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The Approach to Accelerate Collaborative New Product Development Process through Managing Knowledge Sharing Behaviors

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Abstract

Knowledge sharing plays a critical role in collaborative new product development (Co-NPD) process. Through knowledge sharing, the excessive revenue of participants in Co-NPD can be easily realized. The research literature shows the way actors create a knowledge-sharing environment to create new products is a quality indicator of Co-NPD. This study summarizes which factors influence the knowledge sharing behaviors in Co-NPD, and it analyzes knowledge sharing behaviors among enterprises in Co-NPD process by evolutionary game theory. The conclusion indicates that the initial value and change tendency of revenue function parameters of knowledge sharing in Co-NPD process affects the choice of knowledge sharing strategy. According to the findings, the governance mechanism for promoting knowledge sharing is expounded to create a high performance of new product development collaboratively. The significance of the results is to help all participants achieve the expected maximum utility in the Co-NPD process by knowledge sharing behaviors.

Keywords: collaborative new product development; knowledge sharing; evolutionary game theory; governance mechanism

1. Introduction

With the increasing change of information technology and fierce competition in the global market, the R&D speed and a great extent innovation in new products became the key factors to win the competitive advantage. The traditional new product development pattern could not adapt to the rapid changes of market and environment. So, resources and knowledge integration of the relative R&D participants to develop new products collaboratively to achieve a mutual benefit situation was becoming the tendency. In collaborative new product development process, every R&D participant need to cross the single knowledge boundary to absorb more knowledge resources, and disseminate knowledge simultaneously to the R&D network including interdependent enterprises, universities and other relative organizations. Then, the knowledge could be a high performance sharing and application in R&D network to realize more efficiency of new product development process than single enterprise. However, how to maximize knowledge value by the knowledge sharing behaviors, and at the same time safeguard against opportunism to satisfy every participant was yet the fatal and difficult problem in Co-NPD process.

The purpose of this study was to design the corresponding governance mechanism to solve the problems in the process of knowledge sharing among actors participated the Co-NPD assignments. The efficient knowledge sharing strategy was explored to accelerate collaborative new product development process, meantime safeguard against opportunism using evolutionary game method. The findings may be beneficial for collaborative knowledge sharing to accelerate the process of new product development.

2. Literature Review

The research about collaborative new product development (Co-NPD) mainly focused on how to use the information systems and techniques to support collaborative work among actors, and solve the conflicts in the process of collaborative new product development. The methods were to allocate resources and skills optimally to complete the new product task together. Lam (2005) built a coordination mechanism model of Co-NPD process to solve the issues such as low efficiency, high cost of product design, heavy loss caused by rework and so on. Daniel (2002) established an order parameter equation and the potential function of Co-NPD chain, and structured a systematic coordination mechanism model. Yan (2002) proposed a sharing strategy based on Internet resources in the process of distributed collaborative product development, and designed a support model of distributed collaborative product development based on the digital and network technology. Ramesh (1999) built a model of joint work and decision-making between collaborating firms and unearthing the complementary role of revenue, cost, and innovative effort sharing mechanisms for new product development. In that paper, they also translated the analytical findings into a managerial framework and illustrated the results with examples from the electronics industries. Ayers (2011) demonstrated the importance of promoting collaborative relationships between R&D and marketing through the findings from a survey of 152 product managers, and found such relationships could be fostered by decentralizing decision making and clarifying the roles of new product development personnel. Littler (1995) studied the risks and benefits of collaborative product development process as well as the key success factors for such relationships. Badrinarayanan (2008) offered a new framework for the understanding and improving the functions of virtual new product development teams by synthesizing relevant perspectives from diverse literature streams. Bstieler (2006) studied the trust formation in collaborative new product development and showed that a higher level of trust clearly differentiates between high performance and low performance collaborative relationships in new product development. Mishra (2009) found that in the new product development, collaborative competence had a direct impact on project performance, but its impact on market performance was indirect, mediated through project performance. Wang (2009) proposed a system framework, entitled the collaborative product development framework for centre satellite system (CPDF-CSS) and presented a case involving the motorcycle industry for evaluating the implementation of CPDF-CSS. Bunduchi (2013) explored the role that trust relationships played during the selection of suppliers in new product development, and found goodwill trust was the key variable explaining the reliance on collaboration. Zhang (2009) proposed an agent-based simulation methodology to evaluate and improve the organizational planning in complex product development projects, and built an agent-based integrated simulation model which could explicitly represent human behavior, organizational interactions and tasks networks.

Knowledge sharing, as the key of knowledge management implementation, was the process of transferring explicit knowledge to the other members of the organization or network (Boer, 2010). There had been much research dealing with knowledge sharing behaviors from different perspectives. Liu & Phillips (2011) found that one of the important obatacles in implementing knowledge management and knowledge sharing was people's tendency toward storing knowledge, because they thought that knowledge meant personnel core competence. Panteli (2005) believed that one of the essential challendges and most difficult part of facilitating knowledge sharing was to make people be willing to share what they know. They put forward the reseason that knowledge was an adhesive property and steady in the people's mind, this inheritance led to slowness, cost, and unreliability of knowledge transfer within inter-organization. Liu (2008) thought that knowledge sharing process was composed of knowledge externalization through knowledge resources and internalization of it by its recievers. In this process, people acquired their needed knowledge not only by internal organizational sources, but also used external sources. According to Bartol (2002), the main requirements of knowledge sharing were social circumenstances, organizational conditions, and technological conditions. From the firm performance perspective, some scholars researched on the relationship between knowledge sharing and the business performance. Yang (2010) suggested that both performance-driven strategies and knowledge management-based competencies should be considered in the implementation of knowledge sharing strategy in Chinese High Technology firms. Law & Ngai (2008) studied that effective knowledge sharing and learning could improve business efficiency, reduce cooperation conflicts, etc., and all the factors ultimately promoted the organizational performance. Huang (2009) researched empirically knowledge sharing and group cohesiveness on firm performance by the technology R&D team in Taiwan, the conclusions indicated transactive memory system positively and significantly mediated the relationship between trust and knowledge sharing, knowledge sharing and group cohesiveness exerts a positive and significant effect on R&D team performance.

How to accelerate Co-NPD process through knowledge sharing behaviors was still required deeper research. Some literatures about the relationship between knowledge sharing and collaborative new product development were sorted out. For example, McAdam (2008) took the aviation industry as an example to explore the model of knowledge sharing in aviation Co-NPD process, and analyzed the effects of organizational factors and technical support tools among sharing the knowledge between collaborators. Kleinsmann (2010) analyzed the knowledge sharing mechanism of Co-NPD team from individual, project and enterprise levels, as well as the relations and types of knowledge sharing among the three levels. Shankar (2013) built a collaborative network structure within the organization to prevent knowledge loss in new product development and identified the sources of K-loss based on our first-hand observations via an in-depth case study of six Indian auto-component manufacturing companies. Zhen (2011) built a novel distributed knowledge sharing model which was proposed for spreading and sharing knowledge among engineers in collaborative product development teams, and this model was based on the engineers' personal knowledge repositories rather than the centralized team knowledge repository in the collaborative team. However, the current literatures presented the importance of knowledge sharing behaviors in Co-NPD process, their work fell short of providing how to manage knowledge sharing behaviors among actors to create a high performance of collaborative new product development. Therefore, this paper is to explore and analyze the game process at sharing knowledge among actors in Co-NPD process by the evolutionary game method to reduce conflicts and safeguard against opportunism. The implications of results are to create more innovative and valuable products for customers by integrating more new knowledge in the Co-NPD process.

3. Key Factors Influencing Knowledge Sharing in Co-NPD Process

With the high integration of cross knowledge areas, single enterprise was increasing difficult to have the knowledge resources of new product development in all areas. It was necessary to choose cooperative partner and share knowledge resources with each other in R&D teams. All participants used their knowledge and skills to accomplish each R&D goal. In our exploratory study, the Co-NPD network consists of the group of firms, research institutions which collaborate to create and develop new products. In the Co-NPD process, the academic research is to "produce codified theories and models that explain and predict natural reality", while business R & D department is concentrated on designing and developing "producible and useful artefacts". However, in the Co-NPD process, the participants not only want to internalize the knowledge and skills from the other companies through learning each other, but also worry that their knowledge will be used by other companies opportunistically. Thus, when they share their knowledge and skills, they show the incompletely judgment and limited rationality affected by a variety of factors at the same time. For instance, suppose that enterprise A and enterprise B are two enterprises in Co-NPD network. They put their knowledge or skills into Co-NPD platform according to their willingness. When the gross earnings that A absorbs the knowledge and skills from B through the Co-NPD platform are greater than the costs, A will tend to choose knowledge sharing. Similarly, so is it for enterprise B. Please note, the knowledge and skills are very difficult to verify and quantitative evaluate, and sometimes even impossible to quantify how much of their investment value, so it is prone to emerging opportunism behaviors among participants. If the contracts is lack of a full-fledged governance mechanism, then the less willingness enterprise A has to share knowledge, the less cost it will pay. At the meantime, for enterprise B, the more willingness it has, the more knowledge and skills it will put into the Co-NPD network, so the more gross earnings enterprise A will get from the platform by learning and internalization. This will encourage actors to choose opportunism behaviors imperceptibly, and it is also harmful to the efficiency of new product development. So, under what conditions it can reduce or avoid opportunism behaviors at sharing knowledge among participants to accelerate Co-NPD Process should be explored.

According to literatures, effective factors on knowledge sharing in the Co-NPD process are summarized by six aspects. It includes the willingness of knowledge sharing, complementary of knowledge resources, difficulty of knowledge sharing, knowledge absorptive capability, cost of knowledge sharing, and risk of opportunism behaviors. The willingness of knowledge sharing presents the attitude and collaboration commitment of actors to participate the Co-NPD. The complementary of knowledge resources indicates the participants can obtain the knowledge resources and skills easily and inexpensively in the Co-NPD network. The difficulty of knowledge sharing means the obstacles and challenges at sharing knowledge supported by information systems, techniques and other infrastructures. The knowledge absorptive capability is one of the most important of knowledge sharing process, which requires the receivers can absorb and internalize new knowledge actually to apply in the development of new products. The cost of knowledge sharing indisputably affects the strategy of R&D partners because the purpose of the actor participated in Co-NPD process is to earn more profits. The risk of opportunism behaviors can highly disturb the trust and collaboration relationships among enterprises in the Co-NPD network. These six aspects are the game focal point of knowledge sharing among the R&D participants, and regarded as the basis of designing the governance mechanism to strengthen the collaboration relationship in NPD process.

4. Game Analysis of Knowledge Sharing in Co-NPD Process

Sharing knowledge and skills among actors based on a full-fledged governance mechanism is useful to help all participants achieve the expected utility. The principle of R&D satisfaction in Co-NPD process complies with the interpretation of game theory for multiple cooperativeness. Moreover, knowledge sharing process in Co-NPD is often a result of learning each other and adjustment in the collaboration relationship. In addition, the knowledge sharing strategy of actors is also a gradual, continuous adjustment process, which is suitable for the evolutionary game theory. Thus, it chooses the asymmetric replication dynamics game method to analyze and discuss the process of knowledge sharing in the Co-NPD.

For simplicity, this paper only studies the game analysis of two enterprises, and they both have the self-learning and absorptive ability of sharing knowledge and skills. Two enterprise's complementary level of knowledge resources is α_i , the degree of difficulty for knowledge sharing is β_i , the willingness of knowledge sharing is γ_i , the ability of knowledge absorption is η_i , the cost of knowledge sharing is c_i , and the coefficient of risk of opportunism behaviors is l_i .

In Co-NPD process, the gross earnings of knowledge sharing are $\pi_i + f_{1i} + f_{2i} - C_i$, in which $\pi_i (i = 1, 2)$ is normal profit if the enterprise does not choose knowledge sharing, f_{1i} is the directly increased profit when knowledge sharing, f_{2i} is the doubled synergy profit when the actor absorbs the shared knowledge and skills, C_i is the cost of knowledge sharing. Then we know that $f_{1i} = \gamma_i \beta_i \alpha_i$, $f_{2i} = \eta_i \gamma_i \beta_i \alpha_i$, $C_i = c_i + l_i \alpha_i$. Thus, the profits of knowledge sharing between enterprises are $\pi_i + \gamma_i \beta_i \alpha_i + \eta_i \gamma_i \beta_i \alpha_i - c_i - l_i \alpha_i$. The game payoff matrix of knowledge sharing in Co-NPD process is showed as Table 1.

Table 1. The game payoff matrix of knowledge sharing between Enterprise 1st and 2st

		The first enterprise	
		Share	Not Share
The second enterprise	Share	$\pi_1 + \gamma_1 \beta_2 \alpha_2 + \eta_1 \gamma_1 \beta_2 \alpha_2 - c_1 - l_1 \alpha_1$ $\pi_2 + \gamma_2 \beta_1 \alpha_1 + \eta_2 \gamma_2 \beta_1 \alpha_1 - c_2 - l_2 \alpha_2$	$\pi_1 - c_1 - l_1 \alpha_1$ π_2
	Not Share	π_1 $\pi_2 - c_2 - l_2 \alpha_2$	π_1 π_2

Suppose that the probability of the first enterprise choosing knowledge sharing strategy is x , so the probability of choosing not to share knowledge is $1-x$; the probability of the second enterprise choosing knowledge sharing strategy is y , and the probability of choosing not to share knowledge is $1-y$. When the first enterprise chooses to share knowledge, the gross earnings of the first enterprise are as follows:

$$U_{11} = y(\pi_1 + \gamma_1 \beta_2 \alpha_2 + \eta_1 \gamma_1 \beta_2 \alpha_2 - c_1 - l_1 \alpha_1) + (1-y)(\pi_1 - c_1 - l_1 \alpha_1) = \pi_1 + y\gamma_1 \beta_2 \alpha_2 (1+\eta_1) - (c_1 + l_1 \alpha_1) \quad (1)$$

When the first enterprise chooses not to share knowledge, the gross earnings are as follows:

$$U_{12} = y\pi_1 + (1-y)\pi_1 = \pi_1 \quad (2)$$

So the average gross earnings of the first enterprise are:

$$\bar{U}_1 = xU_{11} + (1-x)U_{12} = \pi_1 + xy\gamma_1 \beta_2 \alpha_2 (1+\eta_1) - x(c_1 + l_1 \alpha_1) \quad (3)$$

According to the principle of symmetry, when the second enterprise chooses to share, not to share, and the average gross earnings are as follows:

$$U_{21} = \pi_2 + x\gamma_2 \beta_1 \alpha_1 (1+\eta_2) - (c_2 + l_2 \alpha_2), U_{22} = \pi_2 \quad (4)$$

$$\bar{U}_2 = \pi_2 + xy\gamma_2 \beta_1 \alpha_1 (1+\eta_2) - y(c_2 + l_2 \alpha_2) \quad (5)$$

The replicator dynamics equation of the first enterprise and the second enterprise are as follows:

$$\frac{dx}{dt} = x\left[U_{11} - \bar{U}_1\right] = x(1-x)\left[y\gamma_1 \beta_2 \alpha_2 (1+\eta_1) - (c_1 + l_1 \alpha_1)\right] \quad (6)$$

$$\frac{dy}{dt} = y(1-y)\left[x\gamma_2 \beta_1 \alpha_1 (1+\eta_2) - (c_2 + l_2 \alpha_2)\right] \quad (7)$$

This paper analyzes the replicator dynamics equation of the first enterprise, so as to the second enterprise.

If $y=\frac{c_1+l_1\alpha_1}{\gamma_1\beta_2\alpha_2(1+\eta_1)}$, $\frac{dx}{dt}$ =0. That means all of x is steady, but the result of game is not valuable for collaboration enterprises. The evolutionary stable strategy (ESS) in evolutionary game theory requires a stable state and an anti-jamming function. When x deviates into x^*, the replicator dynamics can still make x return to x^*. It means that when x is lower than x^*, $\frac{dx}{dt}=F(x)>0$; when x is higher than x^*, $\frac{dx}{dt}=F(x)<0$; the derivative $F'(x)$ of stable state ($F(x)$) must be lower than 0. Therefore, when $y>\frac{c_1+l_1\alpha_1}{\gamma_1\beta_2\alpha_2(1+\eta_1)}$, ESS is $x^*=1$; when $y<\frac{c_1+l_1\alpha_1}{\gamma_1\beta_2\alpha_2(1+\eta_1)}$, ESS is $x^*=0$. So does the second enterprise. When $x>\frac{c_2+l_2\alpha_2}{\gamma_2\beta_1\alpha_1(1+\eta_2)}$, ESS is $y^*=1$; when $x<\frac{c_2+l_2\alpha_2}{\gamma_2\beta_1\alpha_1(1+\eta_2)}$, ESS is $y^*=0$.

The results of evolutionary game analysis are showed as Fig. 1.

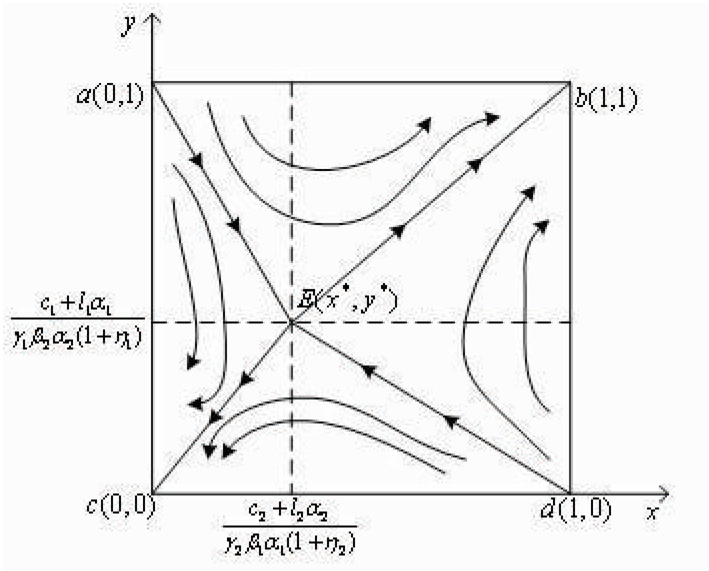

Fig 1. Replicator dynamics and evolutionary tendency between enterprise 1st and 2st

From Fig.1., we can conclude that the evolutionary game process of knowledge sharing in Co-NPD converges to b (1, 1) and c (0, 0), matching with two evolutionary stable strategies which are the enterprises 1st & 2st choosing knowledge sharing or not in the meantime. Two unstable points, a (0, 1), d(1, 0) and a stability point E (x^*, y^*) are consisted of the critical value line A-E-D of evolutionary game at different state. If the point is in the upper right by the critical value line A-E-D, the enterprises 1st & 2st will both choose the knowledge sharing strategy in this situation. If the point is in the bottom left by the critical value Line A-E-D, They will both not choose the knowledge sharing strategy in this situation. Furthermore, the enterprises 1st & 2st will consider some key factors such as the complementary of knowledge resources, the difficulty of knowledge sharing, the knowledge absorptive capability, the cost of knowledge sharing, and the risk of opportunism behaviors to decide which dominant strategy they choose to tend to convergence points b (1, 1) or c (0, 0). So, the evolutionary equilibrium depends crucially on the judgment and implementation strategy of the enterprises 1st & 2st at sharing their knowledge in the Co-NPD process.

5. Governance Mechanism for Promoting Knowledge Sharing

According to the evolutionary game analysis of knowledge sharing in Co-NPD process, the long-term evolutionary equilibrium of Co-NPD network is actors might all choose knowledge sharing strategy or not choose. In the game process, the initial value and its change tendency of the revenue function parameters will lead the evolutionary trend of convergence to different equilibrium points. Therefore, when designing the governance mechanism, the effects of these parameters should be fully considered to promote knowledge sharing in the Co-NPD network.

Firstly, the participants owned highly complementary knowledge and skills are priority selective partners to develop new products collaboratively. The level of complementary knowledge resources α_i is one of the most important factors influencing knowledge sharing among actors involved in Co-NPD network. The higher of parameter α_i is, the higher dependence is among participants each other to obtain more complementary and necessary knowledge or skills. So, they are prone to the knowledge sharing strategy. The evolutionary game results will also converge to a stable point b (1, 1) , so that each participant is willing to choose the knowledge sharing strategy.

Secondly, the knowledge-absorbed capability of partners should be estimated cautiously when they design the governance mechanism and choose participants composed of the Co-NPD network. Because the knowledge absorptive capability can directly or indirectly affect their investment of knowledge and resources in new product development, especially at the early stage of collaborative R&D. When the actors involved in the R&D have a strong organizational learning and knowledge absorptive capability, the innovation ability will become stronger on the basis of its accumulated knowledge, skills, and resources. So the doubling synergy revenue $f_{2i} = \eta_i \gamma_i \beta_i \alpha_i$ will also become larger. They are more willing to invest resources into the Co-NPD platform.

Thirdly, incentive mechanism and reputation management should be an important part of contracts and regulations. The stronger willingness of knowledge sharing (γ_i) is, the shared knowledge is more easily learned and absorbed by partners. The application of new knowledge is more extensive, and the Co-NPD process is more efficient. Then, more enterprises will choose knowledge sharing strategy. Undoubtedly, the contracts should also include corresponding penalties to supervise and restrain the behaviors of all participants.

Finally, the trust and commitment relationship of employees and managers should be obvious and felt everywhere in the Co-NPD network. If the resources of participants in Co-NPD network are high complementary, trust and commitment will be the preferential and endogenous strategy. Each participant expects to strengthen the frequency and intensity of knowledge sharing to structure an interdependence relationship. At the same time, trust and commitment should start from the top for providing a very homely atmosphere. Then, the risk of opportunism behaviors will also decline. The optimal use of the whole knowledge resources in Co-NPD network can be realized to ensure the success of new product development.

6. Conclusion

Globalization and technological advancements have changed the market world and made enterprises face more challenges. The innovative and speedy development of new products is the most essential factors for their salvation and success in facing the challenges of the market world. The need for effective knowledge sharing both internally and externally is a key driver for NPD, especially in collaborative new product development process. Using the primary aim as stated in the introduction, the study seeks to summarize the key factors influencing knowledge sharing in Co-NPD network, and expound the game process of knowledge sharing among participants in Co-NPD network. Some conclusions are as follows: Firstly, the efficiency of knowledge sharing is influenced by the willingness of knowledge sharing of partners, the complementary of knowledge resources, knowledge absorptive capability, the cost of knowledge sharing and the risk of opportunism behaviors. Secondly, according to the evolutionary game results of the knowledge sharing in Co-NPD process, the evolutionary tendency and equilibrium are related to the judgment of the above factors. These factors influence the cooperation strategy, commitment, and investment of knowledge and skill resources in the Co-NPD network, and facilitate a stable knowledge-sharing strategy for Co-NPD. Finally, a governance mechanism for promoting knowledge sharing is designed including the complementarities of knowledge resources, the knowledge-absorbed capability of partners, the trust and commitment relationships, and supervision and constraint of opportunism behaviors, etc. The significance of the results is to help all participants achieve the expected maximum utility by the knowledge sharing behaviors in Co-NPD process.

In particular, for anyone interested in related topics, research in the future may be approached in the following directions: (1) May take a step further and consider the characteristic of multiple stages, and different levels of Co-NPD process, and compare the differences in knowledge sharing results produced by evolutionary game method or other methods. (2) May take a step further and add parameters influencing knowledge sharing from formal and informal constraint conditions. Propose a more scientific and integrated model to make the study more comprehensive and complete.

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