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Study of the Game Theory Analysis and Incentive Mechanism of Inter-Organizational Knowledge Sharing in Cooperative R&D

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Abstract

With the technological development and social demand, an increasing number of multi-field complex products come into being and call for the research and development (R&D) of many enterprises. Since the R&D is related to a large amount of knowledge, it is of great significance to realize effective knowledge sharing and establish an incentive mechanism to promote the knowledge sharing. This study constructed an inter-organizational knowledge sharing model for cooperative R&D and a static inter-organizational knowledge sharing game theory model. Subsequently, it analyzed the decision matrix of cooperative organizations in detail. Finally, it proposed an incentive mechanism to realize knowledge sharing, which a feasible method for improving the effect of the inter-organizational knowledge sharing in cooperative R&D.

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Keywords: cooperative R&D; knowledge sharing; game theory; incentive mechanism; inter-organization

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1. Introduction

In the growth and competition processes of enterprises, knowledge has become a core asset of enterprises. Meanwhile, knowledge management is also treated as a major content and included in the strategic development. In particular, in the enterprises majorly developing and researching high-tech products, the whole R&D process is an intensive knowledge management process since it involves the inter-organizational design and manufacture of multiple fields. The inter-organizational knowledge sharing therein is a key link. Especially for some key technologies and design methods, the knowledge sharing is an important guarantee for the successful R&D of a product.

As for the cooperative organizations, knowledge sharing is a game process for measuring cost and pursuing individual benefit. Therefore, to guarantee the realization of high-qualified cooperative R&D, it is needed to analyze the inter-organizational cooperative R&D mode and knowledge sharing game theory model, and promote the implementation of knowledge sharing using effective and reasonable incentive mechanism. This study analyzed the game theory mode in inter-organizational knowledge sharing process and proposed the incentive mechanism for the inter-organizational knowledge sharing.

2. Research status

At present, the knowledge sharing has been repeatedly researched. Related researches mainly focus on the inner-organizational knowledge sharing and inter-organizational knowledge sharing.

C. L. Witherspoon[1] completed a meta-analysis and found knowledge sharer intention and attitude, rewards and organizational culture positively contribute to knowledge sharing intentions and behaviors. H. H. Chang[2] combined the theories of social capital and individual motivation to investigate the factors influencing knowledge sharing behavior in a virtual community, which found that altruism, identification, reciprocity, and shared language had a significant and positive effect on knowledge sharing. S. Gächter[3] used game theory to predict knowledge sharing behavior in private-collective innovation, and tested predictions in a laboratory setting. F. Wijnhoven[4] proposed a realistic game-theoretical model for analyzing knowledge sharing based on five assumptions. C. B. Ho[5] proposed two models of knowledge sharing build a single-instance two-person game to characterize individuals' tacit knowledge sharing behavior. F Barachini[6] proposed that the underlying mechanism for knowledge sharing is rather based on a trading process. H Yang[7] proposed a novel agent-based modeling approach to simulate the actions of knowledge sharing between actors in an organization.

Chinese researchers also studied knowledge sharing. Ji Huisheng [8] investigated the route selection and solutions of the knowledge sharing in the cooperative R&D of enterprises and established the knowledge sharing game theory model of the cooperative R&D of enterprises. Jiang Ronghua[9] conducted a game analysis on knowledge sharing and designed corresponding knowledge contribution incentive function to promote the knowledge sharing behaviors of employees. Jiang Guorui [10] researched the credibility of cooperation and proposed strategies to improve tacit knowledge sharing. Li Dan [11] discussed the cooperative dynamic repeated game in scientific researches and the strategic process of the knowledge sharing in incomplete information game. Chen Lei [12] analyzed the enterprise's knowledge sharing process in the case of incomplete information and limited rationality from the perspective of evolutionary game and concluded the key factors influencing the knowledge sharing relationship evolution of enterprise; Ning Ye[13] analyzed the benefit and costs of the organizations in knowledge alliance in the process of knowledge sharing using complete information dynamic game method.

3. Inter-organizational knowledge sharing model

The R&D of modern complex products requires the participation of multiple cross-cutting and distributed cooperative organizations in different R&D phases. These organizations are correlated to each other and responsible for their own tasks. Driven by the overall R&D process, they collaborate with each other in the R&D tasks of different organizations, levels, and fields to complete the R&D of a product together. However, within the same organization, there are also communication, cooperation, and task transfer among different departments, as well as the frequent knowledge flow and work flow among the designers of different departments and organizations. Fig. 1 shows the mode of inter-organizational knowledge sharing model.

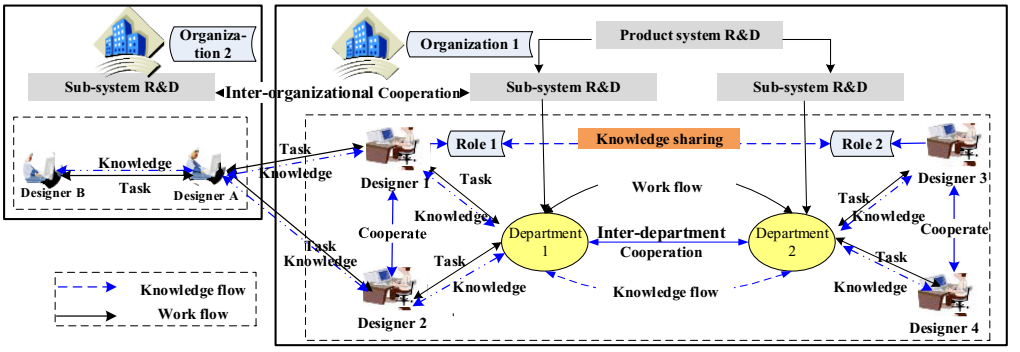

Fig. 1 The mode of inter-organizational knowledge sharing

4. The game theory model of inter-organizational knowledge sharing

Game theory concerns how decision makers make decisions in the case of the interactions of decision-making subjects and the equilibrium of the decision made. Game theory has two basic assumptions:

- The decision-making subjects are rational, i.e. each decision-making subject will maximize its interests under the given constraints;
- The cooperation of the decision-making subjects is affected by conflict and behaviors, and the information is asymmetric usually.

As for the organizations involved in the cooperation, knowledge sharing is actually a process of making decision on “sharing” or “non-sharing” the knowledge gasped by each organization. The more the knowledge gasped by an organization, the more opportunity for achieving benefit. That is to say, the organization is active in acquiring the knowledge shared from the outside; however, in case of sharing the knowledge gasped, organizations are negative in sharing their knowledge to the outside if the organization may see a reduction on its benefit. Organizations are willing to share knowledge with the outside in the two cases below:

- According to knowledge -sharing, organizations obtain certain benefit that is greater than the cost of the knowledge production;
- The acquisition of knowledge increases the net benefit of organization and shows positive effect.

In general, if the benefit of an individual obtained by knowledge sharing is greater than the cost of the knowledge sharing, the individual may choose knowledge sharing. In the following, this study established a static knowledge sharing game theory model and discussed the individual benefit and payment to make appropriate decisions.

4.1. The hypotheses of inter-organizational knowledge sharing game theory model

The hypotheses of inter-organizational knowledge sharing game theory model are indicated as follows:

- Hypothesis 1: The utility of participants are maximized.
- Hypothesis 2: The risks of participants are neutral.
- Hypothesis 3: The value of knowledge is quantifiable and evaluable.
- Hypothesis 4: The cost of knowledge sharing costs is measurable.
- Hypothesis 5: The knowledge shared by participants is divisible.
- Hypothesis 6: The game-related information of participants is complete.

Hypothesis 1 is the starting point of this study, namely, the basic motivation of the participants for knowledge sharing is to pursuit utility maximization. The utility here includes current "benefit" acquired from the knowledge shared by other participants and the future potential benefit brought by knowledge sharing.

Hypothesis 2 refers to that participants hold a neutral attitude (neither be dauntless or extremely unsupported) for the risks brought by knowledge sharing.

Actually, hypotheses 3 and 4 have a certain gaps with actual organizational knowledge management and knowledge sharing. The measurement of knowledge value is a focus and difficulty in field of knowledge management. A number of researchers and organizational managers have been trying to study and solving this problem. Although this problem is not in the scope of this study, related research conclusions play a favorably complementing and perfecting role for the model in this study.

Hypothesis 5 is originated from a viewpoint that knowledge sharing participants can decide to completely, partially, or do not share their knowledge according to conditions. This viewpoint is in accordance with the practice of the sharing behaviors.

Hypothesis 6: in the need for simplification, it is assumed that both parties in the game own complete information, that is, each participant has complete information about the knowledge-providing and transferring condition and the knowledge sharing cost and benefit of the other participant.

4.2. Static game theory model

It is assumed that there are two participants (organizations) $i\left(i=1,\ 2\right)$ in the knowledge sharing game; the knowledge levels of the two participant are k_i; in case of no knowledge sharing, the normal benefit brought by the knowledge level for participants is u_i; The absorbing ability of participants for the knowledge shared by other participants is $a_i\left(0<ai\le 1\right)$. Therefore, $a_i k_j\left(i\ne j\right)$ is the benefit of participant i brought by the knowledge obtained from others; meanwhile, only the participants who share knowledge can obtain the knowledge provided by others; In addition, the organizations participating in the knowledge sharing provide a reward coefficient $b_i\left(0<b_i<1\right)$ for the participants who share knowledge according to the knowledge shared. Thus $b_i k_i$ is the reward of participant i sharing the knowledge. The time and energy of participants paid for knowledge sharing and the possible competitive advantages weakening risks caused by knowledge sharing constitute the cost of knowledge sharing. Assuming that the coefficient of knowledge sharing cost is $c_i\left(0<ci\le 1\right)$, $c_i k_i$ is the cost paid by participant i in the knowledge sharing. By comparing the benefits and costs of the sharing or non-sharing knowledge, participants make their decisions. According to the basic hypotheses above, the benefit matrixes of both participants in the knowledge sharing is accessed. (Table 1)

Table 1. The benefit matrix of both participants in knowledge sharing

	Participant 2（Sharing）	Participant 2（Non-sharing）
Participant 1（Sharing）	$u_1 + a_1k_2 + b_1k_1 - c_1k_1, u_2 + a_2k_1 + b_2k_2 - c_2k_2$	$u_1 + b_1k_1 - c_1k_1, u_2$
Participant 1 (Non-sharing)	$u_1, u_2 + b_2k_2 - c_2k_2$	u_1, u_2

5. Analysis on the inter-organizational knowledge sharing game

As suggested by the benefit matrix, the strategy selections of the both participants are correlated to the values of parameters. Firstly, we discuss the strategies may be selected by participant 1 when the strategy of participant 2 is determined.

- If participant 2 selects the sharing strategy, the benefit of participant 1 includes $u_1 + a_1k_2 + b_1k_1 - c_1k_1$ (sharing) and u_1 (non-sharing). When $u_1 + a_1k_2 + b_1k_1 - c_1k_1 > u_1$, namely, $a_1k_2 + b_1k_1 - c_1k_1 > 0$, participant 1 may choose to share its knowledge.
- If participant 2 chooses the non-sharing strategy, the benefit of participant 1 includes $u_1 + b_1k_1 - c_1k_1$ (sharing) and u_1 (non-sharing). When $u_1 + b_1k_1 - c_1k_1 > u_1$, namely, $b_1k_1 - c_1k_1 > 0$, participant 1 may choose to share its knowledge.

Similarly, when the strategy of participant 1 is determined, the strategies that may be selected by participant 2 are same with above.

Subsequently, the related parameters are discussed. The results are shown below (for participant 1):

- If $b_1k_1 - c_1k_1 > 0$, $a_1k_2 + b_1k_1 - c_1k_1 > 0$ no matter of the sharing or non-sharing strategy of participant 2, participant 1 would choose to share its knowledge. This result indicates that the benefit provided by the shared participant to the sharing participant is enough to compensate the loss of the sharing participant for the knowledge- sharing;
- If $b_1k_1 - c_1k_1 < 0$ while $a_1k_2 + b_1k_1 - c_1k_1 > 0$, only when participant 2 chooses the sharing strategy, would participant 1 share its knowledge. This suggests that the benefit provided by the shared participant to the sharing participant is not enough to compensate the loss of the sharing participants for the knowledge-sharing. Therefore, it is needed of the knowledge sharing of other participants, so that this participant can obtain benefit from the knowledge shared by others to compensate the loss fully.
- If $a_1k_2 + b_1k_1 - c_1k_1 < 0$, no matter of the sharing or non-sharing strategy of participant 2, participant 1 would not share its knowledge. This result indicates that the knowledge owned by participant 1 is very important and hard to be accessed. Once the knowledge is shared to others, can the loss of participant 1 be hardly compensated, or, can the knowledge be hard taught to others.

Similarly, for participant 2, there are:

- If $b_2k_2 - c_2k_2 > 0$, $a_2k_1 + b_2k_2 - c_2k_2 > 0$, no matter of the sharing or non-sharing strategy of participant 1, participant 2 would choose to share its knowledge. This result indicates that the benefit provided by the shared participant to the sharing participant is enough to compensate the loss of the sharing participant for the knowledge- sharing;
- If $b_2k_2 - c_2k_2 < 0$ while $a_2k_1 + b_2k_2 - c_2k_2 > 0$, only when participant 1 chooses the sharing strategy, would participant 2 share its knowledge. This suggests that the benefit provided by the shared participant

to the sharing participant is not enough to compensate the loss of the sharing participant for the knowledge-sharing. Therefore, it is needed of the knowledge sharing of other participants so that this participant can obtain benefit from the knowledge shared by others to compensate the loss fully.

- If $a_2k_1 + b_2k_2 - c_2k_2 < 0$, no matter of the sharing or non-sharing strategy of participant 1, participant 2 would not share its knowledge. This result indicates that the knowledge owned by participant 2 is very important and hard to be accessed. Once the knowledge is shared to others, can the loss of participant 1 be hardly compensated, or, can the knowledge be hard taught to others.

By summing up the two cases above, it has access to the decision matrix concerning the strategies and parameter valuing of the both participants (Table 2). It should be noted that when $b_1k_1 - c_1k_1 < 0$ while $a_1k_2 + b_1k_1 - c_1k_1 > 0$, and $b_2k_2 - c_2k_2 < 0$ while $a_2k_1 + b_2k_2 - c_2k_2 > 0$, the behavior of each participant will lead to the same behavior of the other one.

Table 2. The decision making matrix of both participants in knowledge sharing

	Participant2 ($b_2k_2 - c_2k_2 > 0$)	Participant2 ($b_2k_2 - c_2k_2 < 0$, $a_2k_1 + b_2k_2 - c_2k_2 > 0$)	Participant2 ($a_2k_1 + b_2k_2 - c_2k_2 < 0$)
Participant1 ($b_1k_1 - c_1k_1 > 0$)	（sharing，haring）	（sharing，sharing）	（sharing，non-sharing）
Participant1 ($b_1k_1 - c_1k_1 < 0$, $a_1k_2 + b_1k_1 - c_1k_1 > 0$)	（sharing，sharing）	（sharing，sharing） （non-sharing，non-sharing）	（non-sharing，non-sharing）
Participant1 ($a_1k_2 + b_1k_1 - c_1k_1 < 0$)	（non-sharing, sharing）	（non-sharing，non-sharing）	（non-sharing，non-sharing）

6. The incentive mechanism of knowledge sharing

According to the analysis above, it can be known that if organizations show willingness to encourage members to share knowledge, the organizations should adopt certain knowledge pricing measures. Such measures were mainly used to compensate the efforts made by the participants in knowledge sharing, and the price that should be undertaken by the participants after the publication of the knowledge. In detail, the measures can be proposed from the following aspects:

6.1. Formulating incentive measures according to the difficulty and importance of the knowledge shared

In case of rewarding the knowledge sharing behavior of individual organization, it is needed to scientifically measure the contributions of the knowledge shared by individual organization. Only the pricing based on the scientific and reasonable measurement on knowledge contribution is fair. The measurement on the knowledge is determined by two factors, namely, the difficulty of obtaining the knowledge shared and the importance of the knowledge shared to the organization. The former marks the costs paid by the knowledge creator to obtain this knowledge (time, efforts, and necessary economic costs), while the latter represent the benefit created by the organization using this knowledge. Basing on the comprehensive consideration on the two factors above, this study constructed the knowledge measurement model and applied this model to calculate the contributions of knowledge. Individual organizations are willing to share their knowledge if they can get economic satisfaction and benefit for organizational development.

6.2. Establishing win-win mechanism and cultivating favorable cooperative environment

In addition to creating benefits, the knowledge sharing subjects also call for the knowledge sharing of other organizations to sustain their advantages in the sustainable development. As indicated by the game analysis above, when $b_1k_1 - c_1k_1 < 0$ while $a_1k_2 + b_1k_1 - c_1k_1 > 0$ (or $b_2k_2 - c_2k_2 < 0$ while $a_2k_1 + b_2k_2 - c_2k_2 > 0$), the sharing participant can obtain benefit from the shared participant. However, it also expects the shared participant to share knowledge. In this way, both participants can achieve the win-win.

7. Conclusions

According to the relevant theories of game theory, this study established the static knowledge sharing game theory model for the inter-organizational cooperative R&D and analyzed the decision matrix of the cooperative organizations in detail. Subsequently, it proposed the incentive mechanism to realize knowledge sharing, which is proved to a feasible method for improving the knowledge sharing effect of the cooperative R&D of enterprises. In the following, we will investigate the dynamic knowledge sharing model, as well as the relative method of knowledge evaluation.

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