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Knowledge Sharing within Innovation Network Members with Netlogo Simulation Platform

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Abstract: **The efficient knowledge sharing is the key element for innovation network's success. The strategies are classified as "sharing", "no-sharing" and "retaliation". The game model of knowledge sharing is set up in terms of the evolutionary game theory. The simulation model is constructed with the Netlogo software platform which is efficient in multi-agent simulation. By modeling and simulation, the evolutionary game equilibrium status of knowledge sharing is analyzed according to different payoff value. The result demonstrates that communication, trust and punishment are all important governance mechanisms for knowledge sharing in innovation network.**

***Keywords:** innovation network; knowledge sharing; evolutionary game; retaliation strategy; Netlogo*

Ⅰ. INTRODUCTION

At the knowledge economy age, knowledge has become the major resource for economic development. For maintaining competitive advantage in the changing market, enterprises have to continue engaging in knowledge innovation. However, due to increasingly complexity of knowledge innovation, the cooperative network innovation among the enterprises has become popular. Ren Zhian's study shows that knowledge sharing in the enterprise network can bring about scale and scope economic advantage[1]; Jennife revealed the relationship of knowledge sharing, innovation systems and performance of the global enterprise networks which denoted that enterprises which take on knowledge sharing will have better performance [2]. Knowledge sharing is becoming the key of cooperative innovation through innovation networks, but it should be noted that innovation network is an organization without strict contractual relationship where the relationships of members are loose and there are no mandatory measures for members' behaviors. In innovation network, knowledge sharing depends on the members' self-wills and expectations for others. Especially for the new-established network, members are unfamiliar for each other so that trust among them is lack, which provides the conditions for member's opportunistic behavior also named "free rider" that is some members freely enjoy the knowledge and technology provided by the others in cooperation but they contributes nothing. This kind of behavior will hinder knowledge sharing motivation of members, losing the performance of innovation networks. Some scholars have analyzed innovation network knowledge sharing mechanism and the process and have applied game theory for analyzing it. For example, Chai Guorong built knowledge sharing model which showed knowledge sharing will face prisoner's dilemma when there are no guarantee measures; otherwise companies are willing to engage in the knowledge sharing after trade-off[3]. Chen Guifang applied game theory to set up a model in which the members of virtual enterprises can infinitely repeated knowledge cooperation game and the conditions of knowledge collaboration were analyzed[4]. However, these literatures were based on the fully rational assumptions discrepant with the actual situation. Because the vast majority of cases, the game actors cannot be completely rational but only limited rational. Hence based on limited rationality of game parties, some scholars recurred to evolutionary game theory studing the knowledge sharing dynamic mechanism of network members. Qin Hongxia and Chen Huadong analyzed the general rules of enterprises' knowledge sharing network formation by means of evolutionary game theory. Their study showed that the initial status and incentives for knowledge sharing networks have an important role in the formation of enterprises' knowledge sharing network[5].Yang Bo and Xu Shenghua established virtual enterprises' knowledge transferring simulation model of asymmetric evolutionary game and used complex adaptive system theory and multi-agent simulation method to conclude the strategy which can be used in knowledge-sharing of asymmetric enterprises[6]. Although these documents took the player's limited rationality into account and part of them used evolutionary game theory and simulation methods to study the characteristics and variations of knowledge transfer within the network, the players' strategies were simplified as two categories, namely active participation in knowledge sharing and "free rider" behavior. With the two types of strategies different actors repeated game and learned from the game process, which endowed knowledge sharing behavior with characteristics of dynamic evolution and stability under certain conditions. However, in addition to these two strategies there are other types of strategies in the network that increase the complexity of knowledge-sharing within innovation network and the original Nash equilibrium of two types of knowledge-sharing strategy will change. Therefore, it is necessary to study the innovation network members' knowledge-sharing behavior changing mechanism and countermeasures problem after increasing the new strategy.

Ⅱ. THREE TYPES OF KNOWLEDGE-SHARING GAME STRATEGY

Innovation network is a new technological innovation cooperation organization which is loosely coupled, dynamic and opened, consisting of a number of enterprises and their related organizations, aiming at products or process innovation including their industrialization based on knowledge sharing. Partners participate in innovation

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activities to achieve the overflowing and diffusion of innovation during the process of the development, manufacturing and commercialization of new products[7]. The network have the characteristics of complex systems including nonlinearity and diversity[8]. Nonlinearity characteristic reflects in the complexity and adaptability of innovation actors, and nonlinearity origins from initiative and adaptability of innovation actors. Every member within the innovation network has its main objective and independent right; during the interactive process, the current environment, historical experience and the relationship between the actors cause the relationships showing on diversity characteristic. A large number of random links exist within the actors of innovation networks. The motives and expectations will be different when sharing the private knowledge with other actors. So the strategies they adopt are also various, which make the knowledge sharing game complex. Evolutionary game theory mainly studies the dynamic process over time of a certain group of members' behavior. In term of evolutionary game theory, actors are assumed to be programmed to adopt the given behavior. The knowledge of successful conduct rules and strategies is continually revised and improved during the evolutionary process. The successful strategy is imitated and produces some general rules as the standard for actors. Under these general rules, actors get "satisfactory" return[9]. Within the existing knowledge sharing evolutionary game models, the main strategies are generally reduced to two types, namely, "sharing strategy" and "no-sharing strategy". Sharing strategy refers to the "actively sharing knowledge with other actors", no-sharing strategy is that "do not share knowledge with other actors". This paper argues that, in addition to the two strategies, there is the third strategy called "retaliation strategy". Such strategy is based on the opponent's strategy to determine its own strategy. That is to say, if other members share knowledge with him, he does so; otherwise adopting no-sharing strategy. This is a dynamic game process. When opponents adopt sharing knowledge strategy, the user of retaliation strategy will adopt same strategy; when the opponents adopt no-sharing strategy, the actor will not share knowledge too. Especially when the opponents also uses retaliation strategy, if the two sides cannot communicate effectively, the actor will judge it as no sharing strategy of knowledge, then himself will not share knowledge too. While if the two sides can communicate effectively, it may lead to both side adopting knowledge-sharing strategy. Based on the above analysis, assuming that each member's benefit is symmetric, the payoff matrix of the game model can be shown in Table Ⅰ. The revenue of both sharing knowledge "p" or payoff by free-riding behavior "s" are both greater than zero, but which is big or small depends on the nature of knowledge sharing. Because knowledge sharing is a means of knowledge innovation, aiming to make knowledge activities have "1+1>2" results. The tacit knowledge within members always need high frequency interacts so maximum synergistic value can be obtained[10], in which case the benefit of speculation is not certainly greater than the benefits of knowledge sharing. If one side of the game use sharing strategy and the other no-sharing strategy, the former will get no income, taking into account the costs of sharing knowledge, then it may get negative income. The benefit of two sides both adopting retaliation strategy may be the same as that of two sides both adopting no-sharing strategy or both adopting sharing strategy after effective communication. Therefore the variables' values are: p, s> 0, q ≤ 0 and v = 0 or p.

Ⅲ.KNOWLEDGE SHARING SIMULATION RESULTS OF EVOLUTIONARY GAME

There are some difficulties to solve the payoff matrix in Table I using the traditional replicator dynamics equation, because it involves more uncertain variables. In order to describe the equilibrium of this dynamic evolution game within different actors based on above three strategies, the paper uses simulation method to study knowledge-sharing strategy changes of members within the network in the case of changing different payoff-values and to analyze different evolutionary equilibrium. The simulation software which this paper has used is Netlogo platform which is used in multi-agent modeling and simulation, especially suitable for the complex system modeling evolving with time. Model can give directions to hundreds of agents and explore the links between micro level about individual behavior and possible macro modes which are emerged from the interaction among many individuals.

TABLE I. GAME PAYOFF MATRIX OF KNOWLEDGE TRANSFER

Members a / Members b	**Sharing**	**No-sharing**	**Retaliation**
Sharing	p, p	q, s	p, p
No-sharing	s, q	0, 0	0, 0
Retaliation	p, p	0, 0	v, v

Suppose the proportion of adopting sharing strategy is x, then the proportion of adopting no-sharing strategy is 1-x. It is not difficult to calculate the expectations of payoff of two strategy and the average expected benefit of the groups, they are: u1=x×p+(1-x) ×q, u2=x×s, u=x×u1+(1-x)×u2. In accordance with the biological evolution duplication dynamic theory, the actors with lower income will change their game strategies and steer to (imitate) those strategies with higher income, so the proportion of members in the group using different strategies will change, meanwhile proportion of specific strategies and their changing velocity are proportional to the magnitude of benefits in excess of average benefits. Therefore, the rate of change of x which mentioned above can be indicated with replicator dynamics equation:

$$F(\mathrm{x}) = \frac{dx}{xt} = x(u_1 - u) = x(1-x)\left[x(p-s) + (1-x)q\right]$$

let F (x) = 0, it can draw that there are up to three stable point or stable state of replicator dynamics , respectively are:

. $x_1 = 0, x_2 = 1, x_3 = q/(q+s-p)$

At the stable point in F (x), the derivative (tangent slope) F(x*) is less than zero or the tangent slope of F (x) at the intersection with the horizontal axis is negative. X fulfilling these requirements is the evolutionary stable strategy in evolutionary game theory[11].

The network members' number is set 300, assuming that the member applying the three strategies are separately 100. Based on the different situations discussed in the previous section and different values of v, it should been reconsider about the evolutionary game equilibrium state.

Case 1: Under the condition of q = 0 and v = 0, respectively input (a) p = 5, s = 3, (b) p = 3, s = 5 into the simulation model, the running results can be shown as Fig. 1(a) and Fig. 1(b):

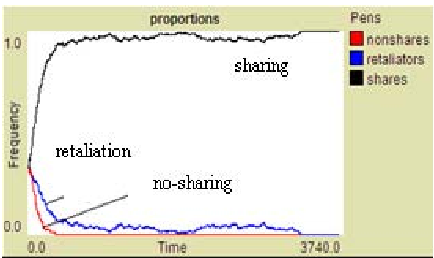

Figure 1(a). v= q =0, p = 5, s = 3

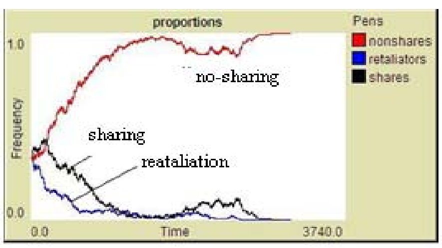

Figure 1(b). v= q =0, p = 3, s = 5

Case 2: Under the condition of q <0 and v = 0, similarly respectively input (a) q =- 1, p = 5, s = 3 and (b) q =- 1, p = 3, s = 5 into the simulation model, then the output is shown as Fig. 2(a), Fig. 2(b):

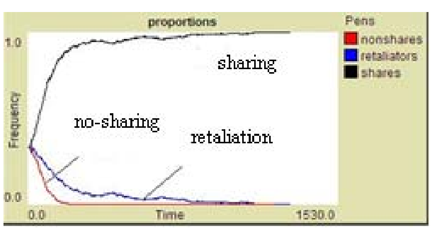

Figure 2(a). v= q =-1, p = 5, s = 3

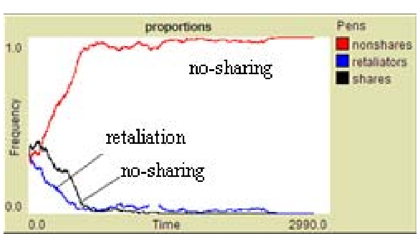

Figure 2(b). v= q =-1, p = 3, s = 5

The simulation results in Fig. 1 and Fig. 2 demonstrate that the proportion of actors adopting retaliation strategy is gradually declining and dropped to zero after game learning process. Under case 1(a) and case 2(a), they find that the benefit of retaliation strategy is lower than the simple sharing knowledge strategy, while under the case 1(b) and case 2(b), the benefit is still not as good as simple no-sharing strategy.

Case 3: Under the condition of q = 0 and v = p, respectively input (a) p = v = 5, s = 3 and (b) p = v = 3, s = 5 into the simulation model, the output as shown in Fig. 3(a) and Fig. 3(b):

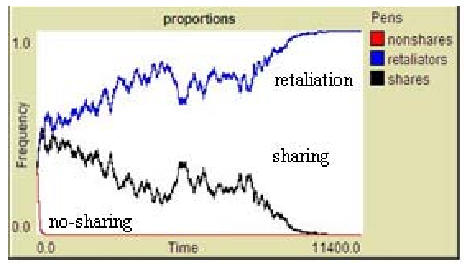

Figure 3(a). v= p =5, q= 0, s = 3

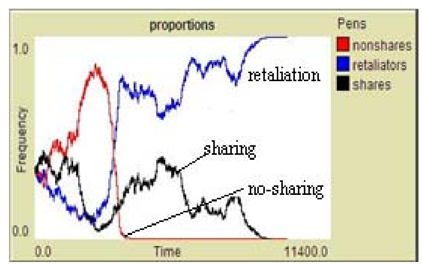

Figure 3(b). v= p =3, q= 0, s = 5

Case 4: Under the condition of q = -1 and v = p, respectively input (a) p = v = 5, s = 3 and (b) p = v = 3, s = 5 into the simulation model, then the output is shown in Fig. 4 (a) and Fig. 4 (b):

Figure 4(a). v= p =5, q = -1, s = 3

The simulation results of Fig. 3 and Fig. 4 show that in the case of v=p, whatever the values of p, q and s are, the proportion of retaliate strategy actors will gradually increase and finally all the actors will choose this strategy. Even though in the case of Fig. 3 (b), the proportion of actors with no-sharing strategy temporarily increases, but after the game learning process, the proportion is falling because the game partners will find this strategy is not dominant.

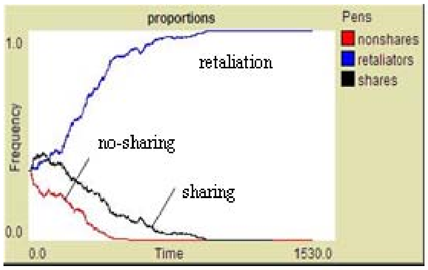

Figure 4(b). v= p =3, q = -1, s = 5

Ⅳ. ANALYSIS OF EVOLUTIONARY GAME SIMULATION RESULTS

It can be seen from Fig. 1-2 that the equilibrium state after introducing new strategy is the same as before. This indicates that when v=0, which means the members who adopt retaliation strategy cannot build confidence through effective communication, game actors adopting retaliation strategy have no effect on the innovation network members' evolutionary game equilibrium, the actors with retaliation strategy will eventually abandon the strategy and steer to sharing or no-sharing policy based on the different values of p and s. Fig. 3-4 show that if v = p that means two sides of retaliation strategy can release signals through communication so as to make one side trust the other one and believe that if he share knowledge with the other one, he will also use the same strategy to repay, so he will take the initiative to adopt sharing strategy and lead to the final result that two sides adopt sharing knowledge strategies. Even the free-rider benefit is higher than sharing knowledge revenue, the network members still adopt sharing strategy, which shows that communication, and trust can overcome the free riding behavior to a great extent and they are important governance means of innovation networks. But it is noteworthy that the assumption is that the cost of building trust through communication is far less than the benefits through knowledge sharing so that the cost can be ignored; if the cost is very high, the result may be different, that is why knowledge sharing is more easily carried out among the members having previous experience of cooperation. The stability of equilibrium shown in Fig. 3-4 is valid because that once network members deviate from this strategy, which means that they destruct the reciprocal contract within members, "retaliating" mechanism will be triggered which can lead to retaliation by other network members with the result that these members will possibly not get new knowledge source forever. Hence in fact it is a kind of punishment mechanism for members who break down knowledge-sharing rules. This mechanism will prevent those who want to become free-riders from giving up knowledge sharing strategy after they take expected speculative gains subtracting punishment into consider. Therefore it can motivate network members sharing knowledge steadily.

Ⅴ. CONCLUSION

It's a fact there are not many individuals in a cooperative innovation firms network simply insist the sharing strategy or no-sharing strategy. Most individuals are actually willing to use retaliation strategy based on reciprocity. The research through Netlogo modeling and simulation can illustrate this viewpoint, at the same time it could also prove trust and punishment mechanisms are both important governance means for innovation network knowledge sharing. The trust between members can overcome speculation to some extent, but there must be punishment mechanism as guarantee. Therefore, the simulation consequence of this paper can be convinced in accordance to reality. According to this paper, the innovation network managers should promote effective communication within members; reduce the costs of building trust among network members and meanwhile make the punishment mechanism effective for each member.

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