \( X_k \), and \( \sum_{i=1}^{m} \omega_{ki} = 1 \). The evaluation set is \( v = \{v_1, v_2, v_3, v_4, v_5\} = \{\text{low, less low, moderate, less high, high}\} \). A set of values are assigned to factors of evaluation set, that is \( v = (0.1, 0.3, 0.5, 0.7, 0.9) \), where the numbers are defined corresponding with the extent of risks. The remarks are divided into five degrees, and it can also be more than five degrees according as the situation requires.

② Establishing the membership degree matrix. According to criterion of evaluation that has been defined, evaluation to the index system on the same layer is made. Here the evaluation is a kind of fuzzy mappings. The fuzzy evaluation matrix from \( X_{ki} \) to evaluation set \( V \) is:

\[
B_k = \begin{bmatrix}
    r_{11} & r_{12} & \cdots & r_{15} \\
    r_{21} & r_{22} & \cdots & r_{25} \\
    \vdots & \vdots & \ddots & \vdots \\
    r_{m1} & r_{m2} & \cdots & r_{m5}
\end{bmatrix}
\]

Where \( r_{ij} (i=1, 2, \cdots, m; \ j=1, 2, 3, 4, 5) \) (while \( k = 1 \) or \( 2, \ m = 3 \), and while \( k = 3, \ m = 5 \)) denotes the membership degree that the sub-factor index \( X_{ki} \) is relative to the remark \( V_j \). The method of
taking value for $r_{ij}$ is: The five kinds comments can be gotten by gathering the grading results of experts. Suppose the number of experts who remarked $v_1$ is $v_{i1}$, and the number of experts who remarked $v_2$ is $v_{i2}$, ..., the number of experts who remarked $v_5$ is $v_{i5}$, then we will get:

$$r_{ij} = v_{ij} / \sum_{j=1}^{5} v_{ij}, i = (i=1,2,\cdots,m)$$

(3)

5 Calculating example analysis

Supposing there is a Virtual Enterprise which has three core enterprises, that is partner A, partner B and partner C. The investments which each core enterprise proceeds with at any of various stages within the cooperative term are shown in Tab.2. The discount rate is 8%.

<table>
<thead>
<tr>
<th></th>
<th>Stage 1</th>
<th>Stage 2</th>
<th>Stage 3</th>
<th>Stage 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Partner A</td>
<td>100</td>
<td>20</td>
<td>30</td>
<td>10</td>
</tr>
<tr>
<td>Partner B</td>
<td>80</td>
<td>50</td>
<td>0</td>
<td>30</td>
</tr>
<tr>
<td>Partner C</td>
<td>50</td>
<td>30</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total profit</td>
<td>90</td>
<td>100</td>
<td>80</td>
<td>60</td>
</tr>
</tbody>
</table>

According to the designed evaluating standards, the experts evaluate the market risk of the partner A in stage 2. Suppose the fuzzy matrix is:
\[ B_1 = \begin{bmatrix} 0.4 & 0.3 & 0.2 & 0.1 & 0 \\ 0.5 & 0.2 & 0.2 & 0 & 0.1 \\ 0 & 0.2 & 0.1 & 0.3 & 0.4 \end{bmatrix} \]

Suppose that the weights set of each main factor which influences the total risk of partner A obtained by AHP is: \( \omega = (0.35, 0.4, 0.25) \), and the weight set of each sub-factor which influences the market risk is \( \omega_1 = (0.5, 0.4, 0.1) \).

According to equation (4), we can get membership vector that the market risk is relative to evaluation set \( \nu \), that is:

\[ C_1 = \omega \bullet B_1 = (0.4, 0.25, 0.19, 0.08, 0.08) \]

Then according to equation (5), we can get market risk coefficient of partner A, that is \( R_1 = 0.338 \). The technology and cooperation risk coefficient can also be obtained as for the same reason. Suppose the technology risk coefficient is \( R_2 = 0.438 \), and the cooperation risk coefficient is \( R_3 = 0.262 \).

According to equation (6), we can get the general risk coefficient that partner A in stage 2, that is:

\( R_{12} = 0.3438 \)

We can calculate all the general risk coefficients which each partner owns at any stages in the same way. The results are shown in Tab.3 as follows:

| Tab.3 Risk coefficients of each partner at different stages |
|-----------------|-----------------|-----------------|-----------------|
| Partner A       | 0.519           | 0.359           | 0.646           | 0.193           |
| Partner B       | 0.427           | 0.464           | 0.537           | 0.245           |
| Partner C       | 0.388           | 0.482           | 0.462           | 0.597           |

According to the profit allocation model, that is equation (1), we can calculate profit what each partner obtained from the Virtual Enterprise at different stage. The results are showed in Tab.4 as follows:

| Tab.4 Profits of each partner obtained at different stages |
|-----------------|-----------------|-----------------|-----------------|
| Stage 1         | Stage 2         | Stage 3         | Stage 4         |
| Partner A       | 44.29           | 30.69           | 37.85           | 15.65           |
| Partner B       | 29.15           | 42.27           | 27.55           | 19.60           |
| Partner C       | 16.56           | 27.04           | 14.40           | 24.75           |

6 Conclusion

There are many fuzzy factors in the course of quantitative analysis on profit allocation of the partners within the Virtual Enterprise, especially the analysis on risks undertook by the partners. So it is very difficult that the profits are allocated reasonably to the partners. On the basis of the profit allocation model within the Virtual Enterprise which is proceeded by predecessors. The work that has been done in this paper is as follows:

Firstly, the profit allocation model of the partners within the Virtual Enterprise is established, which conforms to the four principles of profit allocation. The time value of funds is considered in this model in view of the periodical operation of the Virtual Enterprises.

Secondly, taking the R&D Virtual Enterprises as examples, we design the evaluation index system of risk coefficient. AHP is used to estimate the weight of each index, and the fuzzy synthetic evaluation model is built to estimate the risk coefficients of the partners within the Virtual Enterprise in this paper. Some new ideas about calculating the risk coefficient of the partners within the Virtual Enterprise are brought forward by qualitative analysis and quantitative studying methods. In addition, the selecting of
risk evaluation index is based on R&D Virtual Enterprises in this paper, and specific conditions should be considered when establishing risk evaluation index system for other Virtual Enterprise types.

In the end, the calculating example is given to explain how to use the profit allocation model to allocate profits within the Virtual Enterprises in different stages.

To a certain extent, the effectiveness of profit allocation by applying the conclusion of the paper depends on the assessment level of experts. So we should choose experts owning a good stock of information and a great deal of experience, and at the same time the information offered to the experts should be as more as possible and as specific as possible.

In addition to the method introduced in this paper, we can also research the profit allocation problem of Virtual Enterprises as well as behavior strategy of each partner within the Virtual Enterprises by using cooperation game method, and there are many documents related which can be as references\(^7,8\).

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**References**


The Author can be contacted from Email: rongjuanlan@sina.com