



A Research on Cooperative Innovation System of Chinese Enterprises Based on Complex System Theory

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Abstract: According to the new optimal game analysis on the innovation ability of Chinese enterprises, the best strategy to compete and cooperate in the game is cooperative innovation, which can attribute the advantage resources among to different parts in the cooperative innovation system, and increase the innovation ability of the enterprises and further improve the whole industry. In the research, a pattern of cooperative innovation system is built for any enterprise as an innovation subject, and the structure and function of the system is revealed from three levels as micro-scope, mid-scope and macro-scope, in doing which, the basic conditions for a healthy development of a cooperative innovation system is discussed. Then basic standards to measuring the state of a cooperative innovation system are established by quantization of the knowledge management entropy and dissipative structure negative entropy. Finally, a possible road is pointed out for the orderly development of the cooperative innovation system in the relation to the environment.

Keywords: cooperative innovation system, complex system theory, dissipation structure, model, knowledge management entropy

1 Induction

Innovation has become the most important energy for any modern enterprises to survive and succeed with the increasing competition in the world market due to the high speed of science and technology development. And as a consequence, cooperative innovation has been the best choice for Chinese enterprises in nowadays^{[1][2][3]}, since it can reduce the risk and cost of the self innovation as well as the hitchhikes of other enterprises, integrate the advantage resources for innovation, and increase the innovation ability and the succeeding rate of innovation for an enterprise. Then it is efficient for enterprises to be more competitive and profitable when they cut a larger share of the market^[4] with an increased science and technology products addition. And the whole industry is to be greatly benefited and improved finally. In this condition, the traditional theory has lost their efficiency to predict the tendency of cooperative innovation system, which holds modern enterprises as innovation subjects; therefore, the innovation theory is developed to the

theory of innovation system and network, the center idea of which is the “system pattern” focusing on innovation^[5]. It is an urgent and meaningful task to research the working and rules of cooperative innovation system under the direction of complex system theory and to build a high efficient cooperative innovation system, which is also an important front-running subject for Chinese government, academic world and business groups.

2 Method

The complex system theory is at the frontier of system science^[6], and is viewed as the science of 21st century. It aims at the method to scientifically explain how a complex system works, and is leading to a new revolution in methodology research of system science^[7].

Ilya Prigogine established the theory of dissipation structure in 1967, which greatly influenced both the science of nature and that of society. It points out that an unbalanced open system, which exchanges material, energy and information with the environment, may be self organized when the units in it are nonlinearly interacting in complexity. This new stable orderly structure or self organized structure is named as dissipation structure, and the theory is called theory of self organization in unbalanced system^[8].

Four conditions are required to build a dissipation structure according to its nature^[9].

The first necessary condition is an open system, for it absorbs energy and materials from the environment to form a negative entropy flow and to resist the entropy, when a close one does not. The entropy is usually created in a system when the energy and materials automatically flows from the region of high density to that of low density until a balance is achieved. During the process the system becomes disordered and balanced.

Another condition is being far away from balance, which means an order when the materials and energy in different region are in a great difference. The condition ensures that the negative entropy flow can create a structure of new order when a balanced system barricades the work.

The third condition is the nonlinearity among different factors in the system. It is the inner reason of

dissipation. Nonlinearity refers to a net form interaction among different factors. The order of dissipation only appears when all the factors and related and influencing to any other one. Then the system will be self organized, and new character will appear. Without the nonlinearity, negative entropy alone does not create dissipation.

The fourth and last condition is fluctuation in chance, which commonly exists in all systems. Fluctuation is the deviation from balance and leads the system from disorder to order. In a balance state, fluctuation is a negative factor to lead a chaos, but in a state far away from balance, a tiny fluctuation in chance will be enlarged rapidly and positively induce a new order. It is a direct reason of dissipation.

The cooperative innovation system is a complex non-linear open system, which is away from the equilibrium, with the fluctuation factors and fulfills the basic condition of dissipative structures^[8]. It is also self-organized like all misbalanced systems^[9].

A cooperative innovation system is above all an open system. There are exchanges of materials, energy and information between the inner system and the outer environment, and the system is competitive and cooperative with other unit in all the aspects like economy, resources, and environment through the market.

And then, the subsystems in the cooperative innovation system are not developed in balance. There are differences among the subsystems in social position, resources obtaining, labour quality, information approaching, technique acquiring, innovation culture and assemble scale and level, etc. In addition, the cooperative innovation systems in the industrial link are not in balance either. As a result, the cooperative system is away from balance in the whole, and in the supercritical state^[10], the innovation policies, the adjustment of industrial structure, the function position fixing of innovation and the strategy of innovation development can all be viewed as fluctuation phenomenon in the orderly coordinating development process of the system.

Eventually, the running of cooperative innovation systems is essentially a process from chaos to order, which is a character of complex systems^[11]. It has many influential factors, levels as well as flexibility. Firstly, the cooperative innovation process is the one that all kinds of factors work and phase transit together nonlinearly. Factors such as subjects, techniques, organizing structure and knowledge are in a frame of innovation purpose, so the running mode and condition directly determines the working of all factors. Secondly, the cooperative innovation system involves different fields, trades, branches of learning and professions. The system can be divided in four levels of science innovation, technique innovation, technical practice and technical theory, which shows a steady working mode of ht system, that is, a steady periodical solution including chaos and repeated structure. It shows distinguished levels and changes in different stages, which suggests an order of organized factors in the system. Thirdly, cooperative innovation

systems are unsteady, nonlinear and emerging, and of Chaos elongation and folding, since both the process and the result of the innovation are unpredictable. The complex nonlinear cooperation innovation system is from chaos to order, so it relies on the initial condition strictly.

To control the complex nonlinearity, entirety thinking and an entirety mode are necessary. The aim is to establish a scientific thinking method to avoid the disadvantages and achieve better ones by working on the tiny changes.

3 A possible cooperative innovation system model and the relative analysis

3.1 A theoretical model

A cooperative innovation system refers to a financial cooperation system established by enterprises sometimes with other units or individuals like a university or institute in order to achieve the biggest profit with the development of innovation resources and ability. The cooperation includes two forms as long term cooperation and short tem cooperation, both of which take contracts as binds to confirm the responsibilities and profit assignments of each participant, and take technical cooperation as a basis to strengthen their innovation ability and to share their advantaged resources. The premise of a successful cooperation is that each participant must be complementary to others, and the credit and reputation can also serve as a capital.

The thesis establishes a cooperative system model from three levels as micro-scope, mid-scope and macro-scope, which have a difference in the innovation ability. The basic unity in this model is innovative system of enterprises. According to their innovation projects and strategy, they link up to be cooperative innovation systems in the same trade, systems in the industrial line and that among the industrial groups. Above all these systems, an innovation system for the state high-tech direction is formed to guide the high-tech development. The relationships are like the following demonstration, such as Fig.1.

The demonstration also illustrates the structure function of each system in different levels. There are scholars questioning the state innovation system^[12], but we believe that the research achievements from the state innovation system represent the highest technical level in our country, which suggests an influence of no substitution. In China, the government can easily gather a large research team to solve some tough difficulties in technology, which is especially important in some important basic theory research fields and some important projects, where no other systems in the sublevels can work effectively.

In the mid-level, the system relies on the game options made by enterprises. Cooperative strategy alliances can effectively avoid the risks and costs of innovation when enterprises share their information and resources to form advanced innovation ability, assembled

innovation strength and dimension profits.

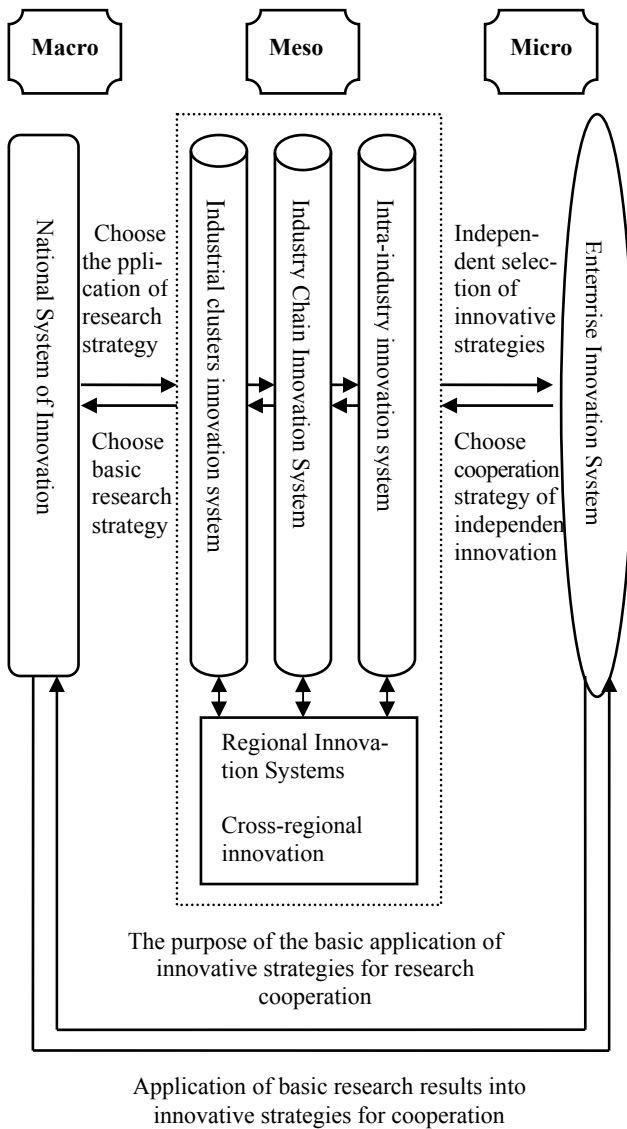


Fig.1 Three levels of the cooperative innovation system and the function model

Innovation systems within enterprises are researchers and investors of the practical tech research and the transitional practitioners. They are subjects of the self innovation of enterprises.

A model is established for the cooperative innovation complex system with enterprises as the subject, such as Fig.2.

Fig.2 is a complex cooperative innovation complex system, which includes systems inside directly joining cooperative innovation: systems in a same trade, in an industry line and industry groups, the auxiliary social systems for the cooperative innovation in the middle, which provide full and essential conditions supporting the positive running of the cooperative innovation system, and the social environment outside, which limits and influences the cooperative innovation process indirectly.

The inner system realizes cooperation from simplicity to complexity, and suggests the developing tendency of cooperative innovation. At present, the development of modern tech is based mainly on that of the nature science and its applying. The researches focusing on science applying, like Pasteur Quadrant category, have appeared in a great deal of fields especially in the frontiers of high tech^[13], and it has been an important tendency of science development^[14].

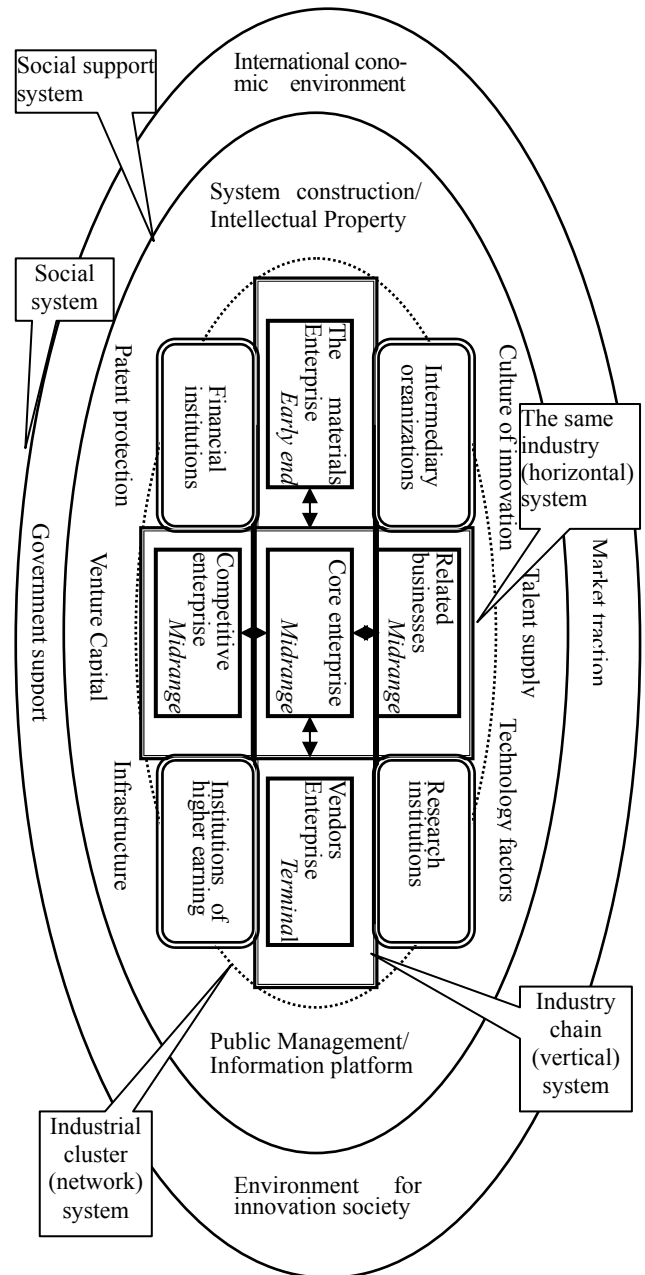


Fig.2 Model for the cooperative innovation complex system with enterprises as subjects

To sum up, the research achievements of the state innovation system, especially those of basic researches, is gradually absorbed into a larger cooperative innovation system, which organizes the innovation

systems of enterprises, the region innovation systems, the cross region innovation systems, and then the state innovation system from different levels into a whole. It is not only an expansion of quality but also an increasing of quantity, since the efficiency of innovation are largely promoted.

3.2 The basic quantity standard for Cooperative Innovation Systems

In order to manage sub systems and factors in a cooperative innovation system scientifically, the knowledge management entropy is introduced into the analysis of cooperative innovation systems^[15]. The calculation formula for the knowledge management entropy of item i is:

$$dS = \sum K_i dS_i \quad (1)$$

In the formula, i is all kinds of factors that influence the entropy of a cooperative innovation system, such as scale of enterprises, investment of R&D, knowledge storage, quality of work team, innovation ability of the team, level of experiment equipments, innovation culture, institution, organizing structure, and ability of learning, of information acquiring and of communication. K_i is the weight of each factor. And S_i is the entropy of each factor, which is calculated by the following formula:

$$S_i = K_a \sum_{i=1}^m P_i \ln P_i \quad (2)$$

K_a in the formula is a coefficient of knowledge management entropy, i is each influencing factor to the entropy in sub systems, and P_i is the probability of the influence of each factor to the entropy. $\sum P_i = 1$. And S_i is the entropy of each influencing factor.

In the exchange of materials and information between the system and the environment, there are negative entropies created by some factors, and the formula is like the following:

$$S_j = -K_\beta \sum_{j=1}^n P_j \ln P_j \quad (3)$$

In the formula, j represents factors that create negative entropies, such as talented persons, smooth running market, sufficient capital support, a well worked public information system, advanced equipment, and supporting policy etc.. K_β means the weight of each influencing factor that creating negative entropies, and P_j refers to the probability of the influence of each factor to the negative entropy, and $\sum P_j = 1$. S_j is the negative entropy of each influencing factor. Through the analysis to the entropies, the total entropy of the system should be:

$$S = S_i + S_j = K_a \sum_{i=1}^m P_i \ln P_i - K_\beta \sum_{j=1}^n P_j \ln P_j \quad (4)$$

When $|S_i| > |S_j|$, and $S > 0$, the cooperation system is disordered, which means the system is not well self organized, and the disorder parameter is strengthened. In this situation, the subsystems do not meet others well and

the entropy dominates. On the contrary, when $|S_i| < |S_j|$, and $S < 0$, the cooperation system is ordered, which shows the system exchanges material and information efficiently enough with the environment and accepts enough negative entropy to reduce the chaos, and the dissipative structure dominates the system.

There is a nonlinear feedback mechanism between the cooperation system and the environment and also between the knowledge-management entropy and the dissipative structure in the system^[16]. Therefore, the factors inside and the interaction among them, along with environment factors, determine the direction of the system. All the factors are important. But to be noted, the exchange of materials and information between the system and the environment does not necessarily mean negative entropy. If the environment support is not efficient to create negative entropy, it may lead to a total disaster for the cooperation system.

3.3 Possible paths of orderly development for the system

The cooperative innovation system is influenced by the environment either directly or indirectly. Different organizations in a cooperative innovation system work together in interaction and are limited and supported by all kinds of variables in the environment. It is a process of relying, conforming, adjustment, assimilation and cooperation. According to the above, the order of cooperation systems relies on the smooth feedback mechanism between the system and the environment, and the first and the most important thing to do is to find paths through which the environment negative entropy is introduced into the system.

Path 1: to establish a public technology information platform. The storage of technology and the speed of knowledge transformation has been a basic determining technical factor for the establishment of cooperation system. They are very important to affect the cooperation direction and profit. So it is necessary to establish a public technology information platform in order that institutions and guilds can serve the cooperation system as bridges of communication between the system and the outer world.

Path 2: to build a healthy competing market. There is a relation of U style function between the market concentration and the innovation intensity^{[17][18]}, which means the best time for innovation is when the competing market is in middle monopolized concentration. Enterprises will initiatively choose their innovation strategy under the pressure of competition.

Path 3: to design a set of supporting tech and financial policies and promote the related legal system. For instance, intellectual property right is actually a financial monopoly right, which will barricade the resources from optimization, and the technique from spreading, but it will urge the competition, encourage the innovation investment and speed the industrialization of new technology. When the government is failed to protect the intellectual property right, most enterprises

will hitchhike, which will restrain the innovative motivation of enterprises. At present, there are not special legal items and systematic policies on cooperative innovation in China; and the present laws and policies are too generous and too theoretical^[19], which will form entropies for the innovation system and barricade the orderly development of the system. To support the innovation system, policies must be taken to encourage the researchers to participate in cooperative innovation, such as to reduce their income taxes in the related activities.

Path 4: to build a tolerant, encouraging and intelligence respective culture environment with the awareness of intellectual sharing and cooperating^[20]. There are abundant culture resources in China, which grow deeply in the behavior and belief of every Chinese people as culture genes. We need to deconstruct and select the traditional culture, and absorb the reasonable and scientific ideas in western culture, as well as their pioneering spirit, to form an influential soft power.

The paths above are to form the negative entropies to realize an orderly development of the system through adjusting the environmental factors, and the key to achieve these is the effort of the government. The function of government is not substitutive in leading research direction, building related equipment and environment, providing a platform, and controlling and regulating the intellectual market, setting basic principles and laws to protect a well running order.

The government can invest the basic research directly to guild the direction of innovation, fund the some fundamental facilities and set up related organizations to support the innovation system. At the mean time, the government can also provide a cyber platform for public technology information service. In macro management, the government can take part in the management, organization and coordination of the cooperative innovation, and regulate the intellectual market by supervising and constricting to avoid repeated work and malicious competition, and thus ensure a steady orderly and efficient cooperative innovation. In policy, the government can make favorable policies to support and encourage cooperative innovation, and set up basic principles of intellectual ownership and profit assignment to reduce the trade cost and internal consumption of energy. There are more than these that the government can provide, such as laws to restrict and regulate the behavior of cooperative innovation in force and the culture environment to respect the intellectual right in mind.

4 Conclusion

As a commercial cooperation system, the innovative cooperation system is an open unbalanced and nonlinear dissipation structured complex system, which needs to exchange material energy and information with the outer environment. There are two methods to turn the system from disorder to order. One of them is to conquer the

inner entropies by choosing different form of cooperation according to the cooperative innovation target. The principle of it should be to minimize the cost and risk and to maximize the innovative profit. Therefore, long term of cooperation is not appreciable, since the knowledge structures of subsystems in it are likely to be similar with the time lasts, and the complementary is decreasing while the probability of entropies is increasing. The scientific management based on a research of regulations in cooperative innovation will effectively restrain the speed of inner entropies. Another method is to ensure a positive exchange and communication between the system and the outer world in intelligence, energy material and information, which induce negative entropies into the system. To achieve this, research on the outer environment and its working mechanism is necessary to create the negative entropy as large as possible. And the government has a great deal to do in the process. It may serve as a law maker, culture builder, public facility provider, basic research investor, and market competition supervisor, and coordinator of cooperative innovation system. In short, all the work needed is to increase negative entropies from both the inside and outside to drive the system away from the balanced nonlinearity.

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