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Research on Profit Distribution of Software Outsourcing Alliances Based on the Improved Shapley Value Model

Xiyan Lv, Suyan Zhao

School of Economics and Management, Beijing Jiaotong University, Beijing, 100044, China.
Emails: lvxiyan@bjtu.edu.cn 12120676@bjtu.edu.cn

Abstract: *With the development of software outsourcing industry, there is a growing trend to establish the software outsourcing alliances. Whether alliances' profit distribution is reasonable affects directly and significantly alliances' stability. This paper introduces the Shapley value method which is a common profit distribution method applicable to multiple people cooperation. Due to the weakness of the Shapley value method, AHP is used to analyze the influence factors and adjust the model. The anticipated outcome of the result is to provide a theoretical support for the profit distribution of the software outsourcing alliances in the future.*

Keywords: *Software outsourcing, alliance, profit, distribution, Shapley value, AHP* (*Analytic Hierarchy Process*).

1. Introduction

As the global software outsourcing market expands continually, software outsourcing has become an important trend in the development of world software industry. The target markets of software outsourcing are mainly concentrated on a few contracting countries like the United States, the European Union and Japan, and a few undertaking countries, such as India, China and Russia [1]. The scale and the management level are the generally valued factors of the contracting companies [2].

However, the majority of our software outsourcing companies cannot rely on its own strength solely to meet the requirements of the contracting enterprises and some smaller SMEs are in a position of embarrassment not to be trusted. Many scholars have done thorough researches in this aspect and put forward their views as well. R o n g Q i n g et al. [3] thought that the major factors of restricting the Chinese software industry from packaging the international software business includes: the small scale, limited market capability and inadequate software talent. X u J i n [4] proposed that the basic factor deciding the ability of undertaking projects is scale. The strategic alliance can form a synergy in a short time by integrating technology, management, capital and information resources together.

In such alliances, maximizing the total revenue through cooperation is still the common goal that all enterprises pursue. The double effect generated by interest can not only urge participants to require cooperation, but also make them influence the healthy operation of alliances as a result of unreasonable distribution of benefits [5]. Therefore, how to consider all kinds of factors and then allocate benefits fairly relates to the stability of alliances. At present, few people research on profit distribution between software outsourcing enterprises. Combining software outsourcing alliances' features, this paper uses Analytic Hierarchy Process (AHP) and Shapley value method to build a profit distribution model and proves its validity by an example, expecting to provide references for the profit distribution of software outsourcing alliances.

2. The influence factors of profit distribution in software outsourcing alliances

Profit distribution of software outsourcing alliances still follows four principles: larger payment for more work, risk compensation, utility maximization and comprehensive optimization [6]. The manifestations of alliances' interests are manifold, not only in monetary form, but also in the form of technology, capacity, reputation and social status, etc. [7]. Therefore, according to the principle of comprehensive optimization, we take enterprises' input factors, work achievements and risk factors into consideration to design the profit distribution mechanism for software outsourcing alliances.

The input factor is the basic element for the software outsourcing enterprises when they participate in the profit distribution and the size that enterprises invest directly affects their final benefits. Due to the differences in their own scales, R&D capabilities and other aspects, members' inputs in cooperation are not the same. Each enterprise's input factors include fixed assets and capital investment, technology and service capabilities, the number of personnel involved in R&D, as well as corporate reputation and position in the industry [8].

Work achievement refers to the workload of the companies to complete, specifically including the completion of the work, the quality of the work done and customer's satisfaction. In software outsourcing alliance as a whole, whether the enterprises can satisfactorily complete their tasks on time directly influences the alliance entire interest. At the same time, the value of the products and services also depends on customer's satisfaction. The higher the customer's satisfaction is, the greater customer's retention and market share will be.

The software outsourcing alliance is an alliance with complex, dynamic and interactive features. It undertakes various risks from the internal system and external environment during creating interests. In general, high-risk should correspond to a high yield. If we do not consider the correlation between risks and benefits, the companies will lack motivation to take risks. The risks existing in software outsourcing alliances include economic and policy environment risk, market risk, technology risk, information security risk, as well as co-operation and dissolution risk.

3. Traditional Shapley value model

Shapley value method is a mathematical method used to solve the problem of multiplayer cooperative game proposed by the famous game theory expert L. S. Shapley [9]. The basic idea is that when *n* individuals are involved in an economic activity, any cooperation form will receive certain benefits and when the economic activities among collaborators are not confrontational, increasing the number of collaborators will not cause cooperative benefits reduction. So multiple people cooperation will bring maximum benefits and Shapley value method is a program to allocate the maximum benefits.

Its definition is as follows. Set $I = \{1, 2, \cdots, n\}$. If any subset S in I corresponds to a real-valued function $v(S)$, it satisfies:

(1) $$v(\phi) = 0,$$

(2) $$v(S_1 \cup S_2) \geq v(S_1) + v(S_2), S_1 \cap S_2 = \phi, S_1, S_2 \subseteq I.$$

We call $[I, v]$ *n*-person cooperative countermeasure. We use x_i to represent an income that member *i* in set *I* should get from the maximum benefits $v(I)$. On the basis of cooperation *I*, the following conditions must be met to make it successful:

(3) $$\sum_{i=1}^{n} x_i = v(I), i = 1, 2, \cdots, n,$$

(4) $$x_i \geq v(i), i = 1, 2, \cdots, n.$$

Member i's Shapley value is $\varphi_i(v)$. The Shapley values of all members' profit allocations are $\varphi(v) = \{\varphi_1(v), \varphi_2(v), \cdots, \varphi_n(v)\}$, which are calculated as follows:

(5) $$\varphi_i(v) = \sum_{s \in S_i} w(|s|)\left[v(s) - v(s \setminus i)\right],$$

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

Among them, s_i is the subset of members i contained in *I*; $|s|$ is the number of elements in subset s; $w(|s|)$ is the weight factor; $v(s)$ is the revenue of subset s; $v(s \setminus i)$ is the total revenue of subset s removed out member i.

In practice software outsourcing alliance is also a kind of cooperation established through some formal or informal contract for achieving specific development goals. For each enterprise, making the profits of the alliance increase is the premise to join it. It is the guarantee of maintaining the outsourcing alliances to operate continuously so that the profits an enterprise gets after joining the alliance is more than before. Therefore, the profit distribution of the software outsourcing alliance can be seen as the profit distribution of multiple people cooperation, and can be resolved by the Shapley value method.

4. The introduction of correction factors based on AHP

Allocating the benefits based on the importance of the cooperative members, the Shapley value method avoids the drawbacks of average allocation, but it ignores the differences of motives and contributions among package enterprise alliance members [10]. Thus, in order to make the profit distribution more fair and more reasonable, this paper amends the Shapley value method by introducing correction factors.

A software outsourcing alliance consists of n members. Denote *I* = (1, 2, …, *n*). V is the total revenue of the alliance and $\varphi_i(v)$ is the interest member i gets; k_1, k_2, k_3 are coefficients separately based on the input factor, work achievement and risk factor. We use P_i to express the weight that member enterprise i accounts on the input factors. T_i indicates the work achievements weight of enterprise i and R_i represents the weight of member enterprise i's risk factor. And we have $\sum_{i=1}^{n} P_i = 1, \sum_{i=1}^{n} T_i = 1, \sum_{i=1}^{n} R_i = 1$.

Considering the input factors, work achievements and risk factors, we can construct the improved Shapley value model in the profit distribution of the software outsourcing enterprise alliance. The improved model is:

(7) $$\varphi_i' = \varphi_i(v) + k_1 V \Delta P_i + k_2 V \Delta T_i + k_3 V \Delta R_i, \; k_1 + k_2 + k_3 = 1,$$

(8) $$\varphi_i(v) = \sum_{s \in S_i} \frac{(n-|s|)!(|s|-1)}{n!} \left[v(s) - v(s \setminus i) \right], \quad i = 1, 2, \cdots, n,$$

in which ΔP_i, ΔT_i and ΔR_i are respectively the difference of the actual input factor P_i and the average factor $1/n$, the difference of the actual work achievement T_i and the average factor $1/n$ and the difference of the actual risk factor R_i and the average factor $1/n$. We have $\sum_{i=1}^{n} \Delta P_i = 0$, $\sum_{i=1}^{n} \Delta T_i = 0$, and $\sum_{i=1}^{n} \Delta R_i = 0$.

4.1. Determine the index weight using AHP

In the improved Shapley value model established in the paper for profit distribution of software outsourcing alliances, the input factor, work achievement and risk factor are respectively expressed by B_1, B_2, B_3 and the elements included in the three indexes are expressed by C_i, i=1, 2, …, 12.

1) Establish the hierarchical structure of AHP

AHP divide the problem into criteria according to the nature and the goal of the problem. It breaks down the factors into target hierarchy, standards hierarchy and scheme hierarchy according to the relationship between factors[11]. The hierarchical structure of factors affecting profit distribution is shown in Fig. 1.

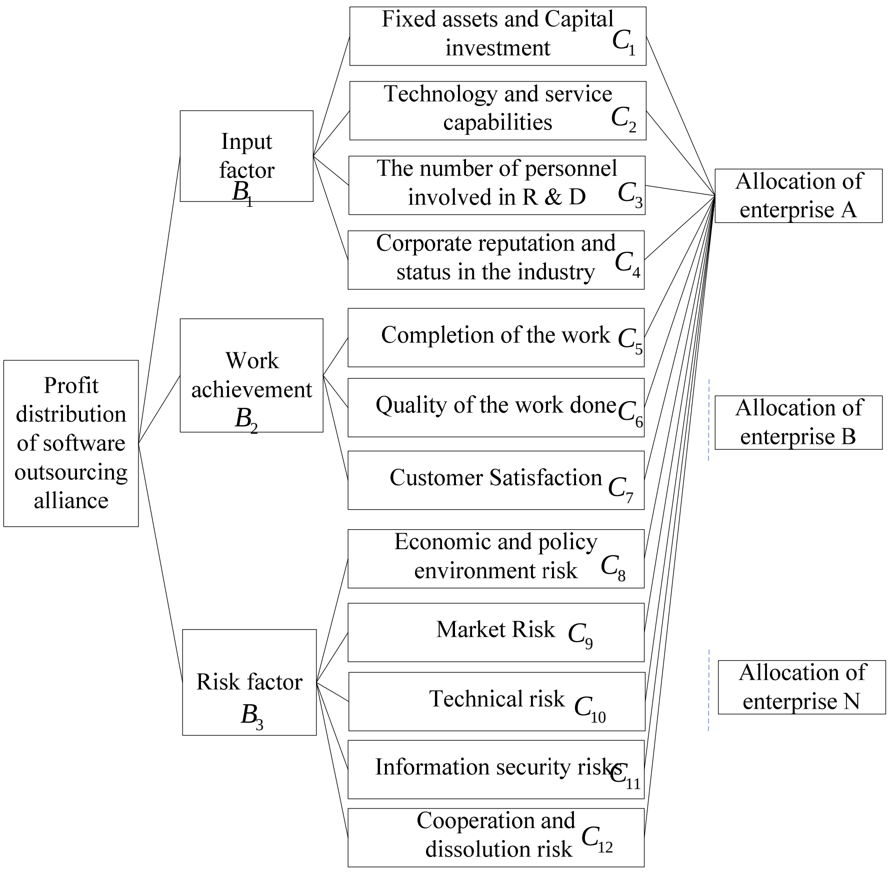

Fig. 1. The hierarchical structure of factors affecting profit distribution

2) Construct pairwise comparison judgment matrix A,

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} = (a_{ij})_{n\times n}.$$

Among the matrix, $a_{ij} > 0, a_{ij} = 1/a_{ji}, a_{ii} = 1$; a_{ij} is the relative importance levels of criteria evaluated by the third party or expert group.

3) Consistency test

Calculate the consistency index $\mathrm{CI} = \frac{\lambda_{\max} - n}{n-1}$ ($\lambda_{\max}$ is the largest eigenvalue of the judgment matrix) and calculate the consistency ratio $\mathrm{CR}=\frac{\mathrm{CI}}{\mathrm{RI}}$. Among the above formula, RI is the average random consistency index and we can obtain it by looking up the table according to the order of a matrix. CR<0.1 is an acceptable result since it shows that the evaluation of the elements in matrix *A* is basically the same. While CR>0.1 defines the consistency of matrix *A* as very bad.

4.2. Determine the coefficients of influence factors

1) Determine the coefficients of the input factor and work achievement

There are both quantitative indicators and qualitative indicators in the input factor and work achievement. It is difficult to determine their weights integrately. So when determining the weight of each index of member enterprises, for quantitative indicators , we get judgment matrices according to the practical data and for qualitative indicators, we obtain judgment matrices through expert scores.

Suppose that through the judgment matrices, we obtain the index weight of the input factors, denoted as K_j, j=1, 2, 3, 4, and the index weight of the factors input by enterprise i is P_{ij}, j=1, 2, 3, 4. Then the coefficient of the input factor of enterprise i is:

(9) $$P_i = \sum_{j=1}^{4} K_j \times P_{ij}.$$

Similarly, we use W_j, j=1, 2, 3, to express the index weight of the work achievement and T_{ij}, j=1, 2, 3, to express the index weight of enterprise i work achievement. Then the coefficient of the work achievement of enterprise i is

(10) $$T_i = \sum_{j=1}^{3} W_j \times T_{ij}.$$

2) Determine the coefficients of a risk factor

By analyzing the risk characteristics of the software outsourcing industry alliances, we select five typical risks to calculate. Fuzzy comprehensive evaluation method is a comprehensive evaluation method based on fuzzy mathematics and it is often used to determine the risk coefficients.

• Determine the evaluation index set

$U = \{U_1, U_2, U_3, U_4, U_5\}$ = {economic and policy environment risk, market risk, technology risk, information security risk, cooperation and dissolution risk}. The coefficient constants of the evaluation index are $A = (a_1, a_2, a_3, a_4, a_5)$.

Evaluation set is $V = \{V_1, V_2, V_3, V_4\}$ ={very high, high, ordinary, low}. $M = \{0.7, 0.5, 0.3, 0.1\}$ is the vector value of each evaluation element and it expresses the corresponding relationship between the evaluation elements and enterprises' risks.

• Establish the fuzzy relation matrices. We obtain the risk fuzzy matrices from the risk assessment panel scoring each enterprise in the light of the evaluation set.

• Calculate the comprehensive membership grade $B_i = A \times R_i$, $i = 1, 2, 3$. Then calculate the risk coefficients of the alliance enterprises through $R' = M \times B^{\mathrm{T}}$. Normalize it to get the final risk coefficient of each member enterprise.

5. Example analysis

Suppose a software outsourcing enterprise alliance has three joint ventures, noted as 1, 2, 3. They separately obtain 350 000 yuan, 250 000 yuan, 80 000 yuan when work alone; 700 000 yuan when 1 and 2 cooperate; 550 000 yuan when 1 and 3 cooperate; 450 000 yuan when 2 and 3 cooperate; 900 000 yuan when 1, 2 and 3 cooperate.

1) Calculate the Shapley value

Let $v(s)$ expresses the revenue of the software outsourcing alliance s with member i involved and let $v(s \setminus i)$ expresses the revenue of the software outsourcing alliance s without member i involved. $\varphi_1(v), \varphi_2(v), \varphi_3(v)$ respectively express the interest of 1, 2 and 3. The Shapley value calculation table of enterprise 1 is shown as Table 1.

Table 1. The income calculating of the member enterprise 1

S_i	1	$1 \cup 2$	$1 \cup 3$	$1 \cup 2 \cup 3$
$v(s)$	35	70	55	90
$v(s \setminus i)$	0	25	8	45
$v(s) - v(s \setminus i)$	35	45	47	45
$\|s\|$	1	2	2	3
$w(\|s\|)$	$\frac{1}{3}$	$\frac{1}{6}$	$\frac{1}{6}$	$\frac{1}{3}$
$w(\|s\|)[v(s) - v(s \setminus i)]$	$\frac{35}{3}$	$\frac{15}{2}$	$\frac{47}{6}$	15

It is easily calculated, $\varphi_1(v)=\frac{35}{3}+\frac{15}{2}+\frac{47}{6}+15=42$. Similarly, the interest enterprise 2 can get is $\varphi_2(v)=32$, and the interest enterprise 3 can get is $\varphi_3(v)=16$.

2) Determine the coefficients of the input factor and work achievement

We use the actual data or experts' evaluation score to get the judgment matrices. Table 2 shows some actual data of the three enterprises. The data contains the capital investment, the number of personnel involved in R&D, the completion of the work, the quality of the work done and the customers' satisfaction.

Table 2. Measurable indicators of the software outsourcing alliance enterprises

Member enterprise	Capital	Number of R&D personnel	Completion of work (%)	Quality of the work (%)	Customer satisfaction (%)
Enterprise 1	550	27	95	99	98
Enterprise 2	280	33	100	95	94
Enterprise 3	150	50	98	98	96

Through calculating, we get the weights of the three influence factors. They are $k_1=0.3014$, $k_2=0.4408$, $k_3=0.2578$. The single ranking weights of the program layer and the total ranking values of the input factors and work achievement are separately shown in Tables 3 and 4.

Table 3. The single ranking weights and the total ranking values of the input factors

Criterion	Fixed assets and capital investment	Technology and service capabilities	The number of personnel involved in R&D	Corporate reputation and status	Input factor weights P_i
Criterion layer weights	0.2343	0.3084	0.1259	0.3314	
Enterprise 1	0.5612	0.7306	0.2455	0.7010	0.6200
Enterprise 2	0.2857	0.1884	0.3000	0.1929	0.2268
Enterprise 3	0.1531	0.0810	0.4545	0.1061	0.1532

Table 4. The single ranking weights and the total ranking values of work achievements

Criterion	Completion of the work	Quality of the work done	Customer satisfaction	Work achievement weights T_i
Criterion layer weights	0.3793	0.2894	0.3313	
Enterprise 1	0.3242	0.3390	0.3403	0.3338
Enterprise 2	0.3413	0.3253	0.3264	0.3318
Enterprise 3	0.3345	0.3356	0.3333	0.3344

3) Determine enterprises' risk coefficients

Experts give scores to the three enterprises with reference to the evaluation set M and then we obtain the risk fuzzy matrices R_1, R_2, R_3:

$$R_1 = \begin{bmatrix} 0.6 & 0.3 & 0.1 & 0 \\ 0.3 & 0.4 & 0.2 & 0.1 \\ 0.5 & 0.2 & 0.2 & 0.1 \\ 0.4 & 0.3 & 0.1 & 0.2 \\ 0.3 & 0.2 & 0.2 & 0.3 \end{bmatrix}, R_2 = \begin{bmatrix} 0.2 & 0.1 & 0.4 & 0.3 \\ 0.5 & 0.3 & 0.2 & 0 \\ 0.4 & 0.4 & 0.1 & 0.1 \\ 0 & 0.2 & 0.5 & 0.3 \\ 0.3 & 0.4 & 0.1 & 0.2 \end{bmatrix}, R_3 = \begin{bmatrix} 0.1 & 0 & 0.6 & 0.3 \\ 0.3 & 0.4 & 0.2 & 0.1 \\ 0.2 & 0.1 & 0.4 & 0.3 \\ 0.2 & 0.3 & 0.1 & 0.4 \\ 0.6 & 0.2 & 0.2 & 0 \end{bmatrix}.$$

Then

$$B = \begin{bmatrix} B_1 \\ B_2 \\ B_3 \end{bmatrix} = \begin{bmatrix} 0.4157 & 0.2691 & 0.1782 & 0.1370 \\ 0.3390 & 0.3225 & 0.2006 & 0.1379 \\ 0.2849 & 0.2016 & 0.3029 & 0.2106 \end{bmatrix}.$$

It is easy to define $A = (0.1028, 0.2362, 0.3666, 0.1154, 0.1790)$ by calculating the risk judgment matrices. Then $R' = (0.4927 \quad 0.4725 \quad 0.4122)$. Normalize them and we will get the final risk coefficients of the enterprises $R_1 = 0.3577, R_2 = 0.3430, R_3 = 0.2993$.

4) Substitute the correction coefficients into (7) and obtain the program of profit distribution of the three enterprises after amendment. It is shown in Table 5.

Table 5. The program of enterprises' profit distribution after amendment

Enterprise 1	Enterprise 2	Enterprise 3	Total revenue
503500 yuan	292800 yuan	103700 yuan	900000 yuan

Obviously, the program of profit distribution after amendment has great difference compared to the former one. The correction model realizes the adjustment of enterprises' interests through adjusting the weights of different factors. The interests assigned to the alliance enterprises have proportional relationship with input factors, work achievements and risk factors. So the proposed modification strategy will help to encourage the enterprises increase the investment, improve the work efficiency and undertake more risks, thereby creating more profits.

6. Conclusions

Technology alliance is a kind of an interest driven organization, where the profit distribution is reasonably directly related to the success or failure of the alliances [12]. Establishing a scientific and rational allocation mechanism can help to maintain the stability and fairness of the alliances. This paper tries to apply the Shapley value method to profit distribution of the software outsourcing alliances and leads in influence factors to amend it and makes the profit allocation of the alliances fairer and more practical. The construction of a new model can not only maximize the alliances' interest, but also make the alliances realize harmonious development.

References

1. Liu, Shaojian. Strategic Study of the Present Situation, Mode and Development of China Undertaking International Software Outsourcing. – International trade, Vol. **26**, 2007, No 6, 27-32.
2. Ma Rong. China's Software Outsourcing White Paper (On). – Software Engineer, Vol. **23**, 2004, No 1, 32-34.
3. Rong Qing, Zhan Honghui. The Analysis of Problems and Countermeasure Existing in China Packaging International Software Business. – Market Modernization, Vol. **34**, 2005, No 23, 19-20.
4. Xu Jin. Review and Prospect of China's Software Outsourcing Industry. – Economic Perspectives, Vol. **50**, 2009, No 11, 75-78.
5. Dongsoo Shin. Choice of Technology in Outsourcing: An Endogenous Information Structure. – Information Economics and Policy, 2004, No 16, 165-178.
6. Ye Huaizhen, Hu Yijie. Research on Benefit Principles of Supply Chain Partners. – Journal of Southwest Jiaotong University, Vol. **39** , 2004, No 1, 30-33.
7. Giannakas, K, M. Fulton. Process Innovation Activity in a Mixed Oligopoly: The Role of Cooperatives. – American Agricultural Economics Association, Vol. **87**, 2005, No 2, 406-422.
8. Ding Shang. Research on Profit Allocation of Supply Chain Cooperative Game. Changsha, Changsha University of Science & Technology, 2009.
9. Jiang Qiyuan. Mathematical Model. – Higher Education Press, Beijing, 2001.
10. Shi Hongwei, Li Ying. Strategy of Enterprise Alliance Accessing Package Based on Shapley Value Model with Differences of Contribution. – Modern Economic Information, Vol. **24**, No 24, 335-337.
11. Xi, X., Q. Qin. Product Quality Evaluation System Based on AHP Fuzzy Comprehensive Evaluation. – Journal of Industrial Engineering and Management, Vol. **6**, 2013, No 1, 356-366.
12. Sheng Yanchao. Study on Profit Allocation of Technology Alliances Based on Improved Shapley Value Method. – Journal of Dalian University of Technology (social science), Vol. **30**, No 2, 34-39.