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Research on Cooperation Mechanism in Strategic Emerging Industry Cluster Based on Multi-agents' Decision-making Behavior

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Why the new strategic emerging industry cluster can form and evolve as a complex social network? It is inseparable of the interaction with the agents' decision-making behavior in the industrial cluster. And because of the interaction among agents' decision-making behavior in the cluster, it will lead to the emergence of cooperation behavior among agents. Based on this, we firstly discussed the mode of decision-making behavior among agents in the strategic emerging industry cluster, and analyzed the influence function of the decision-making behavior among multi-agents. Secondly, we use the simulation technology to analyze the cooperation mechanism among agents under the influence of decision behavior. And we conclude that when the cooperation will of the agent in the cluster reaches a certain threshold, any some changes of the factors influencing the cooperation willingness will lead to enhance the cooperation confidence significantly among agents, and the "butterfly effect" will be happened, and the cooperation ratio will increase significantly.

1. Introduction

In recent years, although the strategic emerging industry has made rapid progress in China, it did not get rid of the development ideas of "high-end industries, low-end technology", and the essential research and development efficiency of the technology needed by the emerging industry is low, and its self-sufficiency rate of the key technology is also low (C. Castellano et.al, 2009). The reason is that the innovative power of the enterprises, colleges and universities, scientific research institutions in the strategic emerging industry in China is not converged at present. And the characteristics of pilot, complexity and risk of technology innovation of the strategic emerging industry objectively requires to strengthen close cooperation among different agents in the strategic emerging industry, and to integrate innovation elements such as talent, technology, capital effectively through cooperation, and to realize the promotion core competitiveness of the strategic emerging industry (Vazquez and Redner, 2007).
The innovation in the strategic emerging industry cluster need to achieve the effective flow and allocation of innovation resources among science and technology enterprises, colleges and universities, research institutions, government agencies and intermediary organizations in the cluster (J.C. Gonz´alez-Avella et.al, 2013), involving science and technology enterprises, universities and research institutions, intermediary organizations, the government and other innovative agents. Among then, the science and technology enterprises is the main agent of technology innovation, universities and research institutions are the source of technological innovation, intermediary organizations are the adhesive of technology, and the main functions of the government is to provide technology policy and innovation environment (Lin et al, 2014). Therefore, in such a complex structure level strategic emerging industry cluster, the different behavior of the agents relates in together, and each agent has its own professional knowledge, skills, experience and proprietary information, they cooperate to innovate with other agents within the cluster, and promote the development of the cluster innovation jointly (Li et al, 2014).
In fact, strategic emerging industry cluster is not only a kind of economic form based on the specialization, but also is a multiple complex social network composed of society, cluster, culture and so on. Why the new strategic emerging industry cluster can form and evolve as a complex social network? It is inseparable of the

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interaction with the agents' decision-making behavior in the industrial cluster. And because of the interaction among agents' decision-making behavior in the cluster, it will lead to the emergence of cooperation behavior among agents (Ma and Zhang, 2013). Based on this, we explore the decision making behavior characteristics among agents in the strategic emerging industry cluster, as well as the impact of the mutual influence on the cooperation.

2. Analysis of decision-making behavior in the strategic emerging industry cluster

(1) Analysis of the decision-making behavior model in the industrial cluster

Strategic emerging industrial cluster as a complex social network, the behavior of each node in the cluster is dependent on each other in the process of cluster evolution. The behavior of each cluster agent is dependent on the other actions taken by other agents in the industrial cluster; any cluster agent will consider the strategy choices of other agents before making decisions (Marin, 2014).

Generally speaking, the decision-making of agent mainly includes two ways, one kind of decision-making behavior is follower of a given group, and the agent always tend to follow the group's decision; another kind of decision-making behavior is not to follow group's decision, namely the decision of the agent is always different with the groups. The influence of strategic emerging industry cluster on the agent's decision-making behavior can be thought of as behavior collection in the community social network, and each agent makes a choice among these possible behaviors (Rusinowska and Swart, 2012).

Definition 1. For any $\phi\neq S\subseteq N$, $B\in\theta$, the consistent set of decision behavior of cluster agent and cluster group S under the influence function B can be expressed as: $F_B(S)$:={$j\in N$| $\forall i\in I_S[(Bi)_{j=}\ i_S]$}

By the same token, the inconsistent set of decision behavior of cluster agent and cluster group S under the influence function B can be expressed as: $\overline{F}_B(S)$:={$j\in N$| $\forall i\in I_S[(Bi)_{j=}\ -i_S]$}

Theorem 1. If $B\in\theta$, S and T is two unrelated loophole set of N, then the following relationship is established:

1) For any time $S\cap T=\phi$, $F_B(S)\cap F_B(T)=\phi$.

2) For all $B\in\theta_{S\to T}$, $F_B(S)=S\cup T$, $\overline{F}_B(S)=\phi$.

Proof: 1) Assuming $F_B(S)\cap F_B(T)\neq\phi$, and there exists $j\in F_B(S)\cap F_B(T)$, satisfying the equation $(Bi)_j=i_S=i_T$. And because $S\cap T=\phi$, so there exists $i\in I_S\cap I_T$ and make the equation $i_S=-i_T$ is established, so the equation $i_S=-i_T$ is inconsistent with the previous equation $(Bi)_j=i_S=i_T$, so the null hypothesis is false, so the equation $F_B(S)\cap F_B(T)\neq\phi$ is right.

2) Assuming $t\in S\cup T$. If $t\in T$, for any $i\in I_s$, $(Bi)_t=i_S$. If $t\in S$, for any $i\in I_s$, satisfying the equation $(Bi)_t=i_t=i_s$, therefore, the equation $t\in F_B(S)$ is established. On the other hand, then for any $i\in I_s$, $(Bi)_t=i_S$. So $t\in S\cup T$, and $F_B(S)=S\cup T$. Now we assuming that suppose $\overline{F}_B(S)\neq\phi$, so the equation$(Bi)_j=i_S=i_T$ is established. If there exits $j\in\overline{F}_B(S)$, so for any $i\in I_s$, the equation $(Bi)_j=-i_s$ is established. So it is inconsistent with the null hypothesis and it means that the null hypothesis is false.

We can conclude from the theorem 1:

Conclusion 1. In the strategic emerging industry cluster, if there are two groups whose actions are inconsistent, and the decision-making behavior of the two groups' followers are consistent with the group's decision-making behavior, then the decision-making behavior of the two groups' followers are also different.

(2) Analysis of the influence function of decision-making behavior in the strategic emerging industry cluster

According to the above analysis, we know that there will be such a tendency when the agent makes final decisions in the strategic emerging industry cluster, that is the agent will think this kind of behavior is right and will follow the group's decision behavior when there are many agents all adopt a certain behavior, we name this kind of influence function as most influence function, using $B^{Maj}_{S\to j}$ to be expressed. On the other hand, in a group, there is a kind of agent itself having a strong ability, and also can be convinced by many agents, so when it takes a certain behavior, the others agents will follow the decision, we name this kind of influence function as dominant influence function (Shen, 2012).

Assuming we use i_k=+1 to express when the agent takes some kind of behavior, and we use i_k=-1 to express the agent doesn't take certain action. So the set of agent adopting certain action can be represented as i^+:={$k\in N$| i_k=-1| }, the set of agent who don't adopt certain action can be represented as i^-:={$k\in N$| i_k=-1| }.

Definition 2. Given| $\frac{n}{2}$| $\leq m\leq n$, for any $i\in I$, the most influence function $B^{Maj}_{S\to j}$ can be defined as:

$$B^{Maj}_{S\to j}i := \begin{cases} +1_N & if\left|i^+\right| \geq m \\ -1_N & if\left|i^-\right| < m \end{cases}$$

That is all agents will adopt this behavior if the most agent in the group in the industrial cluster most all take certain behavior; and all agents will not adopt this behavior if the most agent in the group in the industrial cluster most don't take certain behavior.

Theorem 2. Given $\lceil \frac{n}{2} \rceil \leq m \leq n$, considering the most influence function $B^{Maj}_{S\to j}$, the following formula is established: For $\phi \neq S \in N$, $j \in N/S$,

$$D_\alpha(B^{Maj}_{S\to j}, S \to j) = \begin{cases} 1, s \geq m \\ \dfrac{\sum_{i\in I^-_{S\to j}} \alpha_i^{S\to j} + \sum_{i\in I^+_{S\to j}} \alpha_i^{S\to j}}{\sum_{i\in I_{S\to j}} \alpha_i^{S\to j}}, s < m \end{cases}$$

Proof: for $\phi \neq S \in N$, $j \in N/S$, $s \geq m$. If i_S=+1, then $|i^+| \geq m$, therefore, the equation $(B^{Maj}_{S\to j} \mathrm{i})j = +1 = is$ is right. If i_S=-1, so $|i^-| < m$, so the equation $(B^{Maj}_{S\to j} \mathrm{i})j = -1 = is$ is right. This means that the equation $I^{pos}_{S\to j}(B^{Maj}_{S\to j})=I_{S\to j}$ is right. So $D_\alpha(B^{Maj}_{S\to j} S\to j))_j=1$.

For $\phi \neq S \in N$, $j \in N/S$, $s<m$. Therefore, we can get:

$$D_\alpha(B^{Maj}_{S\to j}, S \to j) = \frac{\sum_{i\in I^{pos}_{S\to j}} \alpha_i^{S\to j}}{\sum_{i\in I_{S\to j}} \alpha_i^{S\to j}} = \frac{\sum_{i\in I^-_{S\to j, S<m}} \alpha_i^{S\to j} + \sum_{i\in I^+_{S\to j, S\geq m}} \alpha_i^{S\to j}}{\sum_{i\in I_{S\to j}} \alpha_i^{S\to j}}$$

We can conclude from theorem 2:

Conclusion 2. In the strategic emerging industry cluster, when most of the cluster agents all adopt some kind of decision-making behavior, the agent will follow the group and make decision-making behavior consistent with the group because of the influence of group decision behavior. When there are only a few agents adopt some kind of decision-making behavior, the agent will decide whether following the decision-making behavior of the group and make the same decision behavior according to all sorts of influence degree of the group.

3. Analysis of cooperation mechanism among agents under the influence of decision behavior

We can learn from analysis results of the above section that the agent will adjust their decision behavior because of the effect of other agents or groups' decision behavior in the cluster innovation network, that is to say, the idea or belief of the agent will change or adjust because of the influence by the other agents or groups in the cluster innovation network. Generally speaking, the cooperation of the key lies in whether it can reach a consensus among different parts, in the industrial cluster, due to the dynamic cluster environment, the resources and information and each subject have differences, led to the belief or subjects to the point of view of heterogeneous and dynamic, and cluster the result of the particularity of the mutual influence between the main body of deeper, and therefore subject to reach consensus in cluster is also very complex(Yang et.al, 2012). Here, we discuss the cluster innovation network from the Angle of view dynamics multi-agent decision-making behavior of how the cooperation of emerging under the influence of each other.

(1) Building the model

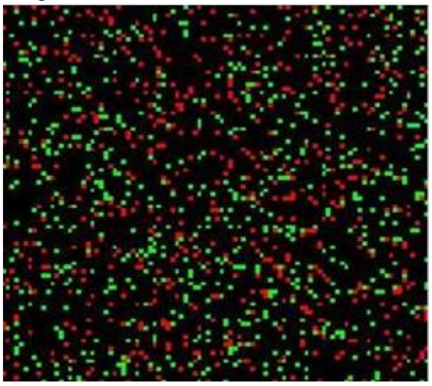
Hypothesis 1: each enterprise in the cluster has different resources and capabilities, and the number of companies is uniform distribution, and the flowing of the enterprise will not occur. The mock object has two main types: one type of agent is willing to innovate, but it is lack of resources and capabilities, another type of agent whose own condition is good wants to share the risk of technology innovation.

Hypothesis 2: there exists certain willingness for all enterprises in the cluster, and assuming the value is divided into three levels including don't want to(the value is 0), neutral (the value is 1), willing to (the value is 2), the stronger the cooperation intention value, the higher the possibility of cooperation.

Hypothesis 3: the will value of cooperation among the enterprises in the cluster all obey uniform distribution. In addition, the resources and capabilities owned by the cooperation of both sides will also affect the success chances of cooperation (Zhou and Wang, 2014).

This model mainly includes four elements: cellular automata, cellular space, neighborhood, and rules. Each lattice in the $L\times L$ two-dimensional uniform grid represents an agent, and red represents the agent who is lack of innovation resources and capabilities, and green represents the agent who has enough innovation resources and ability, and black represents other subjects in the cluster(as it is shown in figure 1). Using the formula $L^t_{i,j}$=(R,S,W,AGE) represents the characteristic attributes of agent (i, j) in time t, among them, R represents the agent who does not participate the cooperation. S represents the characteristics of an agent, which is the strong or weak of the innovation resources and ability. W represents the cooperation will, and AGE represents the innovation resources and ability of the agent (Zhu, 2010).

This model uses the Moore field(as it is shown in figure 1), and black represents the cellular(i, j), and the gray represents its neighborhood area. And the will of the agent and its cooperation behavior is affected by the neighborhood area.



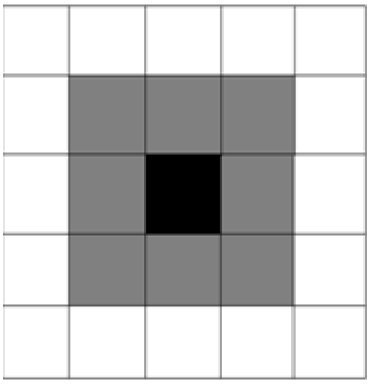


Figure 1: Running figure of simulation system *Figure 2: Moore field*

(2) Simulation results

According to the simulation model established above, the step length of the running of the simulation system is 48, and we simulate four years of cooperation among agents in the cluster. The random of the model is strong, and the ratio of accumulative cooperation after repeatedly running is shown in figure 3. And according to the figure 3, we can conclude that although there exists slightly difference among straight slope, the cooperative proportion shows straight distribution, and it means that the number of cooperation within each system time is basically the same, this is consistent with the model assumptions. And the proportion of cooperation in average year is shown in table 1. From the results shown in figure 3 and table 1, the simulation results of the model is consistent with the reality basically, And the proportion is small and there has fluctuations.

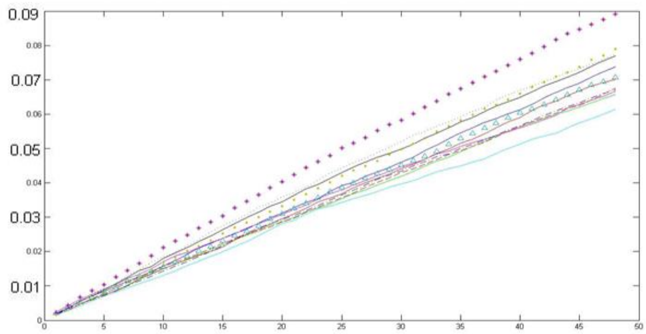
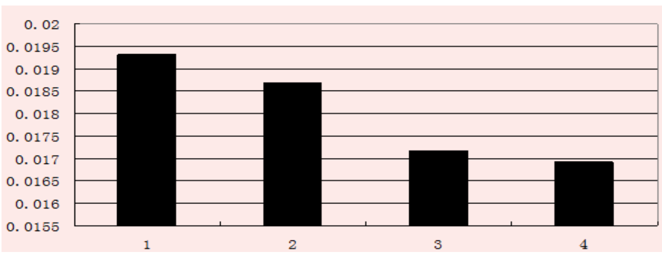


Figure 3: Cumulative proportion of cooperation

Table 1: Cooperation proportion average year



At the same time, we don't change other parameters setting, and adjust will mean to the initial cooperation, the change of cooperation ratio is shown in figure 4. The figure shows that the cooperation ratio change staged with the increasing of random value. And in the willingness of the average range of [1, 1.2], the slope is very big, and it means that the small change of the mean of willingness can lead to the significant changes of the number of cooperation.

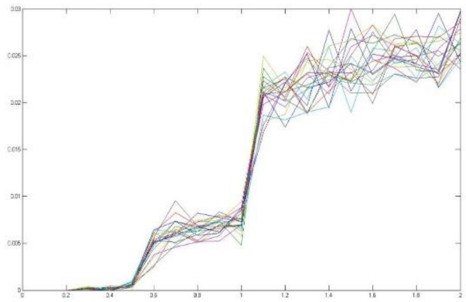


Figure 4: The relationship of mean of will and cooperation proportion

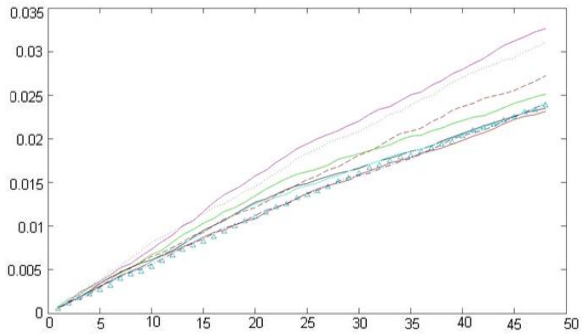
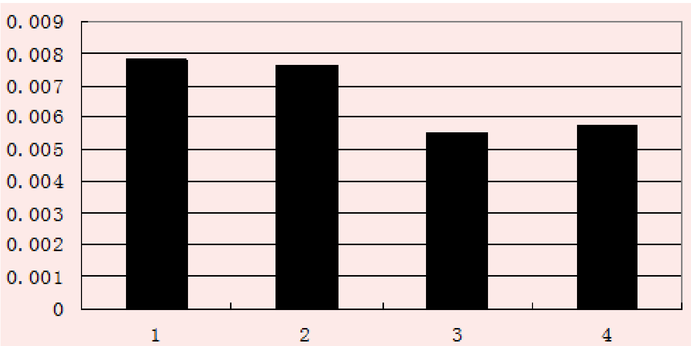


Figure 5: Cumulative proportion of cooperation

In addition, we try to reduce the average value of willingness from 1.185 to 1.1825, and the result is shown in figure 5 and in table 2. Through the comparative analysis, we can know that although the basic curve in figure 5 is still in a shape of straight line, but the cooperation proportion reduced from 0.075 to 0.025 or so, and the ratio of cooperation average annual dropped from 0.018 to 0.014.

Table 2: Cooperation proportion average year



The above data shows that when the cooperation will of the agent in the cluster reaches a certain threshold, any some changes of the factors influencing the cooperation willingness will lead to enhance the cooperation confidence significantly among agents, and the "butterfly effect" will be happened, and the cooperation ratio will increase significantly. Under the condition of reality (the will mean is ∈ [1, 1.2), we can effectively promote the cooperation among agents in the cluster by improving the influence factors of the cooperation intention.

4. Conclusions

We firstly discussed the mode of decision-making behavior among agents in the strategic emerging industry cluster, and analyzed the influence function of the decision-making behavior among multi-agents. Secondly, we use the simulation technology to analyze the cooperation mechanism among agents under the influence of decision behavior. And we received the following conclusions:

Conclusion 1: In the strategic emerging industry cluster, if there are two groups whose actions are inconsistent, and the decision-making behavior of the two groups’ followers are consistent with the group's decision-making behavior, then the decision-making behavior of the two groups’ followers are also different.

Conclusion 2: In the strategic emerging industry cluster, when most of the cluster agents all adopt some kind of decision-making behavior, the agent will follow the group and make decision-making behavior consistent with the group because of the influence of group decision behavior. When there are only a few agents adopt some kind of decision-making behavior, the agent will decide whether following the decision-making behavior of the group and make the same decision behavior according to all sorts of influence degree of the group.

Conclusion 3: Any some changes of the factors influencing the cooperation willingness will lead to enhance the cooperation confidence significantly among agents, and the "butterfly effect" will be happened, and the cooperation ratio will increase significantly when the cooperation will of the agent in the cluster reaches a certain threshold.

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