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The incentive mechanism in knowledge alliance: based on the input-output of knowledge

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ABSTRACT

This study examines the input and output of the incentive mechanism of the knowledge in knowledge alliances (KAs). Through the mathematical model and the empirical analysis, the results show that the input-output ratio of knowledge has a positive influence on the incentives in KAs, while the input scale and output scale of knowledge have no significant influence. This study explores the influencing factors of the incentives in KAs from the input-output perspective using multiple methods and provides guidelines for the optimal benefit allocation in KAs. Further, the research results apply to other fields, providing a theoretical basis for strengthening the interaction between alliance members and how members of KAs can obtain the maximum knowledge output with limited knowledge input and how to motivate alliance members' knowledge input.

Introduction

In the knowledge economy era, the business success of new product development is coming to rely more and more on knowledge (Pertusa-Ortega, Zaragoza-Sáez, & Claver-Cortés, 2010). Allee (1997) and Davenport and Pruzak (1998) think knowledge is professional intellect, including know-what, know-how, know-why, and self-motivated creativity, or experience, concepts, values, beliefs, and ways of working that can be shared and communicated.

It is difficult for a single organization to complete a large project, which usually requires complex, diverse and different special knowledge. Most organizations have established alliances with clients, firms, or competitors. Alliance is a carrier of knowledge as it provides a platform for firms to outsource knowledge as well as gain knowledge from outside. Many scholars consider different parts of knowledge to be complementary and expected to increase the benefits of enterprises (Wang & Shao, 2012; Makri, Hitt, & Lane, 2010). Meanwhile, strategic alliances can effectively promote organizational performance (Bhattacharyya, 2018). Therefore, it is important to understand how to influence the willingness of alliances to share knowledge, thus helping accelerate the process of knowledge sharing and learning among alliances (Bouncken, Pesch, & Reuschl, 2016). Many organizations have been concerned about the appropriate way to encourage their alliance partners to input more knowledge resources for more benefits. The existing research proves that introducing an incentive mechanism can significantly improve knowledge sharing among supply chain enterprises (Wang & Qiao, 2018). Therefore, establishing a rational incentive mechanism will also enhance the input efficiency in KAs and maximize knowledge complementarity.

Both empirical and theoretical evidence is provided on the effectiveness of the incentive mechanism (O'Dell & Grayson, 1998; Alavi & Leidner, 2001). Alavi and Leidner (2001) suggest that more research is expected to address the issues of what types of incentives are effective in improving knowledge management in organizations. Harder (2008) shows that tangible rewards have negative correlations with autonomous motivation for employees. Li and Jhang-Li (2010) apply game theory to analyze the incentives in different forms of communities of practice like individual profiles and decision structures.

Scholars have also studied incentive mechanisms in the field of knowledge management. Li (2018) studies the strategy of knowledge sharing between individuals in organizations from the perspective of the dynamic cooperative game and evaluates the role of incentives in their knowledge sharing. Han, Rapoport and Fong (2019) take multi-

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partner project teams as research objects to explore the impact of incentive contracts on enterprise input and project performance and provide suggestions for enterprises to allocate fixed efforts between production and cooperation. Xiong, Wang and Wu (2021) use game theory to construct an incentive model of knowledge sharing in virtual scientific research organizations to promote knowledge sharing behavior and improve the organization's innovation ability based on the negative impact of risk avoidance and a fault-tolerant environment. Based on the characteristics of KAs, selecting the knowledge-sharing strategy is a dynamic process based on continuous adjustment. Taking KAs as the research object, Sun, Li and Luo (2014) classify the influencing factors of incentive synergy in KA into four dimensions: knowledge subject behavior, incentive synergy structure, incentive synergy motivation, and KA status. Although different perspectives have been taken on knowledge sharing incentive mechanism research, the characteristics of KAs are less discussed. In addition, relatively few scholars combine knowledge input, knowledge creation, knowledge collaboration, and knowledge spillover into organizational decision-making (Ding & Huang, 2010). Based on this research gap, this paper considers the characteristics of KA, the dynamic change process of continuous adjustment of knowledge sharing, and variables such as input and output of knowledge to conduct in-depth research on the incentive mechanism of KA. This study provides suggestions for enterprises in KAs to have better knowledge sharing through the incentive mechanism.

By designing the incentive mechanism of KAs from the perspective of knowledge input and output based on the dynamic development of the KAs, this paper contributes to strengthening the interaction of alliance members and finding the optimal benefit allocation to motivate each member. The rest of the paper is as follows: Section 2 defines knowledge collaboration and KAs. Section 3 designs the incentive mechanism of KAs based on the mathematical model and analyzes the model. Section 4 raises the research hypotheses based on theories and results of the model analysis and tests the rationality of the model through the empirical analysis. Section 5 discusses the results. The last section includes the concluding comments and the limitations of this paper.

Literature review

Knowledge alliance and knowledge collaboration

Demsetz (1988) defines the existence of the firm as a response to the demand for knowledge specialization and division in the economics of knowledge. To maximize production, firms function as knowledge aggregation with the joint efforts of specialized employees who have expertise in diversified professional areas. One can understand this form as a think tank integrating various parts of knowledge entailed in business operation such as manufacturing, designing, and marketing. Cooperation and exchanges among individuals are greatly encouraged within a firm, leading to collaborative input in production as well as less coordinating costs and higher work efficiency.

However, an entity cannot hoard its own knowledge and isolate itself from sharing and accepting in an open environment, especially in ever-changing times when self-sufficiency is getting difficult. Firms create and manage new knowledge through strategic alliances to keep abreast of the growing trend and foster sustainable competitive advantages (Inkpen, 1996). Hamel, Doz and Prahalad (1989) define alliances as "a window on partners' broad capacities." The alliance serves as a platform through which companies can establish cooperative links with their partners, gain easier access to each other's knowledge and outsource their own expertise, allowing for the flexible application of expertise (Grant & Baden-Fuller, 2004). Strategic alliances have a variety of arrangements, including joint ventures, R&D partnerships, and distribution and supply agreements (Inkpen, 1998). Parkhe (1991) describes the global strategic alliance as an essential feature of the international structure in firms. In the context of emerging markets where it is no longer sufficient for firms to rely solely on their own capabilities, relationship capital among alliance partners affects the effectiveness and quality of learning processes in strategic alliances (Lo, Stepicheva, & Peng, 2016). In consequence, companies need to build more relationships with partners worldwide. Multinational companies are a typical form of global strategic alliance. The geographically dispersed subsidiaries and branches of multinational companies have access to different knowledge resources (Ferraris, Santoro, & Bresciani, 2017). Therefore, we also name these organizations/strategic alliances as KAs. Existing studies show that knowledge transfer, absorptive capacity, and knowledge internalization within an alliance contribute to knowledge internalization among partners and positively impact alliance productivity and performance (Rajan & Dhir, 2021). Therefore, multinational companies can become more competitive in foreign markets, distribution channels, and production capacity.

With the advent of the knowledge-based economy, knowledge is becoming a dominant resource for the sustainability and competitiveness of enterprises (Ferreira, Mueller, & Papa, 2020). KAs come to the fore because organizations need to manage knowledge for survival and growth (Paoloni, Coluccia, Fontana, & Solimene, 2020). When a KA is formed, the communication within the alliance and the cooperation among the partners enter into a new stage. Knowledge transfer can improve the cooperative relationship between partners, but a collaborative orientation is needed to support a successful knowledge transfer (Whitehead, Zacharia, & Prater, 2019). The general phenomenon of collaboration can be defined as a process of joint decision-making among key stakeholders in a problem domain (Kramer & Gray, 1990). Collaborations can be understood as the process of co-laboring, sharing, and creating something new (Anklam, 2002). Knowledge collaboration within organizations can be defined as the trade-offs between diversity and commonality of knowledge when there are gains of specialization in knowledge acquisition and storage. In this paper, these organizations are named as KAs. The primary task of KAs is to coordinate the efforts of specialists within the alliances. The organizational efforts and knowledge collaboration require shared perceptions and values within an alliance to optimize individual effectiveness of employee engagement (Macey & Schneider, 2008). These efforts include the involvement of knowledge, energy, time, and resources (Macey & Schneider, 2008) or the investment of people's physical, cognitive and emotional resources in diversified work roles (Kahn, 1990). Knowledge sharing and collaboration in the supply chain can significantly affect customer satisfaction, thus improving the competitiveness of enterprises in the supply chain (Haque & Islam, 2018). In the study of the cooperation effect of KAs, from the influencing factors of the knowledge cooperation effect in KAs, cooperative intention, learning ability, knowledge attribute, and knowledge activity have significant effects on knowledge cooperation of KA (Cheng & Chang, 2020). KA is a knowledge network composed of different knowledge chains, where are the aggregation of the industry-university-research institute and the supply chain organization. Knowledge synergy in knowledge chains is an important way to promote knowledge value-added, realize knowledge synergy effect, and form knowledge advantage (Cheng, Gu, & Quan, 2018). From the knowledge management process perspective, collaborative knowledge management of knowledge chains promotes the flow and sharing of knowledge resources at all levels in knowledge chains. It is also a kind of whole process management to promote knowledge synergy (Cheng, Gu, & Quan, 2017). Cheng, Gu and Chang (2019) indicate that cultural synergy is the soft power to promote knowledge synergy in knowledge chains, which can promote knowledge synergy.

Incentive mechanism

An organization's ability to effectively create, share, and use knowledge is highly dependent on its internal human resources (Antunes & Pinheiro, 2020). Incentives, as a human resource practice, foster employees' knowledge sharing. Incentives include cash bonuses, stock bonuses, and stock options, which are rewards employees can receive based on the organization's performance (Liu & Liu, 2011). Enterprises can improve employees' willingness to share knowledge and promote knowledge sharing by introducing incentive mechanisms, such as reducing the cost of knowledge sharing among employees, giving employees appropriate spiritual encouragement, and paying performance wages. Thus, knowledge sharing improves enterprises' overall efficiency and output (Zhang, Duan, & Zhao, 2020). Similarly, we define incentives as a method to encourage the involvement of every organization member in the KAs. According to the expectancy-value theory (Vroom, 1964), the more one perceives positive outcomes associated with a given action, the more inclined one will be to perform that action (Wright, Dunford, & Snell, 2001). There are three perspectives on knowledge incentive mechanisms: the external view, the internal view, and the introjected view. External incentives increase individuals' pressure to perform better under conditions of insufficient monitoring. Examples of external incentives include money and praise as well as avoidance of punishment (Gerhart & Rynes, 2003; Foss, Minbaeva, Pedersen, & Reinholt, 2009). Qualitative compensation plans integrate employees, and financial compensation is a key factor determining knowledge management (Marshall, Prusak, & Shpilberg, 1996; Massey, Montoya-Weiss, & O'Driscoll, 2002). Other studies argue that incentives may motivate performance from internally psychological perspectives such as self-efficacy and performance feedback (Ashton, 1990; Liu & Liu, 2011). The internal view is that psychological incentives involve doing an activity because it aligns with the individual's intrinsic interest and personal values (Ryan & Deci, 2000). The introjected view combines both external and internal incentives. Individuals are not acting on verbalized expectation but on what they believe others want them to behave. In this sense, individuals internalize external demands. Thus, behavior is self-regulated but not intrinsically motivated (Foss, Minbaeva, Pedersen, & Reinholt, 2009). Based on the participants' perception of each other's situation, Liu, Feng, and Li (2018) establish a social incentive mechanism based on synergy and show that the incentive mechanism can bring higher benefit to the synergy members under the background of synergy. They also find that in addition to constructing a positive incentive mechanism according to relevant indicators, the core enterprises of the alliance also need to introduce negative incentive mechanisms in operation, such as introducing punishment mechanisms and improving punishment coefficients. The negative incentive mechanism could have a better incentive effect than a positive mechanism (Hong, Huo, & Su, 2017).

Incentive model design

Model hypothesis

The cooperation and interaction among the main bodies of the knowledge chain are the key links to realize the synergetic effect of the knowledge chain, which are realized by the input of the knowledge, technology, and exclusive resources of the main bodies. In order to facilitate the construction of the model, we name the two subjects of the knowledge chain as subject A and subject B.

Model hypothesis 1:We suppose A and B as two members in a KA, and they get involved in the collaborative activities by putting their specialized knowledge, technology, or other resources. We establish the following model using Cobb-Douglas Production Function to describe the benefits of participating in collaborative activities.

$$\phi(A,B) = kA^aB^b + \mu \tag{1}$$

A and *B* separately represent the input of knowledge, technology, and exclusive resources for A and B, *a* and *b* separately represent the input-output elastic coefficient of A and B, ϕ is the collaborative benefit, *k* is defined as the value of cooperation, and μ is the stochastic disturbance.

During the process of knowledge collaboration, the amount of *A* and *B* follow the rule of marginal utility: when *A* and *B* increase, ϕ will increase. However, the speed of ϕ's increase will gradually slow down. We use the following inequalities to show this change:

$$\frac{\partial\phi(A,B)}{\partial A} > 0,\ \frac{\partial\phi(A,B)}{\partial B} > 0$$

$$\frac{\partial^2\phi(A,B)}{\partial A^2} < 0,\ \frac{\partial^2\phi(A,B)}{\partial B^2} < 0$$

From the models above, we know that $0 < a < 1,\ 0 < b < 1$. μ is normally distributed and follows $N \sim (0, \sigma^2)$. Therefore, we can calculate expected benefits:

$$E\phi(A,B) = kA^aB^b$$

KAs mainly work to maximize benefits and strengthen core competence, as every single company in an alliance also regards the pursuit of benefits as a major goal. To explain the connection between input and benefit, we put forward model hypothesis 2 and model hypothesis 3.

Model hypothesis 2: We establish the following formula to measure the input costs of A and B:

$$\mathrm{C(A)} = \frac{\lambda A^2}{2}, \mathrm{C(B)} = \frac{\varphi B^2}{2}$$

λ and φ are both input-cost coefficients for *A* and *B*.

Model hypothesis 3: The importance of KA lies in the knowledge collaboration effects it exerts. Under the mechanism of knowledge collaboration, members integrate an organization's internal and external resources to make the total benefits outperform the pure sum of single benefits of independent members (we name the latter as basic benefits). Thus, we believe that knowledge collaboration creates much greater value than physical cooperation, and we name the surplus value as collaborative benefits. More significantly, we suppose members in a KA have two sources of benefits-from the basic benefits and the collaborative benefits. Based on the models of Holmstrom and Milgrom, we suppose that the payoff function for A is:

$$\theta(\phi) = \omega + \beta\phi$$

$\theta(\phi)$ represents the total benefits A makes from knowledge collaborative activities, ω indicates the basic benefits, β is the benefit coefficient of A when engaged in knowledge collaborative activities, and $0 < \beta < 1$.

Model building

We establish the following equation to describe the expected benefits *A* gains through collaborative activities with *B*:

$$E(R_A) = E(\theta(\phi) - C(A)) = \omega + \beta kA^aB^b - \frac{\lambda A^2}{2} \tag{2}$$

A could receive the optimal benefits by adjustment, and (3) shows the partial difference of (2):

$$a\beta kA^{a-1}B^b - \lambda A \tag{3}$$

Suppose the result of (3) is zero, we can get the first-order condition to maximize the expected benefits of *A*.

We establish the following equation to describe the expected benefits *B* gains through collaborative activities with *A*:

$$E(R_B) = E(\phi(A,B) - \theta(\phi) - C(B)) = (1-\beta)kA^aB^b - \omega - \frac{\varphi B^2}{2} \tag{4}$$

B could receive the optimal benefits by adjustment, and (5) shows the partial difference of (4):

$$b(1-\beta)kA^aB^{b-1}-\varphi B \tag{5}$$

Suppose the result of (5) is zero, we can get the first-order condition to maximize the expected benefits of B.

We can get the simultaneous formulas (6) from (3) and (5). When the revenue function is determined, (6) indicates the optimal input conditions:

$$\begin{cases} a\beta kA^{a-1}B^b-\lambda A=0 \\ b(1-\beta)kA^aB^{b-1}-\varphi B=0 \end{cases} \tag{6}$$

In order to unleash the enthusiasm and initiative of each member, make members participate in collaborative activities in KAs, and achieve collaboration effects of KAs, it is necessary to ensure the expected benefits of each member are greater than the opportunity cost of participating in the collaboration.

$$\begin{cases} E(R_A)\geq C_A \\ E(R_B)\geq C_B \end{cases}$$

C_A and C_B represent the opportunity cost of A and B separately.

Model solution

The incentive mechanism of KAs motivates each member through interest distribution. However, according to the rule of marginal effect, when the incentive exceeds the optimal solution, it is not necessary for the KAs to pay more benefits to each member. Therefore, the constraint of A can be expressed as:

$$E(R_A)=C_A$$

$$\omega+\beta kA^aB^b-\frac{\lambda A^2}{2}=C_A$$

$$\omega=C_A-\beta kA^aB^b+\frac{\lambda A^2}{2} \tag{7}$$

If we use (7) to express ω in (4) then:

$$E(R_B)=kA^aB^b-C_A-\frac{\lambda A^2}{2}-\frac{\varphi B^2}{2} \tag{8}$$

We set (8) as the target function and solve the maximum of this function. (6) is the constraint condition of (8). It's meaningless when each member puts no knowledge into collaborative activities, so $A\neq 0,\ B\neq 0$.

If we multiply (3) by A and multiply (5) by B, a deformation equation can be calculated as follows:

$$\begin{cases} a\beta kA^aB^b-\lambda A^2=0 \\ b(1-\beta)kA^aB^b-\varphi B^2=0 \end{cases} \tag{9}$$

From model hypothesis 1, we know the target function indeed has an extreme value, and we can construct $F(A,B)$ applying the Lagrange multipliers method.

$$F(A,B)=kA^aB^b-C_A-\frac{\lambda A^2}{2}-\frac{\varphi B^2}{2}-m\left(a\beta kA^aB^b-\lambda A^2\right) - n\left[b(1-\beta)kA^aB^b-\varphi B^2\right] \tag{10}$$

m and n are both Lagrangian multipliers. We solve the partial differentials of A and B:

$$\begin{cases} akA^{a-1}B^b-\lambda A-a^2m\beta kA^{a-1}B^b+2m\lambda A-nb(1-\beta)kaA^{a-1}B^b=0 \\ bkA^aB^{b-1}-\varphi B-abm\beta kA^aB^{b-1}+2n\varphi B-nb^2(1-\beta)kA^aB^{b-1}=0 \end{cases} \tag{11}$$

By simulating (9) and (10), we can get the simultaneous formulas (12):

$$\begin{cases} \dfrac{1}{\beta}(1-nb)-1-am+2m+nb=0 \\ \dfrac{1}{1-\beta}-1-am\dfrac{\beta}{1-\beta}-nb+2n=0 \end{cases} \tag{12}$$

Then we take the derivative of β in (10) and let the result be zero:

$$ma=nb \tag{13}$$

The following simultaneous equations can be deduced through uniting (12) and (13):

$$\begin{cases} (2ab+2a^2-4a)m^2-2abm+b=0 \\ (2ab+2b^2-4b)n^2-2abn+a=0 \end{cases} \tag{14}$$

$$\begin{cases} m=ab\pm\dfrac{\sqrt{ab(a-2)(b-2)}}{2a(a+b-2)} \\ n=ab\pm\dfrac{\sqrt{ab(a-2)(b-2)}}{2b(a+b-2)} \end{cases} \tag{15}$$

(10) implies that the values of m and n should be minus so that we can calculate the optimal benefits coefficient:

$$\tilde{\beta}=\frac{1}{1+\sqrt{\frac{b(2-a)}{a(2-b)}}} \tag{16}$$

Using (16) to express (6), we can deduce (17) to show the optimal resolution of input of A and B

$$\left\{ a\tilde{\beta}kB^b=\lambda A^{2-a}b\left(1-\tilde{\beta}\right)kA^a=\varphi B^{2-b} \right. \tag{17}$$

(17) can be transformed as (18) by calculating the a_{th} power and $(2-a)_{th}$ power of the two equations separately in (17)

$$B^{4-2b-2a}=\frac{\left(a\tilde{\beta}k\right)^a\left[b\left(1-\tilde{\beta}\right)k\right]^{2-a}}{\lambda^a} \tag{18}$$

If we make the natural logarithm of both sides of equation (18), we get the following (19):

$$(4-2b-2a)\ln y = a\ln\left(a\tilde{\beta}k\right)+(2-a)\ln\left[b\left(1-\tilde{\beta}\right)k\right]-a\ln\lambda-(2-a)\ln\varphi \tag{19}$$

Taking both sides of the equation (19) to calculate the exponential function, we can get the collaborative input of B under the condition of the optimal benefits coefficient:

$$\tilde{B}=e^{\frac{a\ln\left(a\tilde{\beta}k\right)+(2-a)\ln\left[b\left(1-\tilde{\beta}\right)k\right]-a\ln\lambda-(2-a)\ln\varphi}{(4-2b-2a)}} \tag{20}$$

Similarly, the collaborative input of A can be obtained under the condition of the optimal benefits coefficient:

$$\tilde{A}=e^{\frac{b\ln\left[\left(b\left(1-\tilde{\beta}\right)k\right)\right]+(2-b)\ln\left(a\tilde{\beta}k\right)-b\ln\varphi-(2-b)\ln\lambda}{(4-2b-2a)}} \tag{21}$$

If we use (20) and (21) to express (7), then the following formula (22) can be obtained:

$$\omega=C_A-\tilde{\beta}k\tilde{A}^a\tilde{B}^b+\frac{\lambda A^2}{2}=C_A-\tilde{\beta}k\tilde{A}^a\tilde{B}^b+\frac{a\tilde{\beta}k\tilde{A}^a\tilde{B}^b}{2} = C_A-\frac{(2-a)\tilde{\beta}k\tilde{A}^a\tilde{B}^b}{2} \tag{22}$$

ω shows the basic benefits of A and $\frac{(2-a)\tilde{\beta}k\tilde{A}^a\tilde{B}^b}{2}$ indicates the collaborative benefits A gains.

We use the modeling language in MATLAB software to verify our assumptions and conduct hypothesis testing. The code segment used to generate and resolve this random instance model is presented in Appendix A.

The simulation result is described in Fig. 1.

Model analysis

We can know from the formula $\tilde{\beta} = \frac{1}{1+\sqrt{\frac{b(2-a)}{a(2-b)}}}$ that the benefit coefficients of A and B can only be affected by the input-output elastic coefficient a and b but not the output value. It means the benefit coefficient is independent of the amount or size of collaborative output and only associated with the input-output elastic coefficient. Moreover, the benefit coefficient has nothing to do with the cost coefficient λ and φ, which means the benefit coefficient has no direct link to the cost of input but can only be determined by the input-output efficiency. Therefore, to establish an incentive mechanism in KAs, we need to fully take account of the ratio of input and output for every member and try to guarantee the fairness of benefit allocation in the alliances. That could be an effective way to unleash each member's initiative and enthusiasm to engage in knowledge collaborative activities and promote the smooth and orderly development of knowledge collaboration.

Based on the formula $\tilde{\beta} = \frac{1}{1+\sqrt{\frac{b(2-a)}{a(2-b)}}}$ we can also know that the benefit coefficient $\tilde{\beta}$ has a negative correlation with the input-output elastic coefficient b of member B and has a positive correlation with the input-output elastic coefficient a of member A. That means in the process of knowledge collaborative cooperation, the more input of B is, the less benefit of A is. The benefit of A is proportional to the resource input of itself in collaborative activities. The more input of A is, the more benefit of A is. This conclusion requires the improvement of members' benefit as an incentive to maximize the input of collaborative resources in KAs and better carry out the collaborative activities and facilitate the knowledge collaboration effects in KAs.

Rationality test of the model

Hypothesis

On the basis of relevant theoretical background and model analysis in Section 3.4, we raise the hypotheses.

Input-output ratio and benefit of cooperation

In the field of scientific and technological research and development, the transfer rate of scientific and technological achievements is regarded as an essential factor of performance evaluation, which promotes the social economy. By studying the relationship between economic development and the input-output efficiency of science popularization resources, Xu and Dang (2021) proposed the increase of the input-output technical efficiency of science popularization and the fluctuation of scale efficiency would increase the input-output efficiency of science popularization. This overall efficiency is relatively high in economically developed areas. Therefore, in future science popularization research, we should not only focus on improving the input of science popularization resources, but also pay more attention to improving the input-output efficiency of science popularization resources under the limited input scale (Liu & and Li, 2017).

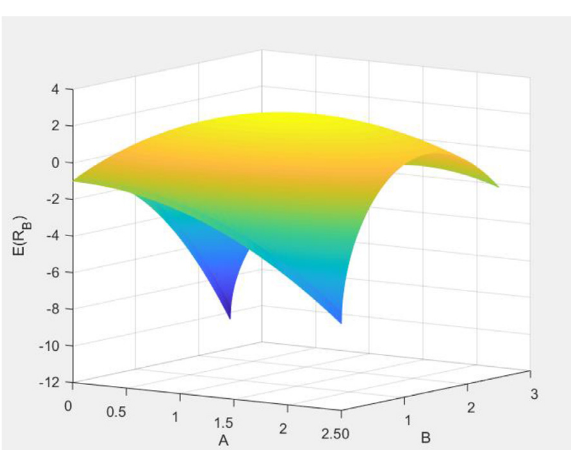

Fig. 1. Model simulation results

Based on the above analysis, we propose *hypothesis* 1:

H1. The knowledge input-output ratio of KA members has a significant incentive effect on the benefits of the members.

Scale of input and benefit of cooperation

Cabrera and Cabrera (2002) pointed out that knowledge is a kind of valuable resource. However, from the point of a single enterprise, sharing knowledge could lead to huge costs. It may even expose the enterprise secret of competitive advantage so that the knowledge contributor in the profit or competition is at a disadvantage, resulting in the prisoner's dilemma and adverse selection. Long, Gu and Zhang (2016) proposed that in the self-organized knowledge sharing, the knowledge contribution of alliance members will exert a crowding-out effect and prisoner's dilemma. However, in the knowledge sharing of other organizations, in the existence of an alliance incentive mechanism, the member's knowledge sharing behavior increases with the partner's knowledge contribution. Jiang and He (2016) point out that knowledge input is the key factor affecting the dynamic changes of enterprise cooperative innovation. The evolution path of cooperative innovation based on knowledge input may be more stable than a completely cooperative innovation strategy and a completely non-cooperative innovation strategy. In addition, the equilibrium state finally reached by this strategy is closely related to the parameters such as knowledge resource input and knowledge input cooperative innovation income coefficient. Zong, Cai and Qi (2014) conduct an evolutionary game analysis of knowledge sharing in cooperative networks. The probability of knowledge sharing is positively correlated with the excess results but negatively correlated with the cost of knowledge sharing. In the field of research and development, Dong and Han (2016) find that the intensity of R&D input does not directly affect the performance of enterprises through the analysis of strategic emerging industries. R&D input can promote the output efficiency of scientific research results, but it has no significant relationship with the overall development efficiency of the enterprise.

Based on the above analysis, we propose *hypothesis* 2:

H2. The scale of knowledge input has no significant incentive effect on the benefits of KA members.

Scale of output and benefit of cooperation

Existing research shows that establishing an organization-based incentive mechanism is an important tool to promote team cooperation and improve team performance. However, return differences may hinder the future combination of continued cooperation (Qin, Mai, Fry, & Raturi, 2016). Wage is regarded as a measure of output. Scholars have studied the impact of wage inequality on cooperation. Some researchers believe that wage disparity has a negative effect on cooperation (Cherry, Kroll, & Shogren, 2005), while others think that the wage difference has no significant impact on the collaboration (Bartling & von Siemens, 2011). Therefore, the pure output value can not have an impact on the cooperation between the two sides.

Based on the above analysis, we propose *hypothesis* 3:

H3. The knowledge output scale of KA members has no significant incentive effect on the members' benefit.

Sample description

The research subjects for the study are staff from firms, colleges, or other institutions in China that have allied with others. As knowledge is a set of skills or experience of every individual, it is abstract and cannot be simply qualified like the performance of an enterprise.

Therefore, the questionnaire survey is the most appropriate method. Questionnaire analysis is standardized, with strict testing of validity and reliability of every question item. Moreover, apart from quantitative data, the questionnaire method is also expected to reflect information marked by attributes, qualities, and attitudes. The recipients of this study are faculty and staff working for enterprises, colleges, and research institutes in Sichuan Province in China. Social media appears to be a convenient and viable way for data collection. Questionnaire was distributed through websites, emails, and visits in person. Besides, the questionnaire data were recorded online, which helps the data processing work and safeguards the recipients' personal information.

We filter our sample since some questionnaires are with invalid answers. For example, all the answers are "completely agree" or "completely disagree," or not finished. We drop those invalid questionnaires. There are 280 questionnaires completed in all, and 26 of them are dropped, leaving us an available sample size of 264 to analyze. The respondent demographic information is shown in Table 1.

Questionnaire design

The questionnaire includes three parts: related concepts, basic information of the samples, and the main content of the questionnaire. The first part introduces the theoretical and practical purpose of this research. It explains relevant concepts to the recipients, including the definitions of KA, knowledge collaboration, input, and output of knowledge. The second part shows the descriptive results as Table 1. The basic information of samples helps conduct descriptive analysis to know the basic distribution of samples and kick off some unqualified questionnaires. The main content of the questionnaire is on a 5-point Likert scale. Every question item is described in a declarative sentence. Recipients need to judge every item and express their degree of recognition by scoring. The scores, ranging from 1 to 5, show different opinions from completely disagree, disagree, to neutral, agree, and completely agree.

Question items are to measure the corresponding hypothesized variables. Specifically, from our statements of hypotheses, the independent variables are input-output ratio (IO), input scale (IS), and output scale (OS). The dependent variable is the incentive mechanism (IM). Therefore, we set a series of questions for multi-dimensional measurement of the five variables (four independent variables and one dependent variable). Moreover, to confirm the hypotheses, the next analysis work is to examine whether the respective question score of the four independent variables has positive or negative correlations with the dependent variables' question score.

Table 1
Respondent demographic information

	Frequency	Percentage (%)
Organization background		
Enterprise	123	48.43
College	37	14.57
Research institution	23	9.06
Governmental department	20	7.87
Financial institution	20	7.87
Others	31	12.20
Number of staff		
Under 300	89	35.04
300-500	76	29.92
500-1000	54	21.26
Over 1000	35	13.78
Operating period of alliance		
Less than 3 years	36	14.17
4-5 years	86	33.86
6-10 years	56	22.05
Over 10 years	76	29.92
Alliance period		
Less than half a year	31	12.20
Less than 1 year	69	27.17
Less than 2 years	68	26.77
Over 2 years	86	33.86

Reliability and validity

We use Confirmatory factor analysis (CFA) to examine the reliability and validity of the questionnaire through SPSS software. Reliability reflects the internal consistency of data. The internal consistency coefficients of the reliability of the unity are weighted sums of the item scores. Cronbach's Alpha coefficient, one of the criteria to test the reliability, is the average value of the split-half reliability coefficient obtained from all possible division methods of the scale items, generally ranging from 0 to 1. Therefore, a large Cronbach's Alpha coefficient implies greater reliability. After testing, the Cronbach's Alpha value of all the variables reaches 0.803, exceeding the 0.8 threshold, which shows that the reliability of sample data is high, having good stability and reliability.

Validity refers to how an instrument truly measures what it is intended to measure. Validity is first measured by the Kaiser-Meyer-Olkin (KMO) value in Table 2. We carried out the Bartlett's test of sphericity and calculate the KMO statistic. Bartlett's test of sphericity is a method to test the degree of correlation between variables. KMO statistic is used to compare simple and partial correlation coefficients between variables. The two criteria are necessary pre-tests to check the validity of the questionnaire model and are also the pre-tests for factor analysis in the next part. If the test result shows a great correlation between variables, then these variables can support factor analysis. As shown in Table 2, Bartlett's test of sphericity was significant ($p < 0.0001$), KMO statistic is 0.753, higher than the threshold value 0.7, suggesting that individual measures of sampling adequacy were generally high, and a strong correlation exists between variables.

Next, we examine the validity through factor analysis. The purpose of factor analysis is to use a few factors to describe the link between the various indexes. Variables in the same class, with more closely related relations, become a factor. With fewer factors reflecting most of the original data information, we can easily determine the main influencing factors. In Table 3, all the factor loadings, which mean the percentage of explained information of the whole questionnaire, exceed the 0.7 thresholds and have relatively good representativeness.

Results and analysis

Table 3 shows the questionnaire items of the four variables. Among them, IO2, IS1, IS2, OS1, and OS2 are all expressed in a reverse way in order to rationally reflect the possible negative correlation.

Through factor analysis, this paper makes a preliminary summary. However, correlation analysis and regression analysis are required to understand the close degree and causal relationship between the influencing factors. Therefore, correlation analysis is carried out on the three factors that have been extracted by factor analysis.

As shown in Table 4, Pearson correlation coefficients of IM, IO, IS, and OS vary between 0.420 and 0.596, greater than 0.4. All of them passed the significance test, which shows the model has great internal consistency. All of the positive coefficients show that IO, IS, and OS positively correlate with IM.

To verify the three hypotheses, we constructed the following regression model:

$$IM = \beta_0 + \beta_1 IO + \beta_2 IS + \beta_3 OS + \varepsilon$$

Table 2
Reliability and validity

Standardized Cronbach's α	KMO	Sig.
0.803	0.753	0.000

Table 3
Results of descriptive analysis and factor analysis

Item	No.	Mean	St.D	Factor loading
Incentive mechanism	IM			
optimal dividend ratio	IM1	3.91	0.706	0.758
optimal production size	IM2	3.98	0.801	0.758
Input-output ratio	IO			
IO ratio of our organization itself	IO1	3.85	0.952	0.769
Our IO ratio should be higher than that of other alliance members	IO2	3.51	1.064	0.769
Input scale	IS			
Input of knowledge and technology is useless to incentive	IS1	3.86	0.922	0.809
Input of time is useless to incentive	IS2	3.89	0.921	0.809
Output scale	OS			
The total amount of output is useless to incentive	OS1	3.79	0.916	0.834
The financial value of output is useless to incentive	OS2	3,85	0.893	0.834

β_0 is the intercept. β_1, β_2 and β_3 are regression coefficients of the three independent variables. ε represents the residual error.

The two kinds of variables in the correlation analysis are not divided into independent variables and dependent variables, which cannot further reflect the causal relationship between various influencing factors and the role of the incentive mechanism. Therefore, to explore the specific effect of various influencing factors on the IM, we use the stepwise regression method to analyze the relationship between variable Table 5. shows the results of the regression of our model using the least square method. The adjusted R square and F all passed the significance test ($P<0.01$), which shows the regression model is significant.

The standardized coefficients are all positive, but as we said above that, IS and OS are expressed as reverse problems. From the results, we can conclude that: the input-output ratio has a positive correlation with the incentive mechanism. The input size and the output size both have no significant relationship with the incentive mechanism. These results are consistent with our initial hypotheses.

Discussion

From the perspective of input and output of knowledge, this study studies the process of KA promoting internal knowledge cooperation through an incentive mechanism. Through model building and model analysis, our main findings are as follows:

First, the core element of the incentive mechanism is the benefit distribution ratio, that is, the benefit coefficient in this study. The optimal benefit coefficient helps to maximize the benefit of the enterprise.

Secondly, as the carrier of cooperation effect, KAs can effectively expand the scale of the whole alliance income. In order to obtain the optimal income in the KA, each member has its own optimal income coefficient.

Thirdly, in the process of establishing the model, the benefit coefficient of the enterprise is expressed by β, the input-output elasticity coefficient. The efficiency coefficient of the main body of the knowledge chain is related to its input-output elasticity coefficient but not directly related to the single input or output.

Table 4
Pearson correlation matrix

	IM	IO	IS	OS
IM	1			
IO	0.420***	1		
IS	0.552***	0.434***	1	
OS	0.455***	0.596***	0.569***	1

Note: ***Significance level at 1% ($P<0.01$)

Table 5
Regression results

Independent variable	Dependent variable Standardized coefficient	t	Sig.
Constant		7.944	0.000
IO	0.170	2.646	0.009
IS	0.410	6.544	0.000
OS	0.121	1.725	0.086
R square		0.353	
Adjusted R square		0.345	
F		45.245***	

Note: ***Significance level at 1% ($P<0.01$)

On the basis of the model analysis, we put forward the research hypothesis combined with the relevant theories, and carried out the empirical analysis to test the correctness of the hypothesis in this paper, the positive correlation between the benefit coefficient of the main body and the input-output ratio of each member is made clear. The conclusions of this study are:

First, from the perspective of knowledge input and output, this paper makes a new evaluation of the knowledge incentive mechanism of KAs, analyzing the operating mechanism of the incentive mechanism under the dynamic development environment of KA. We find that the factors of incentive mechanism of KA is helpful to maximize the benefits of each member and improve the cooperation efficiency of the whole KA.

Secondly, the work efficiency or the input-output ratio of the members of the alliance is directly and positively related to the distribution of benefits. The increase of the production efficiency of the main body of the knowledge chain is equal to the increase of the benefits, thus encouraging the members to actively participate in the knowledge cooperation, promoting the cooperative benefits of knowledge alliances.

Thirdly, there is no correlation between the proportion of benefit distribution and the absolute value of input and output. Therefore, improving the efficiency of the whole production line and production efficiency can be more conducive to increasing the income share of the alliance members for enterprises to bring better cooperation benefits.

Conclusion

Theoretical implication

KA is a platform for enterprises to create and manage new knowledge, and its internal knowledge cooperation process develops and changes with the dynamic development of the alliance. In order to improve the cooperation benefit of the entire alliance, it is necessary to establish a reasonable and scientific incentive mechanism. Under the background that scholars have done a lot of research on the incentive mechanism of internal knowledge cooperation from different perspectives such as multi-partner project team and virtual research organization, this paper studies the incentive mechanism of KA from a new perspective and takes the dynamic nature of KA into consideration. The innovation introduces three variables of knowledge input scale, output scale, and input-output ratio to conduct an in-depth study on the incentive mechanism of KA, which makes up for the vacancy of existing research in this field. It provides theoretical support for enterprises in KA to get better cooperation benefits.

Practical implication

In the era of knowledge economy, the emergence of KAs has become an important carrier of enterprise innovation and development. Therefore, in the current environment, enterprises need to understand the knowledge cooperation process of KAs. Meanwhile, in order to encourage the alliance partners to invest more knowledge resources and get more benefits, the alliance also needs to establish a suitable and effective incentive mechanism to improve the input-output efficiency of the KA. In this paper, from the Angle of knowledge input and output of KA incentive mechanism are studied, designed to provide the basis for strengthening the interaction between alliance members, and to seek the optimal distribution of interests, to motivate members how to get the most knowledge under the limited knowledge in production, how to motivate members of knowledge input, provide impliecations for KA members. According to the solution results of the model, enterprises in the KA can apply the theory to practical operations:

First, improving knowledge output can effectively stimulate the KA members of knowledge input. Consequently, KA members can improve the learning ability and innovation ability to improve the efficiency of knowledge input and output, better benefit allocation proportion, make whole KA reach a better cooperative effect, and promote the KA members.

Second: knowledge synergy is the core link of knowledge synergy and cooperation among members of KA. The existence of KA can better promote knowledge collaboration, improve the benefit of knowledge collaboration, and enhance the knowledge output in the process of knowledge collaboration. Alliance members can obtain better knowledge input-output benefit and stimulate the knowledge input of alliance members.

limitations

Although the conclusions of this paper are consistent with our previous assumptions, we still have the following limitations:

Generalization. In the empirical part, we only distributed the questionnaire to some KA organizations in China, so the collected data is limited. We can expand the scope of data collection and conduct in-depth research in the future, generalizing the conclusions of the study.

Interference of environmental factors. Because the dynamic development of KA may be related to organizational culture, policy background, and other factors, but this paper does not introduce the influence of these external environments for the study of core issues, future research could introduce these environmental influences.

The universal applicability of the study needs to be improved**.** The development of KA and the construction of incentive mechanisms are related to the local culture. Therefore, the study in this paper may need to be further revised to strengthen the universal applicability of the mechanism. A more representative sample is needed to service each national KA.

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Appendix A

```
syms x y; k=6;a=0.5;b=0.5;lamda=2;phi=3;C_A=1; z=k.*x.^a.*y.^b-C_A-lamda.*x.^2./2-phi.*y.^2./2; dzx=diff(z,x);dzy=diff(z,y); format short;
[xx,yy]=solve(dzx,dzy,x,y);
A=diff(z,x,2);B=diff(diff(z,x),y);C=diff(z,y,2);
D=A*C-B^2;
A1=subs(subs(A,'x',xx),'y',yy);D1=subs(subs(D,'x',xx),'y',yy); if ((A1<0)&&(D1>0)) disp('the local maximum'); elseif((A1>0)&&(D1>0)) disp('the local minimum'); elseif(D1<0) disp('not existed'); else disp('not definite'); end
A0=vpa(xx)
B0=vpa(yy)
```

The output shows that:

A0 =1.3554030054147672479433270793372

B0 =1.1066819197003215924087902734403

And we use the following code segment to simulate the result and draw the picture:

```
A=0:0.005:2.5; B=0:0.005:2.5;
[X,Y]=meshgrid(A,B); k=6; a=0.3; b=0.5; lamda=1; phi=3; C_A=.5;
E=k.*X.^a.*Y.^b-C_A-lamda.*X.^2./2-phi.*Y.^2./2; mesh(X,Y,E); xlabel('A');ylabel('B');zlabel('E(R_B)');
```

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