

Research on the Factors Affecting Synergy of Enterprise Innovation Network Based on ISM

Wei Yunfeng, Ruan Pingnan

Beijing University of Technology, School of economics and management, Beijing - China

Abstract--The synergy of enterprise innovation network will not only improve the performance of innovation, but also improve the stability of network organization. So it is very important to study the influencing factors of synergy for enterprise innovation network. Paper summarized 11 influencing factors of innovation synergy from 4 dimensions based on the literature review. All 11 influencing factors are divided into 4 levels by the interpretation structure model, and the path of synergy influence factors is: the external environment of the enterprise innovation network -- individual level factors -- the internal environment of the enterprise innovation network -- the relationship between nodes-- synergy. In all of the influencing factors, government is the core factors which affect the innovation synergy through the impact of market regulation and policy system on resource allocation and collaborative innovation policy support.

I. INTRODUCTION

Enterprises in order to overcome the limitations of its own innovation ability and the innovation resource scarcity, actively seeking partners to form the network organization, we call it the enterprise innovation network. Enterprise innovation network organization form can improve the utilization rate of innovation resources in the process of innovation, reduce the cost of innovation, share innovation risks with partners, and improve the process of innovation speed, but all these advantages are the prerequisite for the realization of the coordination. Due to individual enterprises are difficult to achieve all the resources which needed for the innovation and cooperation network has the characteristics of increasing marginal returns, so the enterprise innovation network has become a new mode of innovation has attracted much attention, and scholars research more and more deeply on it [22]. However, there are some problems in the innovation network, which are difficult to identify the cooperative nodes; the internal shared resources are not balanced between the innovative nodes in the initial stage of the innovation network, which leads to the value of the innovation resources cannot be used to the maximum; "free rider" phenomenon; the efficiency of innovation network is low; the development of instability and so on. The key to solve these problems is how to form a highly collaborative pattern of cooperation and identify the factors which affect the synergy. German physicist Haken first systematically proposed the synergy theory, according to the theory, "synergy is a complex system which contains many subsystems, and the cooperative behavior of each subsystem will produce the interaction of each subsystem separately"[7]. Ansoff, a strategic management scientist in the United States, has also stressed in his book "corporate strategy": "System consisting of two

or more individuals, if the individual and the individual can effectively achieve the sharing of resources, cooperation, can greatly improve the overall performance of the system."^[1] However, in the practical application of the field of management, the theory of synergy has not achieved the expected success. The failure cases in real life have no effect to use the "synergy" widely. As porter said "the main reason for the failure of synergy is that the company did not really understand it or not to implement it correctly, rather than the concept of 'synergy' " ^[3]. Similarly, the synergy of enterprise innovation network failed to achieve success, mainly due to the managers did not really understand, "what is synergy?" "What are the factors that affect the synergy of innovation?" "Enterprise innovation network should be how to achieve synergy?" This paper will solve the above questions. Research on the influencing factors of synergy can help us to build enterprise innovation network, to make better cooperation among the various subsystems and improve the innovation performance.

II. CONTRIBUTIONS

In theory, using ISM to analyze the problem, it can enrich the theoretical content of enterprise innovation network synergy factors. In practice, find out the influence factors of the cooperative can provide help for the management of enterprise innovation network, improve innovation performance.

III. ENTERPRISE INNOVATION NETWORK

Scholars have different understanding of the Enterprise Innovation Network. Freeman is the first one to put forward the definition of innovation network, he defined innovation networks as follows (Freeman, 1991): "Network organization is a basic institutional arrangement to cope with systemic innovation. Networks can be viewed as an interpenetrated form of market and organization. Empirically they are loosely coupled organizations having a core with both weak and strong ties among constituent members... We emphasize the importance of cooperative relationships among firms as a key linkage mechanism of network configurations. They include joint ventures, licensing arrangements, management contracts, sub-contracting, production sharing and R&D collaboration." Reference [8] and [11] define the innovation network from the point of view of knowledge and learning. The former thinks that the innovation network integrated the formal and informal relationship between the organization and the organization. Later scholars defined the innovation network

as an integrated system, which has the following characteristics: relatively loose, informal, interrelated and so on. Cui Yonghua, Wang Dongjie [5] just put forward the main body of collaborative innovation network. Tang Liyan [15] believes that synergy innovation network of small and medium sized enterprise is equivalent to collaborative innovation network. It refers to an open innovation network with the formation of synergy about advantages of agglomeration, knowledge spillover and technology transfer, between small and medium sized enterprise and other innovative subjects based on long-term stable interaction and cooperation. Other scholars defined from the point of view of the innovation process, emphasize the heterogeneity of innovation network, collaboration, and dynamic and benefit sharing.

Based on the reference to the existing literature, we defined the enterprise innovation network as: the enterprise in order to achieve the purpose of innovation to seek cooperation partners, such as: other enterprises, government agencies, schools, scientific research institutions, intermediaries etc., sharing of innovation resources, innovation risk sharing cooperation network is formed by connecting the contractual relationship of interaction. Enterprise innovation network should emphasize the following points: (1) Innovation is the main purpose of the enterprise innovation network, and the emphasis among nodes in the network is the interaction and cooperation of different innovation resources. (2) Enterprise is the main sponsor and the implementation of innovation behavior. (3) Enterprise is the core of the network, is also the most important economic individual and innovative achievements to the implementation. (4) Nodes only need to be relation connected, there is no geographical restrictions. The general enterprise innovation network structure is shown in Fig. 1.

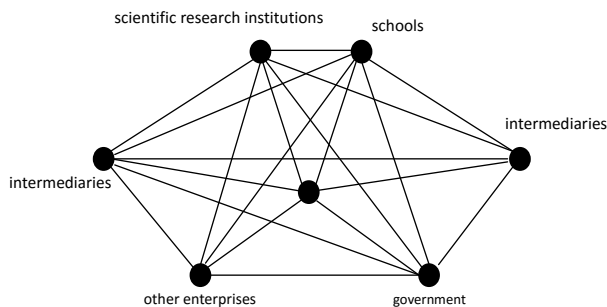


Fig. 1 The structure of enterprise innovation network

IV. SYNERGY

Synergy is the basic concept of the Coordination Theory, and the result is the synergy effect. Synergy effect is the interaction and coordination among subsystems in the system, which brings together the effect of the whole system, and the overall effect is greater than the sum of the benefits created by the subsystem separately.

Bai Junhong, Chen Yu and Li Jing[2] viewed synergy as a

response mechanism, that is, Within the system of each subsystem to innovation as the center, collaborative response to promote innovation and emergence mechanism, and this mechanism is required for the formation of under the nonlinear interaction of various subsystems. Within the system, forming an atmosphere of encouraging innovation, innovation occurs in a conscious state, in which people think of innovation as a conscious act. Xu Qingrui, Zhu Ling and Wang Fangrui[21] think synergy is the basis of the participation of elements in their respective functions, to enhance their efficiency, through the qualitative change of the efficiency of the mechanism interaction, the synergy effect includes two parts, including value added and value creation. Synergy in enterprise innovation network to the capability of two or more firms to work effectively together, planning and executing innovation network toward common goals [6].

Most of the existing researches adopt the concept of "integration", which reflects the process of the integration of the subsystems through communication and cooperation in the process of innovation. Integration is closely related to the concept of Synergy, but there are still many differences between the two concepts. "Integration" emphasizes the consistency and integration of each subsystem, it pay more attention to the process. "Synergy" is more emphasis on the complex interactions between the subsystems, resulting in a single factor or the main body cannot achieve the overall effect, that is, the synergy effect, the emphasis is on the results. Therefore, "Synergy" namely the synergistic effect, emphasizes the result, it can achieve the whole effect through complex interactions between the various subsystems which the individual cannot be achieved, performance in the interaction strength of the relationships among the subsystems, and the degree of closeness and order between the various innovative elements.

V. ANALYSIS OF INFLUENCE FACTORS OF SYNERGY

Enterprise innovation network is involved in a large number of nodes, and the relationship between nodes is complex. As an open system, the enterprise innovation network is constantly interacting with the external environment, therefore, it has a great influence on the synergy [13].

Paper uses the scale development method, through the literature research, interviews and expert group to discuss dimension of the factors influencing the synergy for enterprise innovation network and the corresponding entry of the Table 1. Based on the research results of many scholars, this paper designs an interview outline for the synergy factors of enterprise innovation network, after discussion with the expert group including 5 experts. We interviewed 19 senior managements, they come from 8 companies which in the technical innovation networks, the interview time for each manager is about 1.5 hours. The existing research results on enterprise innovation network collaborative factors are research foundation of paper, we integrated the opinion of

expert group and the understanding of managements about the synergy of the enterprise innovation network, and divided the factors affect synergy of enterprise innovation network into 4 dimensions: “Individual”, “Relationship between nodes”, “Internal environment of network” and “External environment of network”. Wang Shanshan, Li Yue, Wang Hongqi and Li Li [19] believe that the willingness to cooperate and their Self-ability are the main individual factors affecting the synergy of alliance. Ceng Wenjie's[4] research shows that cooperative relationship is the most important factor to affect the coordination, he had set up 4 sub factors in the dimensions of partnership: trust, communication, promise and cooperation. Xie Xuemei[20] thinks that the factors of internal environment of network such as collaborative culture, benefit distribution, evaluation and motivation are also affect the synergy. Ma Juan, Chen Antao[10] pointed out that the External environment of network mainly include market environment and policy support. So we set 11 influence factors in the 4 gradations on Table 1.

VI. METHODS

ISM

Interpretative structural model (ISM) is a qualitative analysis method, which was proposed by Professor Warfield J. of the United States in 1973 to analyze the complex social economic system. The basic idea of the model is to extract the components of the problem, using computer technology to deal with the relationship between the various elements with directed graph, matrix and other tools [16]. The model can change the system which the structure is not clear to an intuitive and multilevel hierarchical structure, and explain the model with the text, to clarify and improve the level of awareness and understanding of the problem. The enterprise innovation network is a complex system composed of a large number of nodes, having lots of influence factors of synergy. The influence factors are related to each other, and the relationship between them is hierarchical. The focus of this paper is to clarify the hierarchy between those factors. Therefore, the research content of this paper is consistent with the basic idea of the structure model. So we think that the ISM and this paper has a very good compatibility.

TABLE 1 FACTORS INFLUENCING THE SYNERGY OF ENTERPRISE INNOVATION NETWORK

Gradations	Influence Factors	Description of Factors	Source
Individual	Collaborative innovation intention	Cooperation is the combination of individual behavior and the behavior of others, only a single individual is willing to cooperate with each other, each member's behavior can be effectively combined.	Wang shanshan, Li yue, Wang hongqi [19]
	Self-ability	Only cooperative parties have the ability of innovation and innovation resources, innovation synergy between enterprises can produce.	
Relationship between nodes	Trust	Only individuals who trust each other will be willing to share their creative resources with each other.	Ceng wenjie[4]
	Communication	Communication between individuals can promote the collaborative development of enterprise innovation network, reduce mutual distrust and mutual suspicion.The degree of communication reflects the ability and willingness of individuals to share innovation resources.	
	Promise	Commitment represents a sense of identity, only a high degree of recognition of the heart, companies will be willing to foster or maintain a collaborative relationship with other companies.	
	Cooperation	Cooperation refers to the common work of many individual organizations to achieve a common goal.	
Internal environment of network	Collaborative culture	Achieving real synergy needs to achieve a "win-win" consciousness, to form a cultural atmosphere to encourage collaboration.	Li qianbing[9]
	Benefit distribution	The stability of the cooperation relation needs to be fair and reasonable.	
	Evaluation and motivation	Link the goals and processes to the process."Process" to replace the "results" will achieve better results	
External environment of network	Market environment	Fierce market competition and technology to accelerate the update to promote enterprises to seek cooperation partners	Ma juan, chen antao [10]
	Policy support	Collaborative innovation needs the policy support and guarantee of the national strategic development policy.	Wang Yumei, Luo gongli [18]

Construction Of Model

(1) Generate adjacency matrix. All the data in the ISM model are scored by experts according to the relationship between the influencing factors. We define the elements

$$A=(a_{ij}) \text{ in } A: a_{ij} = \begin{cases} 0 & S_i \text{ has no direct effect on } S_j \\ 1 & S_i \text{ has a direct effect on } S_j \end{cases} \text{ Expert}$$

group determine the relationship between the 11 factors, according to the correlation of elements to establish adjacency matrix A. Then we get the adjacency matrix A as the shown below:

$$A = \begin{matrix} & \begin{matrix} 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 & 10 & 11 \end{matrix} \\ \begin{matrix} 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \\ 8 \\ 9 \\ 10 \\ 11 \end{matrix} & \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \end{bmatrix} \end{matrix}$$

(2) The reachable matrix. Adjacency matrix A and the unit matrix I with the same order we get (A+I). Then calculate the (A+I) according to the Boolean rule (0+0=0, 0+1=1, 1+0=1, 1+1=1, 0*0=0, 0*1=0, 1*1=1) by using software of Matlab2010 until $M=(A+I)^{n+1}=(A+I)^n+(A+I)^{n-1}$. We get the reachable matrix $M=(A+I)^4$, the reachable matrix M is shown below:

$$M = \begin{matrix} & \begin{matrix} 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 & 10 & 11 \end{matrix} \\ \begin{matrix} 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \\ 8 \\ 9 \\ 10 \\ 11 \end{matrix} & \begin{bmatrix} 1 & 0 & 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 & 1 & 1 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 1 & 1 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 1 & 1 & 0 & 0 & 1 & 0 & 0 \\ 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 & 1 & 0 \\ 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 & 1 \end{bmatrix} \end{matrix}$$

Decomposition reachable matrix. According to the reachable matrix, the reachable sets $R(S_i)$ and antecedent set $A(S_i)$ of the elements can be obtained. Then compute $R(S_i) \cap A(S_i)$ like the flowing Table 2.

Then according to (1), We decompose the reachable matrix into hierarchies.

$$L_i = \{S_i | R(S_i) \cap A(S_i) = R(S_i), i = 1, 2, \dots, n \} \quad (1)$$

The elements in L_1 are the first tier of the hierarchy of the interpretative structure model, then we get rid of the elements in L_1 from reachable set, and continue to implement the formula (1) again and again, until the division is completed.

According to the results of the level division and the relationship between the factors of synergy for the enterprise innovation network, then we get the ISM model, as shown in figure 1.

TABLE 2 REACHABLE SET, ANTECEDENT SET AND INTERSECTION

i	R(S _i)	A(S _i)	R(S _i)∩A(S _i)
1	1,7	1,10,11	1
2	2,8	2,10	2
3	3	3,7,8,9	3
4	4	4,7,8,9	4
5	5	5,7,8,9	5
6	6	6,7,8,9	6
7	3,4,5,6,7	1,7	7
8	3,4,5,6,8	2,8	8
9	3,4,5,6,9	9,11	9
10	1,2,10	10	10
11	1,2,9,11	11	11

VII. ANALYSIS

(1) On the first floor are the external environmental factors, including the market environment and policy support, they are the dynamic factors of the formation of innovation synergy. The more intense the competition in the market environment, the more it can bring the sense of urgency to the enterprise, the enterprise must strive to improve its ability, otherwise it can only be eliminated by opponents who is better than it faced the fierce competition. Enterprises needs to innovate if it wants to win in the competition, because they do not have enough resources and innovation ability, so , enterprises seeks cooperation partners to carry out collaborative innovation, thus promoting the formation of enterprise innovation network. Policy support plays an important role in encouraging and supporting the collaborative innovation process of enterprise innovation networks. It is affects the intention of collaborative innovation and Individual capability of nodes through it affects the allocation of resources between the nodes. In addition, the evaluation and incentive system of enterprise innovation network will also be affected by its response.

(2) The second layer is the individual level factors, including: individual ability, willingness to collaborative innovation, they are the root causes of synergy. The formation of collaboration requires the participation of each node in the network, and the premise is sharing the innovation resources. Therefore, the level of node capacity and collaborative innovation will be the prerequisite and foundation for the innovation of enterprise innovation network. As the paper mentioned above, in the innovation networks of innovation resources are shared, individual cooperative innovation will influence the innovation resources sharing degree and influence innovation network collaborative innovation culture formation. Node's individual ability also directly affects the position of nodes in the innovation network and the allocation of power and responsibility.

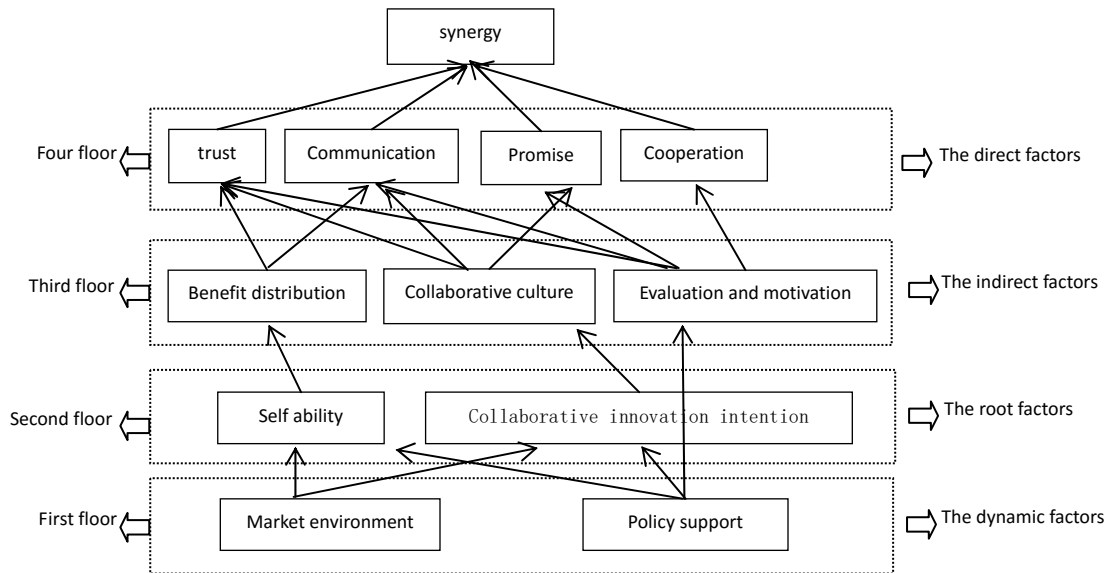


Figure 1 The ISM of the influencing factors of synergy for enterprise innovation network

(3) The third layer is the environmental factors in the network, including: the right and responsibility distribution, collaborative innovation culture, evaluation and incentive, they are indirect factors for the formation of innovation synergy. The internal environment of innovation network is influenced by the "psychological security" and "fairness" of individual nodes. Fair distribution of responsibilities and benefits, good culture atmosphere of innovation and collaborative, reasonable evaluation and incentive are direct impact on the network nodes' feeling "psychological security" and "fairness". Only when the network node feels "fair" and "safe", it can reduce the contradiction and conflict between the nodes, so that the nodes can communicate and cooperate well with other nodes.

(4) The fourth layer is the relationship between nodes, including: trust, communication, commitment, cooperation, they are the direct factors of the formation of innovation synergy. Synergy formation is the frequent interaction among nodes in the innovation process through innovation network, and the trust, communication, commitment and cooperation directly affect the formation of innovation synergy. The unobstructed communication can break the mutual suspicion and mistrust, the trust between the nodes can promote innovation resources sharing degree, the commitment of the node can improve the recognition of the cooperation relationship with other nodes, and the cooperation between the nodes directly affects the development of the innovation work, so that it can achieve the goal of innovation.

From the perspective of vertical, the path of how influence factors affect synergy is that as the follows: the external environment of enterprise innovation network -- individual level factors -- the internal environment of enterprise innovation network -- the relationship between nodes-- synergy. The government plays a key role in all the influencing factors, which affect the innovation synergy through the impact of market regulation and policy system on

enterprise innovation network in the market environment and government policy support, through the impact of the allocation of resources properties of various influential factors in the above three levels of influence. Market environment and policy support impact on the above 3 levels of the factors through affect the allocation of resources. The influencing factors of the above three levels is controllable factors in the enterprise innovation network, The second layer, individual factors (individual and collaborative innovation intention) will have an impact on the factors of front two layers, and ultimately affect the formation of the overall synergy. Therefore, the individual level factor is not the most direct, but it is the most important influencing factor in the enterprise innovation network.

VIII. CONCLUSION (CONCLUSION AND MANAGEMENT ADVICE)

The characteristics of multi agent and heterogeneity of enterprise innovation network nodes determine that the formation of innovation synergy effect will be affected by many factors. We need to clarify the logical level between the impact factors to reduce barriers of synergy and achieve the development of collaborative innovation network. Paper sorts out 11 main factors that affect synergy based on the theory of innovation network, and according to the theory of ISM we construct the model of enterprise innovation network innovation synergy influence factors, and get the path of innovation synergy influence factors is: the external environment of the enterprise innovation network -- individual level factors -- the internal environment of the enterprise innovation network -- the relationship between nodes-- synergy. The government plays a key role in all the influencing factors, which affect the innovation synergy through the impact of market regulation and policy system on

resource allocation and collaborative innovation policy support. According to the research, under the current background of the times and the development of China's economic situation, the government led, including the market environment and the policy system of the enterprise innovation network synergy has played a key role. It is mainly through the formulation of policy system, market regulation and innovation resources of resource allocation to promote the enterprise innovation network formation, and realize the in a fair environment, collaborative culture atmosphere, good relationships of nodes in the complete target innovation. Therefore, some important measures to promote the synergy of enterprise innovation networks are: to strengthen the government's leading role, improve the ability of the government to formulate scientific policy system, the implementation of a reasonable allocation of resources.

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