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Optimization of Innovation Environment for Technology-Based Small Micro Enterprises

—The Perspective of Synergistic Innovation

Quan Deheng
School of Management
Wuhan University of Science and Technology
Wuhan, China
hiven128@126.com

LI Yongzhou
School of Management
Wuhan University of Science and Technology
Wuhan, China
lyzdym@sina.com

***Abstract*—This paper was aimed at the innovation environment of technology-based small micro enterprises. Based on the synergistic innovation model, it explored the equilibrium solution between technology-based small micro enterprises, and between them and the public organization. The results show that the greater difference between the synergistic subjects, the higher synergistic innovation performance will be; moreover, the maintaining of synergistic innovation relies on multiple participants. Finally, the results and proposals motivate policy makers to optimize innovation environment of technology-based small micro enterprises from the perspective of synergistic innovation.**

Keywords—Technology-based small micro enterprises; Synergistic innovation; Innovation environment; optimization

I. INTRODUCTION

As the most dynamic factor in the economy of all countries, technology-based small micro enterprises are becoming the significant force for innovation. Meanwhile, the support for the development of technology-based small micro enterprises is becoming the crucial measure of the strategy after the financial crisis in 2008. Domestic and overseas experience also shows that technology-based small micro enterprises are significant force to promote the development of emerging industries. And they are with the strategic value of promoting the overall level of national economy, optimizing the industrial structure, accelerating the transformation of scientific and technological achievements, helping to form the diverse pattern of innovation between research institutes, large enterprises and technology-based small micro enterprises. However, the experience from Silicon Valley and Tsukuba Science City indicates that relying solely on the support from traditional policies cannot fully achieve the target. Consequently, it is essential to optimize the external innovation environment. Thus, this paper tends to analyze the equilibrium solution of synergistic innovation for technology-based small micro enterprises and present policy recommendations to optimize the innovation environment from the perspective of synergistic innovation.

II. REVIEW OF THE THEORY

A. Synergy Theory and Synergistic Innovation

In 1970s, great attention has been paid to the interaction between the subjects of innovation and its innovation environment, as well as the synergistic effect among innovation subjects. Synergy theory, founded by the famous physicist Hermann (1978), which investigates relationships between units of the system composed of macroscopic space, time or functional structure [1]. While in the process of researching the innovation with synergy theory, Prahalad and Gary (1990) considered that synergistic innovation could centralize and integrate R&D resources of different enterprises, share R&D risk, enhance the power of R&D [2]. And the research of Lawrenee and Lorsch (2006) indicated that a high degree of alienation and synergy generated high performance in the innovation process [3]. Meanwhile, the greater difference between innovative members, the better synergistic effect. Lavied (2006) pointed out that the higher the heterogeneity of enterprise core resources and diversity, the more it stimulates the enterprises to actively explore the external access to resources, effectively enhances the external communication mechanism [4] and enhance the enterprise synergistic innovation capability.

Hu Enhua (2007) stated that synergistic innovation refers to the process, whose complex nonlinear interaction cannot appear in individual enterprise [5]. Via the comparison of the domestic and overseas experience for synergistic innovation, Zheng Gang and Liang Xinru (2006) proposed C3IS model, which is consisted of communication, competition, collaboration, integration and synergy. And they pointed that the achievement of synergistic innovation needs to run through the five stages above [6]. Yu Weizhen, Li Wenjie (2016), takig 300 technology-based small micro enterprises in Zhejiang province as samples, pointed out that core resources promote the growth of enterprises through under the intermediary effect of synergistic innovation via the model of synergistic innovation [7].

B. Synergistic Innovation of Technology-based Small Micro Enterprises

The traditional theory of innovation considers innovation as a function of endogenous variables of innovation subjects. That is to say, the innovation performance of enterprise is only related to the internal factors, such as R&D investment, talent quality and so on, which is also proved by the management practice of large enterprises. Nevertheless, overseas researches reflect that there is close contact between the development,

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especially the innovation performance and the capacity and the external environment. Meanwhile, the development of technology-based small micro enterprises is not alone, but together with the other enterprises in external environment. And it is generally believed that the positive impact of innovation environment on enterprises is mainly due to the synergistic effect of the environment. Mansfield (1995) declared that the area assembled by universities and public research institutions has special advantages in the high level of scientific research, the transformation of high-tech achievements and high-quality talent aggregation [8]. Diez (2000) also claimed that there did exist the assistance on technology providing and diffusion from public research institutions, but its function is less than other members in innovation network [9].

Therefore, the pattern of the individual achieving the technical innovation singly cannot meet require of enterprises' R&D. A synergistic relationship between enterprises or between enterprises and universities as well as enterprises and research institutions needs to be built to achieve the complementary advantages of resources, and to enhance the level and efficiency of innovation. And this synergistic relationship consequently forms as a kind of innovation system. When the elements of the innovation environment are sufficient and the structure is reasonable, the external factors of the innovation environment will cooperate with the internal factors to promote the synergistic innovation performance.

III. Model and Hypotheses

A. The Composition of Model and Hypotheses

Innovation is the process of imputing innovation elements to obtain output by innovation subjects. Thus, the synergistic innovation model of technology-based small micro enterprises is consisted of innovation elements and independent decision-making innovation subjects.

1) Innovation element

It is the sum of all kinds of resources needed in the innovation activities. This paper assumes that elements affecting the innovation output are a finite set, set as E,$\pi = \{e_1, e_2 \ \ldots e_n\}$; the innovation output is a function of innovation elements investment, set as π, π=F(E).

2) Innovation subject

It is the owner of innovation elements who has the power to make the independent decision and which includes technology-based small micro enterprise, research institutes of universities and other individuals or organizations supporting innovation. Each innovation subject only processes a part of elements set asE_i, whole elements of the innovation subject is a subset of E, $E_i \subseteq \mathrm{E}$. When the innovation subject innovates alone, the innovation output is $\pi = f(\mathrm{E}_i)$.

Innovation elements are processed by innovation subjects, while innovation subjects have the power of independent decision-making. That is to say, the investment of innovation elements is merely affected by innovation subjects. Therefore, the innovation elements are independent of each other. Furthermore, the output for the same element under the influence of different innovation subjects is discrepant, due to the diverse ability of usage. According to the characteristics of synergistic innovation, we present the following hypotheses.

H1: The investment of innovation elements is independent;

H2: Innovation output is a function of innovation elements;

H3: Innovation output is independent; there is no need for a combination of investment;

H4: The same kind of innovation subject of the situation for usage of elements is the same;

H5: Innovation subjects are rational.

B. The Construction of Model

In the process of synergy, the subject introduces new innovation elements from the other participants to improve innovation performance. In order to maintain the stability of synergy, the participants must be able to benefit from it. Therefore, the construction of model consists of the following three aspects:

1) Behavioral process of synergy for innovative subjects

We assume that the set for elements of one innovative subject isE_i, the function of output is$\pi_i = f_i(E_i)$, and the set for elements of all innovation subjects isE*, $E^* = \bigcup_{i=1}^{n} E_i$; in the state of synergistic innovation, the function of whole output is $\pi_c = \sum_{i=1}^{n} f_i(E^*)$, the set of investment for the individual is E^*, the function of the individual output is $\pi_i^c = f(E^*)$.

2) The Necessary condition for synergistic innovation

The synergistic innovation of technology-based small micro enterprise is the result of self-organization, unlike the government leading science and technology projects. The basic of synergy lies in that the output of it in the synergistic state is greater than the sum of individual innovative output. Thus, the necessary condition for synergistic innovation is $\pi_c \geq \sum \pi_i$.

3) The sufficient condition of synergistic innovation

Since each innovative subject is an independent decision maker, it is necessary to make the output in the synergistic state higher than that of the individual state. Thus, the sufficient condition of synergistic innovation is $\pi_i^c \geq \pi_i$.

Therefore, the model of synergistic innovation for technology-based small micro enterprises is:

$$\max \pi_c = \sum_{i=1}^{n} f_i(E^*)$$
$$s.t. \begin{cases} \pi_c \geq \sum \pi_i \\ \pi_i^c \geq \pi_i \end{cases} \quad (1)$$

IV. Analysis

A. The Equilibrium between Enterprises

We assume that the number of synergistic enterprises is n, the set of elements processed by the individual isE_i. Thus, the set of elements processed by all enterprises is E^*, $E^* = \bigcup_{i=1}^{n} E_i$. In the synergistic state, the set of elements the individual i obtained is$\overline{E_i}$, $\overline{E_i} = E^* - E_i$. In the non-synergistic state, the individual investment of elements is E_i, $E_i = \{e_{ik}\}$, $\mathrm{k} = (1,2,\ldots \mathrm{m})$; the output of innovation is $\pi_i = f(\mathrm{E}_i)$. The

condition of maximizing the innovation output is $\frac{\partial \pi_i}{\partial e_{ik}} = 0$, i= (1,2, ... n), k = (1,2, ... m) for the individual i.

In the synergistic state, the every enterprises investment of elements is E^*, the whole innovative output is $\pi^c = nf(E^*)$, $E^* = \{e_1^*, e_2^*, ... e_n^*\}$. The condition of maximizing the innovation output is $\frac{\partial \pi^c}{\partial e_i^*} = 0$. The output for the individual i is $\pi_i^c = f(E^*)$, the condition of maximizing the innovation output is $\frac{\partial \pi_i^c}{\partial e_i^*} = 0$. In non-synergistic state, the E_i has reached the equilibrium restrained by the condition of $E_i \subseteq E^*$, and only when the sum of the investment and output for the elements is greater than zero, the equilibrium of the synergy can reach, which is restrained by the sufficient condition of $\pi_i^* \geq \pi_i$.

As for $\overline{E_i}$, partial derivative of each element is $\frac{\partial \pi_i^c}{\partial \overline{e_{ik}}}$, the output is $R_k = \int_0^{Q(\overline{e_{ik}})} \frac{\partial \pi_i^c}{\partial \overline{e_{ik}}} d(\overline{e_{ik}})$; the sum of investment and output added the $\overline{E_i}$ is $\Delta \pi_i^c = \sum_{k=1}^m R_k = \sum_{k=1}^m \int_0^{Q(\overline{e_{ik}})} \frac{\partial \pi_i^c}{\partial \overline{e_{ik}}} d(\overline{e_{ik}})$, and the sufficient condition of synergistic innovation is $\Delta \pi_i^c > 0$. Thus, $\pi^c = n\pi_i^c$; if $\Delta \pi_i^c > 0$, the sufficient condition of synergistic innovation is $\pi^c > \sum_{i=1}^n \pi_i$.

Therefore, the necessary and sufficient condition of synergistic innovation between enterprises is:

$$\Delta \pi_i^c = \sum_{k=1}^m \int_0^{Q(\overline{e_{ik}})} \frac{\partial \pi_i^c}{\partial \overline{e_{ik}}} d(\overline{e_{ik}}) > 0 \quad (2)$$

B. The Equilibrium between the Enterprise and Public Organization

This paper takes the synergistic innovation between the enterprise and research institutions as an example. We assume that the set of innovation resources for the enterprise is E_e; the set of innovation resources for the research institution is E_r; the set of all elements is E^* in the synergistic state, thus, $E^* = E_e \cup E_r$.

In the synergistic state, the set of innovative elements getting from the research institution for the enterprise is $\overline{E_e}$, the set of innovative elements getting from the enterprise for the research institution is $\overline{E_r}$, and $\overline{E_e} = E^* - E_e$, $\overline{E_r} = E^* - E_r$.

In the non-synergistic state, as for the enterprise, $\pi_e = f(E_e)$, and the condition of maximizing the innovation output is $\frac{\partial \pi_e}{\partial e_{ei}} = 0$, i = $(1, 2, ... m)$; as for the research institution, $\pi_r =$ g (E_r), and the condition of maximizing the innovation output is $\frac{\partial \pi_r}{\partial e_{ri}} = 0$, i = $(1, 2, ... m)$.

In the synergistic state, the set of innovation elements for the enterprise and the research institution are E^*, the whole output of innovation is $\pi^c = f(E^*) +$ g (E^*) , $E^* = \{e_1^*, e_2^*, ... e_n^*\}$, and the condition of maximizing the synergistic innovation output is $\frac{\partial \pi^c}{\partial e_i^*} = 0$. In addition, if $E_e \subseteq E^*$ and $E_r \subseteq E^*$, the E_e and E_e all reach the equilibrium in the synergistic state. According to the necessary condition of the enterprise and the research institution for the synergistic innovation, the sum of innovative output for both $\overline{E_e}$ and $\overline{E_r}$ must be greater than zero. And the partial derivative of output for $\overline{E_e}$ is $\frac{\partial f}{\partial \overline{e_{ei}}}$, the partial derivative of output for $\overline{E_r}$ is $\frac{\partial g}{\partial \overline{e_{ri}}}$, thus, increment of innovation output after synergistic innovation is:

$$\Delta \pi = \sum_{i=1}^m \int_0^{Q(\overline{e_{ei}})} \frac{\partial f}{\partial \overline{e_{ei}}} d(\overline{e_{ei}}) + \sum_{i=1}^k \int_0^{Q(\overline{e_{ri}})} \frac{\partial g}{\partial \overline{e_{ri}}} d(\overline{e_{ri}}) > 0 \quad (3)$$

Restraining by the sufficient condition of synergistic innovation, the output for the e3nterprise and the research institution must be greater than before.

As for the enterprise, the output of innovation is $\pi_e^c = f(E^*)$ and the condition of maximizing the synergistic innovation output is $\frac{\partial \pi_e^c}{\partial e_i^*} = 0$. The E_e reaches the equilibrium restrained by $E_e \subseteq E^*$. The sun of innovative output must be greater than zero after synergy. We assume that the partial derivative of $\overline{E_e}$ for the output is $\frac{\partial f}{\partial \overline{e_{ei}}}$, thus, the increment of innovative output is:

$$\Delta \pi_e = \sum_{i=1}^m \int_0^{Q(\overline{e_{ei}})} \frac{\partial f}{\partial \overline{e_{ei}}} d(\overline{e_{ei}}) > 0 \quad (4)$$

As for the research institution, the output of innovation is $\pi_r^c = f(E^*)$, and the condition of maximizing the synergistic innovation output is $\frac{\partial \pi_r^c}{\partial e_i^*} = 0$, and the E_r reaches the equilibrium restrained by $E_r \subseteq E^*$. The sum of innovative output must be greater than zero after synergy. We assume that the partial derivative of $\overline{E_r}$ for the output is $\frac{\partial g}{\partial \overline{e_{ri}}}$, thus, the increment of innovative output is:

$$\Delta \pi_r = \sum_{i=1}^k \int_0^{Q(\overline{e_{ri}})} \frac{\partial g}{\partial \overline{e_{ri}}} d(\overline{e_{ri}}) > 0 \quad (5)$$

Therefore, the necessary and sufficient condition of synergistic innovation is:

$$\begin{cases} \Delta \pi = \sum_{i=1}^m \int_0^{Q(\overline{e_{ei}})} \frac{\partial f}{\partial \overline{e_{ei}}} d(\overline{e_{ei}}) + \sum_{i=1}^k \int_0^{Q(\overline{e_{ri}})} \frac{\partial g}{\partial \overline{e_{ri}}} d(\overline{e_{ri}}) > 0 \\ \Delta \pi_e = \sum_{i=1}^m \int_0^{Q(\overline{e_{ei}})} \frac{\partial f}{\partial \overline{e_{ei}}} d(\overline{e_{ei}}) > 0 \\ \Delta \pi_r = \sum_{i=1}^k \int_0^{Q(\overline{e_{ri}})} \frac{\partial g}{\partial \overline{e_{ri}}} d(\overline{e_{ri}}) > 0 \end{cases}$$

V. RESULTS

The essence of synergistic innovation is to inject new elements of innovation for enterprises, and the innovative output of elements is the root cause of synergistic innovation performance, which is known from the analysis of the previous chapter. And the formation of synergistic innovation is the combination of reasonable collectivity and reasonable individual, which has following two characteristics.

The greater difference between the synergistic subjects, the higher the performance of synergistic innovation will be.

According to (2) and (3), the promotion of innovation performance between enterprises or between the enterprise and public organization result from the new innovative element injected. Thus, the more elements including, the higher performance there being. Furthermore, the more elements including, the greater the difference between synergistic subjects.

The maintaining of synergistic innovation between technology-based small micro enterprises bases on the game of multiple participants. Since technology-based small micro enterprises are the independent decision makers, there is not a leader for the governance structure of synergistic innovation. And if $\pi_i^c \leq \pi_i$, the synergy will not be maintained.

VI. CONCLUSIONS

The core of synergistic innovation for technology-based small micro enterprises is promoting the voluntary cooperation between enterprises or between enterprises and non-enterprise subjects. Thus, this paper provides the following proposals.

Strengthening the construction of technology parks and incubators. According to (2), it better to make the increment of output to be greater than zero by establishing the cooperation. While the effect of agglomeration from technology parks and incubators on the geographic space eliminates information barriers, reduces transaction costs and minimizes likelihood of elements' output in negative. Therefore, the first assignment of optimization is enhancing the function of agglomeration.

Building public technology and service platform. The output of advanced scientific research equipment, which is rare innovative element for enterprises, is relatively high. While the public technology platforms transfer the cost of elements to the government pay so that the benefits retain in enterprises. Thus, it is vital to establish the open public technology platform, especially the information service platform of technology and trading platform of technical achievements to share scientific and technological resources.

Establishing coordination mechanism of multiple subjects. According to (4) and (5), the necessary condition for the synergy of multiple subjects is increment of innovative output. Hence, it necessary for the department of decision-making to set up an effective coordination mechanism of the interests, especially the distribution mechanism of the interests to ensure all participants benefit from synergistic innovation.

Enhancing the guidance of policy and encouraging the financial institutions or business organizations to provide service support. With the strength of capital and management, the innovative output of financial institutions or business organizations is relatively high. Consequently, it is critical for the department of decision-making to encourage the financial institutions or business organizations to explore the new pattern of supporting the development of technology-based small micro enterprises as well as reduce the risks by economic or non-economic leverage.

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