

Evolutionary Game and Alliance Management Analysis of tacit knowledge flow in Enterprises

Yuguo Yang

School of Accounting, Guangzhou College of Commerce, Guangzhou Guangdong, China,
526597753@qq.com

Key words: Tacit knowledge; evolutionary game; replicator dynamics equation

Abstract. Combined with the evolutionary game theory, this paper analyzes the factors and mechanisms that affect the tacit knowledge flow by using the replicator dynamics equation, and concludes that the degree of tacit knowledge flow in enterprises is determined by the cost of tacit knowledge dissemination, the incentive of enterprises to the tacit knowledge communicators, and the income generated by two-way knowledge flow and one-way knowledge flow, etc. From the point of promoting the mechanism of the tacit knowledge flow of enterprises, this paper puts forward some thought methods, such as establishing internal and external knowledge alliance, strengthening knowledge management and encouraging, to link and overcome the problem of "island of knowledge" of organizational knowledge flow.

1. Introduction

The concept and theory of tacit knowledge was first put forward by British philosopher Michael Polanyi in 1958^[1]. He believed that tacit knowledge refers to experience, impression, perception, team understanding, technical know-how, organizational culture, habits and customs and other knowledge that difficult to communicate and express, generally exist in the individual; Explicit knowledge refers to formal and standardized knowledge expressed in written words, charts and mathematical formulas, which can be specifically communicated, disseminated and stored, such as product appearance documents and data specifications.

In 1995, Yoshiro Noshino and Takuhiro Takeshi in Japan put forward the famous SECI model. They thought: "Tacit knowledge is highly personal knowledge with its own special meaning, so it's hard to standardize and not easy to pass on to others." ^[2] In 1998, Drucker pointed out that tacit knowledge is a kind of skill that can only be understood, but not explained. It is difficult to code or cannot be coded, and can only be proved by demonstration.

Zhu H M (2016) held the thought that tacit knowledge is privatized and acquired by individual experience for many years. Because tacit knowledge is not easily encoded and privatized, it is difficult to be transferred. After development, tacit knowledge is going to produce knowledge innovation.^[3]

Scholars hold the same mainstream view on the definition of tacit knowledge, that is, tacit knowledge in enterprises, in the hands of the internal members and organizations of the enterprise, is the internal tacit knowledge that is difficult to be imitated, encoded or cannot be encoded, and difficult to be expressed clearly in words and languages. In a broad sense, it also includes the tacit knowledge acquired from the outside of the enterprise. It includes tacit knowledge of skills (skills, technique, know-how, experience, etc.) and tacit knowledge of knowledge (insight, intuition, perception, values, mental models, tacit understanding, enterprise culture, etc.).

Tacit knowledge flow and transformation are the starting points and keys of enterprise knowledge innovation. Relative to explicit knowledge, tacit knowledge is more important and can create more value for enterprises, which make it become the foundation and source of forming core competitive ability of enterprises. Therefore, this paper discusses how to realize the full flow of tacit knowledge in enterprises, promote the knowledge transmission and sharing among the knowledge subjects within enterprises, and make tacit knowledge work and become the resources must be researched and developed in the group enterprise, especially the science and technology innovation-based enterprise.

At present, due to the characteristics of tacit knowledge and the existence of various obstacle factors, there are some difficulties in taking tacit knowledge flow in practice, as well as in practice of tacit knowledge management. This has also become a major obstacle to the establishment of dynamic capability and the formation of long-term competitive advantage for current enterprises. By using evolutionary game theory correlation ideas and analytical tools, this paper hopes to find out the obstacles and solutions to the flow of tacit knowledge.

2. The evolutionary game analysis of tacit knowledge exchange among organizational members

Professor Chengyu Xie has put forward the concept of "Frog Game" that the evolution of frog is the result of game evolution. Because the frog's ancestors had neither ears nor sound, after a long period of survival and evolution, the male frog was able to sing very loudly, and the female frog had excellent hearing accordingly. This is actually the result of game learning in a long-term evolutionary process^[4]. Knowledge sharing is also a long-term process and tacit knowledge flow can also be analyzed by dynamic replication.

Organization members generally have two strategic choices about tacit knowledge they obtain: choose to exchange with other members of the organization or choose not to exchange (this paper calls this situation "hide "). The game between the members of the organization is carried out under the conditions of finite rationality and circumstances with uncertainty, so the game among the members can form the evolutionary game model. Suppose there are two members of the organization, and their strategy mix and corresponding benefits are as follows: the original output level of both individuals is P, that is to say, both of them choose to hide, and when there is no tacit knowledge flow, the benefit of them is P; If both of them choose to impart their own tacit knowledge to each other, they will gain an additional benefit M. If only one side chooses to exchange, then the other side will get an additional output N because of the acquisition of tacit knowledge. Spreading tacit knowledge takes time, effort, and opportunity costs, which we assume are C. The game matrix of tacit knowledge exchange among organizational members is shown in Table 1.

Table 1 the game income matrix of tacit knowledge exchange among organizational members

MEMBER 1		EXCHANGE	HIDE
	EXCHANGE	$P+M-C, P+M-C$	$P-C, P+N$
	HIDE	$P+N, P-C$	P, P
		MEMBER 2	

Let's suppose that the proportion of members of enterprise who are with sense of teamwork and willing to impart their own tacit knowledge to others is x ($0 \leq x \leq 1$), and the proportion of members who are unwilling to impart their tacit knowledge to others is $(1-x)$. We can find out the evolution law of tacit knowledge exchange game among members--replicator dynamic equation.

$$\begin{cases} U_1 = x(P+M-C) + (1-x)(P-C) \\ U_2 = x(P+N) + (1-x)P \\ U_3 = xU_1 + (1-x)U_2 \end{cases} \quad (1)$$

U_1 , U_2 , U_3 separately are the expected income of the members who choose to transmit tacit knowledge, the expected income of the members who choose to hide tacit knowledge, and the average expected income of the members of the enterprise.

We also can get the replicator dynamic equation RDE:

$$F(x) = dx/dt = x(U_1 - U_3) = x(1-x)(x(M-N) - C) \quad (2)$$

$$F'(x) = 3(N-M)x^2 + 2(M-N+C)x - C \quad (3)$$

According to RDE, three possible stable state points can be obtained: $x_1=0$, $x_2=1$, $x_3=C/(M-N)$

In evolutionary game theory, "evolutionary stable strategy", or ESS, represents the stable state in which a population withstands the invasion of a mutation strategy. Selten (1983--1988) defined it as:

In a game of finite roles, when the strategy s^* is an ESS, if and only if:

- (1) for any s^* , $f(s^*, s^*) \geq f(s^*, s)$
- (2) $s^* \neq s$, if $f(s^*, s^*) = f(s^*, s)$, then $f(s^*, s) > f(s, s)$

So we can say that an ESS must satisfy the following two conditions:

$$\begin{cases} F(x) = 0 \\ F'(x) < 0 \end{cases} \quad (4)$$

In conjunction with (2) (3) (4), we can see that $x_1=0$ will always be the stable state point as long as tacit knowledge dissemination cost $C > 0$

In the process of tacit knowledge exchange and dissemination, choosing to impart knowledge to other members inevitably takes time, effort, and the corresponding opportunity cost. In addition, tacit knowledge itself is difficult to encode, which determines the inevitable cost of tacit knowledge flow^[5]. So $C > 0$ can be considered always hold. Therefore, in this model, members who choose to share tacit knowledge with other members will bear the cost, but they will not gain additional benefits unless the other also choose to share. After repeated games, all members of the organization will choose to hide their tacit knowledge and there will be no tacit knowledge flow within the enterprise. The phase diagram of the replicator dynamic equation as shown in figure 1:

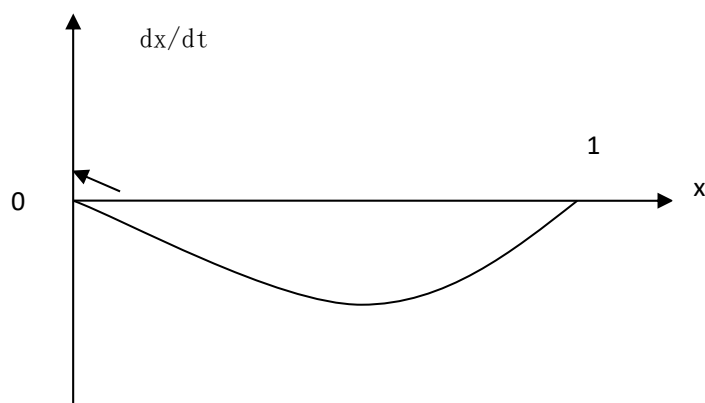


Figure 1 The phase diagram of the replicator dynamic equation of tacit knowledge exchange among organizational members

3. The evolutionary game model of adding organizational incentive factors

The above evolutionary game model does not take into account the incentive of organizations to for employees who choose to disseminate their own tacit knowledge, leading to the proportion, of which members of the organization who choose to share knowledge, $x=0$. To solve this problem, organizations usually reward the employees who have a sense of cooperation and share tacit knowledge, and improve the income of these members to stimulate internal tacit knowledge flow. We assume that those members who choose to exchange tacit knowledge can get additional income Q from the organization, while other returns of game will not change, then the corresponding game matrix is shown in Table 2.

Table 2 Income Matrix of tacit knowledge Exchange with organizational incentive exchange among organizational members

MEMBER 1	MEMBER 2	
	EXCHANGE	HIDE
	EXCHANGE	HIDE
EXCHANGE	$P+M+Q-C, P+M+Q-C$	$P+Q-C, P+N$
HIDE	$P+N, P+Q-C$	P, P

MEMBER 2

Based on this, a new replicator dynamic equation can be obtained.

$$\begin{cases} U_1 = x(P+M+Q-C) + (1-x)(P+Q-C) \\ U_2 = x(P+N) + (1-x)P \\ U_3 = xU_1 + (1-x)U_2 \end{cases} \quad (5)$$

$$F(x) = dx/dt = x(U_1 - U_3) = x(1-x)(x(M-N) + Q - C) \quad (6)$$

$$F'(x) = 3(N-M)x^2 + 2(M-N+C-Q)x + Q-C \quad (7)$$

Discussion:

(1) When $Q < C$, the reward given by the organization is less than the cost of knowledge sharing

$F'(0) = Q - C < 0$, so $x_1 = 0$ is the point of stability of evolution, that is, when the income from incentive is less than the cost of tacit knowledge flow, the direction of evolution is the same as when there is no incentive. In the end, no member in the organization will choose to share their tacit knowledge with others, and the evolution of the organization to the stable point of $x_1 = 0$ will just be slowed down by the income of Q caused by the incentive. The phase diagram of the replicator dynamic equation as shown in figure 2a.

(1) When $Q > C$ and $M > N$, that is, for employees who choose to exchange tacit knowledge, the rewards offered by the organization are greater than the cost of knowledge sharing, Moreover, the additional output of two-way tacit knowledge exchange is larger than that of one-way exchange. At this time, $F'(0) = Q - C > 0$, $x_3 = (C - Q)/(M - N) < 0$ (because of $0 \leq x \leq 1$, we reject the x_3), so both of x_1 , x_3 are not the stable points. In the other hand, $C - Q < 0 < M - N$ can be deduced that $N - M + C - Q < 0$, so $F'(1) = N - M + C - Q < 0$, $x_2 = 1$ is the evolutionary state stability point. In this kind of environment, members are influenced by organizational motivation and two-way exchange, which is more than that of one-way exchange. After repeated games, members tend to spread their own tacit knowledge. Tacit knowledge in the organization is fully flowing. The phase diagram of the replicator dynamic equation as shown in figure 2b.

(2) When $Q > C$ and $M > N$, that is, for employees who choose to exchange tacit knowledge, the rewards offered by the organization are greater than the cost of knowledge sharing, but the extra additional output brought by two-way tacit knowledge exchange is smaller than the extra output brought by one-way exchange. If $0 < x_3 = (C - Q)/(M - N) < 1$, Then it can be deduced that $Q - C < N - M$, so $F'(1) = N - M + C - Q > 0$; And because $F'(0) = Q - C > 0$, so both of $x_1 = 0$, $x_2 = 1$ are not the stable points. $F'(1) > 0$, $F'(0) > 0$, According to Lagrange's mean value theorem, $F'(x_3) < 0$, so, $x_3 = (C - Q)/(M - N)$ is the evolutionary state stability point. That is to say, in the above organizational environment, after repeated games many times, there will be a proportion of $x_3 = (C - Q)/(M - N)$ of organization members choose to spread their own tacit knowledge. The phase diagram of the replicator dynamic equation as shown in figure 2c.

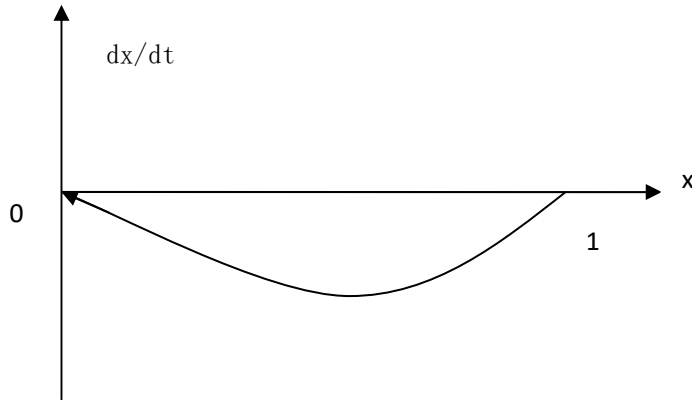


Figure 2a The phase diagram of the replicator dynamic equation adding organizational incentive factors ($Q < C$)

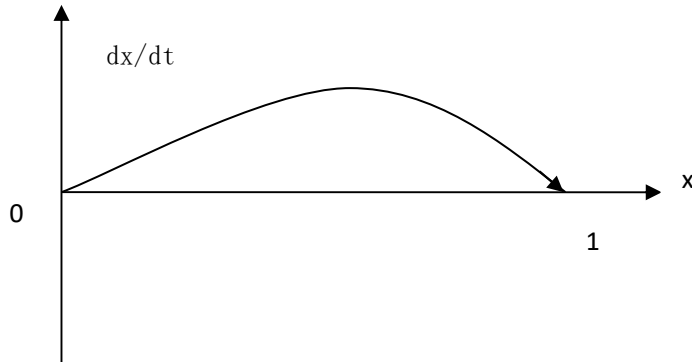


Figure 2b The phase diagram of the replicator dynamic equation adding organizational incentive factors ($Q > C$, and $M > N$)

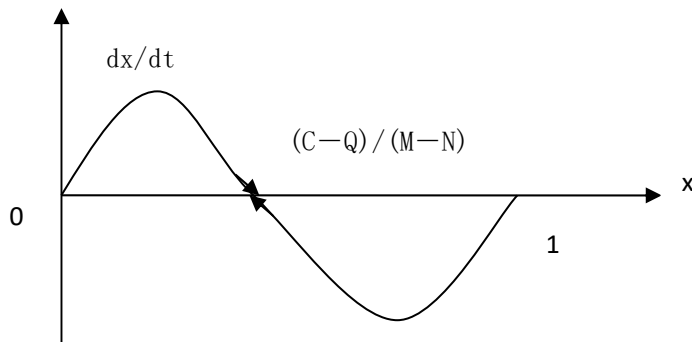


Figure 2c The phase diagram of the replicator dynamic equation adding organizational incentive factors ($Q > C$, and $M < N$)

4. Conclusions and management recommendations

From the evolutionary game analysis above, it can be seen that the fluency degree of tacit knowledge flow in enterprises is determined by the numerical value of the corresponding influencing factors such as Q, C, X , M, N and so on. That is, the fluency degree of tacit knowledge flow in enterprises depends on the reward given by enterprises to the owners of tacit knowledge, the cost of tacit knowledge transmission and the benefits generated by two-way knowledge flow and one-way knowledge flow, etc. If we want to promote tacit knowledge flow to enhance the ability of enterprises, we must change the size of these factors and the relationship between them.

1. Establishment of tacit knowledge reward system in Enterprises

If the organization does not give incentive, there will not be tacit knowledge flow in the enterprise, so we can see the importance of organizational incentive to knowledge flow. Organizational motivation includes material and spiritual aspects. For material incentives, enterprises can establish a proportional relationship between incentives and the outputs of employees spreading tacit knowledge, that is, $Q=RM$ or $Q=RN$ ($0 < R < 1$). The greater the value R is, the more stimulating the tacit knowledge flow will be^[6]. In this way, employees can be encouraged to share knowledge with others, and enterprises can benefit from tacit knowledge flow. Because, in fact, the enterprise is also a player in the game. This proportional relationship can ensure that the incentive costs provided by enterprise do not exceed the benefits of tacit knowledge flow.

Based on the above analysis and conclusions, the reasons why this paper advocates the combination of material and spiritual incentives are following. On the one hand, in consideration of motivation theory and demand theory, spiritual motivation is more effective for some knowledge workers in a specific environment. The practice of enterprise shows that the effect of material incentive is decreasing in marginal utility, and the effect of spiritual incentive is more obvious. On the other hand, compared with material incentive, the cost of spiritual incentive can be neglected basically. From the perspective of cost saving, spiritual incentive is more meaningful.

2. Reduce the cost of tacit knowledge flow and implement alliance management.

Cost is an obstacle to the exchange and flow of tacit knowledge. In order to promote the tacit knowledge flow, enterprises must adopt the measures of alliance management to reduce the cost of tacit knowledge flow.

(1) Establish an organizational structure conducive to knowledge flow. The traditional pyramidal organization has too many levels and lacks flexibility, which is not conducive to the flow of knowledge. Realize the flattening or networking of the organization to make the enterprise become a learning organization, which has a harmonious soft environment that can facilitate the flow of knowledge. It is beneficial to the knowledge exchange and sharing of the organization, to the innovation and application of knowledge, to the improvement of the adaptability of the enterprise and to the cooperation spirit of the team.

(2) Create an enterprise culture that encourages the flow of knowledge to encourage learning and knowledge exchange. Innovative enterprise culture will create a good atmosphere for the tacit knowledge flow, reduce the time and energy costs required for knowledge exchange, and more importantly, knowledge-oriented enterprise culture will improve the learning ability of its members. It makes the coding and decoding of tacit knowledge more fluent, consequently improving the efficiency of tacit knowledge flow and reducing the cost.

(3) Strengthen infrastructure for knowledge flow and adopt advanced information technology. The flow of tacit knowledge needs the support of information technology. Enterprises should set up the information network system according to their own strength, and create the hardware conditions for realizing knowledge sharing. Advanced information technology can increase the efficiency of saving information and knowledge exchange. For example, Building a knowledge base, network data platforms, electronic discussion systems and so on, can help enterprises to fully share and exchange among internal and external as well as owners of tacit knowledge in enterprises. It is worth mentioning that the recent emergence of Enterprise Blogger, a knowledge management tool, which has further implemented the personification strategy of knowledge management and is very conducive to the dissemination of tacit knowledge.

2. The relationship between income M brought by two-way tacit knowledge flow and income N brought by one-way tacit knowledge flow will also affect the tacit knowledge flow of enterprises. we can see that the implementation of $M > N$ or the reduction of the $|M - N|$ value will have a positive effect on the tacit knowledge flow: if $M > N$ can be implemented, then the game will evolve to the stable point $x_2 = 1$; If $M < N$, reduce the value $|M - N|$, and the value $x_3 = (C - Q) / (M - N)$ will be increased accordingly, which means that the proportion of members in the organization that choose to exchange tacit knowledge will increase. There are two reasons that will

hinder two-way knowledge exchange. First, two-way exchange will cause tacit knowledge to lose its exclusive, then the original knowledge subject will share the benefits of tacit knowledge with others. Another reason is that under the limitations of a fixed time and environment, two-way knowledge exchange pay for efficiency costs. Because tacit knowledge is often difficult to code and communicate, both sides that exchange knowledge may have "island of knowledge", that is, there is no close connection between the two sides 'original tacit knowledge. At this time, the efficiency of two-way exchange is very low, and the income brought about is less than one-way exchange. Of course, two-way exchange also has advantages. If the two sides can connect "island of knowledge", they can generate "sparks" in the exchange, and then realize the production and innovation of knowledge in the exchanges. Based on this conclusion, we recommend that:

(1) Implement knowledge management and set up a specialized knowledge management team. Knowledge management is a new type of management model that meets the requirements of the knowledge age. It can combine computer-based information management system and interpersonal network-based communication system to form a knowledge network or intelligence network with cognitive ability and innovative ability. Therefore, implementing knowledge management and setting up a specialized knowledge management team can help organizational members improve their ability to innovate and produce knowledge, and increase the chance of knowledge "spark"^[7]

(2) Formulate a flexible and effective performance appraisal system and protect "tacit intellectual property rights ". Mastering key tacit skills, know-how and experience can be an access to special benefits and privileges, while passing them on to others through exchange loses its competitive advantage. Therefore, the owner of tacit knowledge usually has monopoly and exclusive psychology, which makes it difficult for tacit knowledge to exchange and transform automatically. Enterprises can set up an effective performance appraisal system and protect the interests of knowledge subjects. For example, they can draw on the concept of "intellectual property rights". Members who obtain tacit knowledge must pay the cost of using tacit knowledge to the original knowledge subjects in order to eliminate monopolies and monopolistic psychology, leading to win-win.

(3) Establish internal and external knowledge alliances and connect "island of knowledges". The above discussion is mainly about the game between the members of the organization. In fact, tacit knowledge exists in the four levels of individuals, departments, enterprises, and enterprise exterior, and the corresponding game also exists in any combination of these four levels. Each level can form a knowledge alliance to participate in the game. Knowledge alliance can reduce the cost of efficiency, and at the same time it can connect "island of knowledge" more effectively. The connection of "island of knowledge" within the alliance will make the alliance more likely to connect with external knowledge and promote the flow of tacit knowledge at a higher level.

Acknowledgment

Fund project: The 13th Five-Year Plan of the philosophy and social sciences of Guangzhou "Research on the countermeasures for the implementation of the innovation driven strategy in Guangzhou to build a national autonomous innovation demonstration zone"(project number: GJ2017024). Guangdong Provincial 2015 teaching quality project "Guangzhou Business School Zhongxingcai Guangzhou Accounting Office Guangzhou branch practice teaching base"(Project No. 2017A039)

About the author: Yuguo Yang (1969-), male, Miao nationality, Luxi people in Hunan province, master, associate professor of Guangzhou College of Commerce. Research direction: corporate financial management. Zepei Yuan (1949-), male, Laohekou people in Hubei province, professor of Management Science and Engineering, School of Economics and Management, Wuhan University, PhD supervisor, main research direction:

Reference:

- [1] M. Polanyi, The Tacit Dimension [M] .London: Routledge & Kegan Paul, 1966.13-51.
- [2] Nonaka I, Takeuchi H, The Knowledge Creating Company[M].New York: Oxford University Press, 1995.21-56.
- [3] Zhu H M,Zhang S T,Jin Z.The effects of online social networks on tacit knowledge Transmission[J].Physica A: Statistical Mechanics and its Applications,2016,441:192- 198.
- [4] Shiyu Xie, Economic Game Theory (second edition)[M] , Shanghai: Fudan University Press, 2001
- [5] Qingpu Zhang, Zhichao Li, Research on the Flow and Transformation of Implicit Knowledge in Enterprises, China Soft Science, 2003(1)
- [6] Xun Yang, Ping Shi, Conditions and Incentives for the Spread of Staff's Personal Implicit Knowledge, Journal of China Ocean University(Social Science Edition), 2005(4)
- [7] Peter F. Drucker et al. (author), Kaifeng Yang (translator), Knowledge Management, People's University of China, 1995
- [8] Yan Li, Research on the transfer of tacit knowledge after corporate mergers and acquisitions [D] Doctoral dissertation of Harbin Institute of Technology, 2016.20-21