An Analysis on Game Theory of Knowledge Transfer Efficiency in Innovation Networks

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Abstract: as more and more companies seek cooperation to conduct technological innovation, knowledge transfer efficiency is a key factor that may affect the outcomes of technological innovation. Innovation network is a new kind of innovation method nowadays. It is necessary to study how subjective behave in the innovation network. The paper applied game theory to analyze the influence of knowledge transfer efficiency on the revenues of companies. It found that revenues is bigger when enterprises built innovation network than that when enterprises do not built innovation network,
Key words: Innovation network; Knowledge transfer efficiency; Game theory; Suggestions

1 Introduction

Economist Joseph Schumpeter put forward the concept of innovation in the book of Theory of Economic Development in 1912 [1]. The model of innovation experienced five generations from the process of linear models to nonlinear models. Technology-push of first generation and demand-pull of second generation are linear models. The third generation is the combination of technology-push and demand-pull that is a nonlinear model. The forth generation is a parallel model and the fifth generation is a network model of systems integration and expansion. It can be seen from development of innovation models that only relying on the strength of individual enterprise to carry out technological innovation could not win in the increasingly fierce competition in the market. Without necessary knowledge and information of technical innovation, enterprises can not completely own and independently innovate. Companies can build innovation networks to share knowledge and technology to conduct technological innovation together. Organizations of innovation network could be enterprises, customers, universities, scientific research institutions and so on. Enterprises could be suppliers, competitors and cooperators. Innovation network can be defined as a dynamic, open and interactive formal or informal relationship that is established by companies and related subjects (universities, research institutions, government, agencies, etc.) in a certain area.

Wei Jiang revealed the generation of cluster innovation networks of small medium enterprises economy and existence of knowledge spillovers in innovation networks from two aspects of the whole cluster and cluster members. He analyzed approaches and influencing factors of cluster knowledge spillovers and dynamic controlling mechanisms of knowledge spillovers [2]. Wu Chuanrong and Zeng Deming have proposed an evaluation indexes system of main factors that affect subjective cooperation in knowledge transfer in innovation networks, and applied the theory of multi-objective optimum decision model to construct a quantitative decision model [3]. Zeng Deming et al. put forward subjective, resources and activities that comprised innovation network from the perspective of knowledge flows, constructed completed process of knowledge flow consisting of knowledge acquisition, knowledge creation, knowledge transfer and knowledge application in the innovation networks [4]. Chai Guorong et al. built enterprise knowledge sharing models of with safeguard measurement and without safeguard measurements in innovation networks according to the effect of knowledge spillovers and synergies. Without safeguard measurements, enterprise knowledge sharing encountered Prisoner's Dilemma. While with safeguard measurements, firms could make a knowledge sharing decision maximizing profits after they thought about gains and losses. Moreover, enterprises were willing to provide more amounts of knowledge sharing with the expansion of the network [5]. Niu Chonghuai et al. proposed a new organizational innovation, namely comprehensive integrated innovation network. Knowledge sharing in the network can help reduce total transaction costs and total transfer time of knowledge transfer in the process of complex technological innovation, thus promoting talents emergence and enhancing capability of organizational scientific and technological innovation [6]. It could be concluded from the literature review that scholars studied knowledge sharing and transfer mechanism in qualitative methods, few involved quantitative analysis. This paper will construct a game model of knowledge transfer efficiency in innovation network to analyze the efficiencies when enterprises build innovation network and when enterprises do not build innovation network, thus providing theoretical reasons for whether to

build innovation network.

2 Model Descriptions

2.1 Basic assumptions

2.1.1 Market demand

Suppose there are 2 enterprises *i*,*j* produce homogeneous production in innovation network. They would establish an innovation network of complementary advantages in the purpose of technological innovation. The total market demand of production of 2 enterprises in the network is

$$Q=q_1+q_2. \quad (1)$$

In the Eq. (1) q_1 and q_2 are the output of enterprise *i*,*j*.

The inverse demand function of products is linear function:

$$P(Q) = a-Q. \quad (2)$$

In the Eq. (2) a> 0, b> 0 is parameters in the demand curve. $Q \leq a / b$; *P* are prices of products before technological innovation

2.1.2 Innovation input

The model assumes that enterprises *i* in the innovation network implements technological innovation to reduce costs and increase profits. It will choose input of technological innovation that maximizes its benefits. x_i represents cost reduction of unit input of technological innovation of enterprise *i*. x_i is called contribution level of technological innovation. x_i positively correlates with input costs. With unit cost reduction increases, input costs increases. The function of innovation input of enterprise *i* is $f(x_i)$, $f'(x_i)> 0$, $f''(x_i)> 0$. It supposes innovation input function of enterprise *i* is a quadratic function:

$$I_i=f(x_i)=0.5x_i^2 , i=1,2. \quad (3)$$

2.1.3 Knowledge transfer efficiency

When enterprise *i* carries out technological innovation to reduce its own costs, because of knowledge spillover effects, the cost of enterprise *j* will be reduced. Similarly, when enterprise *j* implements technological innovation to decrease its own costs, the costs of enterprise *i* will be reduced as well. *w* indicates knowledge transfer efficiency, in the range of $0 <w <1$. When innovation input $f(x_i)$ of enterprise *i* makes it own costs reduce by x_i, at the same time the costs of the enterprise *j* will be reduced by w_ix_1. Similarly, innovation input $f(x_j)$ of enterprise *j* makes it own costs reduce by x_j, at the same time the costs of the enterprise *i* will be reduced by w_ix_j. The model sets up knowledge transfer efficiency in innovation network is w_n, knowledge transfer efficiency when enterprises without innovation networks is w_s. Assuming $w_s \leq w_n$, which means that knowledge transfer efficiency within innovation network is higher than that without innovation networks. The reason is that companies have set up formal and informal exchanges and communication in innovation network that will enhance knowledge transfer efficiency, which is consistent with the actual situation.

2.1.4 Production costs

Assuming the unit costs of production of enterprise *i* consist of fixed cost c_i, cost reduction of its own technological innovation input x_i, cost reduction by technological innovation input of the other enterprises is w_jx_i. So the unit costs of production of enterprise *i* could be expressed as:

$$C_i=c_i-x_i-w_jx_i, (i=1,2, j=2,1). \quad (4)$$

2.2 Revenue functions

The purpose of technological innovation is to achieve the lowest costs and highest profits. Enterprises could continuously conduct technological innovation to enhance market competitiveness in the condition of maximizing their own interests. The dissemination of technological outcomes, that is, knowledge transfer, could enable other businesses to benefit from copying and imitation. Therefore, this paper selects knowledge transfer efficiency as a key variable, to establish the function of technological innovation input, analyzing the role of knowledge transfer efficiency in the innovation network. It assumes that revenues are formed from product sales subtracting innovation input. The payoff function of enterprise *i*, *j* can be expressed as:

$$y= (a-q_1-q_2-c_1+x_1+w_2x_1)q_1-0.5x_1^2 \quad (5)$$

$$y= (a-q_1-q_2-c_2+x_2+w_1x_2)q_2-0.5x_2^2 \quad (6)$$

3 Model Solutions

The decision-making of whether firms construct innovation networks to implement technological innovation experiences two phases: the first stage is enterprises decide whether to establish innovation networks to conduct technological innovation or not. The second stage is each firm determines its own

level of technological innovation input. The whole process is a dynamic game process that can be solved by backward induction. Therefore, first the paper solves Cournot-Nash equilibrium outputs of enterprises within innovation network and without innovation network, and then calculates technological innovation level of each enterprise in the two cases.

3.1 Game model and solving when enterprises do not build innovation network

When companies do not build innovation networks, as they produce homogeneous and replaceable productions, they will implement technological innovation to gain competitive advantages. Companies would choose the input level of technological innovation to maximize profits. In order to facilitate the analysis, assuming fixed cost and knowledge transfer efficiency of the two companies are equal, namely, $c_1 = c_2 = c$, $w_1 = w_2 = w$. Therefore, the revenue functions of two firms can be expressed as:

$$y= (a-q_1-q_2-c+x_1+wx_1)q_1-0.5x_1^2 \quad (7)$$

$$y= (a-q_1-q_2-c+x_2+wx_2)q_2-0.5x_2^2 \quad (8)$$

Derivative Eq. (7) and Eq. (8), get the best yield of *i*,*j* firms are:

$$q_1^*=1/3[a-c+(2-w)x_1+(2w-1)x_2] \quad (9)$$

$$q_2^*=1/3[a-c+(2-w)x_2+(2w-1)x_1] \quad (10)$$

Corresponding maximum benefits of two enterprises are:

$$y_1^*=1/9[a-c+(2-w)x_1+(2w-1)x_2]^2 -0.5x_1^2 \quad (11)$$

$$y_2^*=1/9[a-c+(2-w)x_2+(2w-1)x_1]^2 -0.5x_2^2 \quad (12)$$

Since the two companies dose not build innovation network, two companies would respectively determine their technological innovation input x_1, x_2. Derivative Eq. (11) and Eq. (12), calculate independent optimal innovation input of lowest costs without formation of innovation network.

$$x_{1s}^* =x_{2s}^* =x_s^2 =[2(a-c)(2-w_s)]/[9-2(2-w_s)(1+w_s)] \quad (13)$$

It can be seen from (13) that x_{1s}^* and x_{2s}^* is a decreasing function of w_s, that x_{1s}^* and x_{2s}^* will reduce with the of increase w_s. Cost reduction of technological innovation input would reduce with the increase of knowledge transfer efficiency. The reason is that when knowledge transfer efficiency between enterprises increases, the achievements obtained from technological innovation of a company would be easily copied and imitated by other companies. Cost reduction of this enterprise would reduce and revenue increase would reduce as well. Therefore, when companies want to obtain higher profits from technological innovation, they must make their innovations can not easily be transferred, that is, to take crypto security measurements on the innovation. This is critical for companies that do not build innovation network.

3.2 Game model and solution of enterprises build innovation network

When enterprises *i*, *j* that produce homogeneous and replaceable productions decide to construct an innovation network for the purpose of technological innovation, they must take lowest innovation costs and highest innovation revenues of the whole network into consideration. The model becomes determining innovation input of two enterprises at the certain rate of knowledge transfer efficiency w_n. Eq. (14) is got from adding Eq. (7) to Eq. (8).

$$y= (a-q_1-q_2-c+x_1+wx_1)q_1-0.5x_1^2 + y= (a-q_1-q_2-c+x_2+wx_2)q_2-0.5x_2^2 \quad (14)$$

Derivative equation (14), figure out optimal innovation input of max cost reduction when companies construct innovation network.

$$x_{1n}^* =x_{2n}^* =x_n^2 = [2(a-c)(1+w_n)]/[9-2(1+w_n)^2] \quad (15)$$

It can be drawn from Eq. (15), that x_{1n}^* and x_{2n}^* is an increasing function of w_n, that is the increase as the increase of w_n. This shows that when companies build innovation networks, the higher knowledge transfer efficiency is, the greater cost reduction of companies is. The cost of transferring company would reduce more, thus getting more profits. The reason is that enterprises in the innovation network would consider the whole interests of network to decide optimal innovation input, pulsing higher knowledge transfer efficiency, would lower costs of all companies in the network, which reduces the whole cost of innovation network.

4 Conclusions and Recommendations of Game Theory

It can be drawn from the analysis of game theory model that when enterprises do not set up innovation network, the increase of knowledge transfer efficiency could reduce the rate of cost reduction. When enterprises form innovation network, the increase of knowledge transfer efficiency could increase the rate of cost reduction. Especially, the knowledge transfer efficiency when enterprises build innovation network is higher than that of they do not build innovation network, this phenomenon is more obviously. So when companies decide to establish an innovation network, they should pay more attention to the knowledge governance mechanism within the network. The essence of knowledge

governance is organizational process of formal organizational mechanisms (including governance structure, incentives, contractual arrangements, etc.) and informal organizational mechanisms (including organizational practices, organizational culture, mutual trade, etc.) that interact on knowledge.

5 Conclusions

The paper construct game model of knowledge transfer efficiency in innovation network based on the theory of knowledge transfer. It targeted two conditions whether enterprises establish innovation network. It concluded that cost reduction in innovation network is larger than that without innovation network, especially transfer efficiency is bigger in innovation network, and cost reduction is more obvious. This article also makes suggestions on how to strengthen knowledge governance of innovation network. These recommendations could provide guide to increase innovation capability of enterprises in innovation network.

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