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Evolutionary Analysis of the Trust Relationship in the Strategic Emerging Industry Clusters based on Complex Network

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Abstract

In this paper, we used the related theory about complex network and probability to analyze the characteristics of network structure of the strategic emerging industry cluster and the dynamics of trust relationship among enterprises in the strategic emerging industry cluster, and we used the simulation method to analyze the influence of network structure characters on the transformation of trust relationship among enterprises. Through the research, we concluded that the strategic emerging industrial cluster as a complex social network with multiple levels also has the characteristics of small world and scale free. At the same time, the trust relationship among enterprises in the cluster will change dynamically, and the transformation of the future state of the trust relationship among enterprises was independent of the past state. In addition, the characteristics of network structure of the cluster have important influence for the change of trust relationship among enterprises.

Key words

Complex network, strategic emerging industry cluster, state transition equation, trust relationship

1. Introduction

In recent years, the development of strategic emerging industries has got rapid progress in China, but it still didn’t get rid of the development ideas which is "high-end industry, low-technology", the R&D efficiency of the core technology and the self-sufficiency of the key technology which is required by the development of new industry. The main reason is that innovation power is dispersing among enterprises, universities, scientific research institutions in the strategic emerging industry in China at present. So it needs to integrate human resources, technology, capital and other innovative elements through strengthening cooperation among agents in the strategic emerging industry to achieve the core competitiveness of industry effectively. The research on cooperation problem of strategic emerging industry cluster has made some achievements, and now the studies mainly focus on the analysis of motive of cooperation, cooperation mode and the governance mechanism of cooperation alliance, as well as the strategy and stability of the collaborative innovation.

For the industrial cluster, the social trust represents the social image of a region, and it plays a very important role for the enterprises in the cluster to absorb the external funding, personnel, customers and so on, and it is advantage to form a regional brand. At the same time, as a part of the industrial cluster environment, trust environment plays an important role in promoting the cooperation among enterprises. In the industrial cluster, people's economic behavior is always closely related to the status of the actor in the cluster. From the viewpoints of practical, Silicon Valley has many success factors, but the important factor which can not be ignored is the cooperation culture and spirit among agents in the Silicon Valley. The development of industrial cluster of Zhejiang province and Guangdong province in China also have the closely relationship with the strong trust mechanism. Therefore, as a kind of special social relationship among enterprises, trust has an important contribution to the formation of industrial clusters and the cultivation of competitive advantage.

In view of this, firstly, we used the idea of complex networks to reveal the characteristics of network structure of the strategic emerging industry cluster, and used the state transfer equation of the probability theory to analyze the dynamics of trust among the enterprises, and we analyzed the dynamic evolution characteristics of the trust among enterprises in the cluster by means of simulation in this paper. Finally, we analyzed the influence mechanism of network structure characteristics of the strategic emerging industry cluster on the trust relationship among the cooperative enterprises, and we want to fill the gaps in the existing research by this research, and providing theoretical guidance and reference to the relevant departments at the same time.

2. Analysis of the network structure characteristics of the strategic emerging industry cluster

Here, we consider an industrial cluster which is composed of N enterprises. The different agents have mutual relation in the cluster. The state technology of the subject i at the t time is expressed by $a_i(t)$, and its technical level is measured by the random $\hat{\sigma}_i(t) \in (0,1)$. And the evolution model includes three main parts:

(1)The entry of the new node and the expanding of the cluster size: at the initial time, it is assumed that the system of industrial cluster has n_0 isolated nodes, at the each time interval in the future, we add a node with its degree is s ($s \le n_0$), and connecting the s edges to the existing s different nodes in the cluster network. This means that there are s other subjects to carry out technical innovation activities with the subject.

(2)Preferential attachment: at the evolution step of each time, selecting a subject i randomly to connect with its nearly subject j, and we assumed that the connect probability $p_i(s_i)$ is proportional to the degree s_i of the node i.

That is $p_i = \frac{\eta_i s_i}{\sum_j \eta_j s_j}$

Through the preferential connection, the technical state of i evolutes from $a_i(t-1)$ to $a_i(t) = a_i(t-1) + \hat{\sigma}_i(t)$, $\hat{\sigma}_i(t) \in (0,1)$ is random variables of independent of the same distribution. In the process of evolution, the subject has three strategies: either to maintain the existing arrangements or to choose the arrangement of the two subjects which are adjacent to him.

If the benefit of the subject i is less than the average benefit $\pi_{AV} = (\pi_{i-1} + \pi_i + \pi_{i+1})/3$ of above three selections, it will choose the arrangement of the most adjacent agent' preference, which means that the subject i will choice from a collection of maximizing the benefit $\{a_{i-1}, a_i, a_{i+1}\}$ as the preferred connection object. Otherwise, it will keep their arrangements at present.

Below, we introduce the main benefit function to measure the behavior of its technological innovation or technical choice:

$$\pi(a_i, a_j) = a_i - k_1(1 - \exp{-(a_i - a_j)}), a_i \ge a_j$$

$$\pi(a_i, a_j) = a_i - k_2(1 - \exp{-(a_j - a_i)}), a_i < a_j \quad j = i \pm 1 \tag{1}$$

k_1 and k_2 represent the cost of the technology is too advanced or too backward. In this way, for each preferential connection, the agent i acquired the benefit π_i:

$$\pi_i = \pi(a_i, a_{i-1}) + \pi(a_i, a_{i+1})$$

(2)

Continuing to repeat the above process until there is no agent to change its existing arrangements.

(3) Reconnected: at the time interval of each evolution, the new node is selected randomly by a given probability p, repeating the above connection and the level of the selected node is still measured by the random variables $\hat{\sigma}(t) \in (0,1)$.

According to the research of Arenas (2000), in the above process of evolution, the technical level of a of the agent i changes its existing technical level to $a+\hat{\sigma}$, if the technical level difference $\hat{\delta} = \|a_{i+1} - a_{i-1}\|$ the agent $i+1$ and agent $i-1$ which is adjacent to the node i is satisfied:

$$(k_1 - k_2) < k^*(\hat{\delta}) = \frac{2\hat{\delta}}{1-\exp(-\hat{\delta})} \text{ or } 2\hat{\delta} - (k_1 - k_2)(1-\exp(-\hat{\delta})) > 0 \quad (3)$$

Node i always selects the technology with highest level of the adjacent nodes, and this behavior will trigger other nodes to carry out a new technological innovation, thus promoting the continuous evolution of technological innovation.

Formula (3) implies that the dynamics of the evolution model is only related to the technological innovation cost $k = (k_1 - k_2)$. In this way, after the evolution with time length T, it will form a cluster innovation network with $N = n_0 + t$ nodes and mt edges. The changes of the node degree of the network will meet $\frac{\partial s_i}{\partial t} = \frac{s_i}{2t}$, and the initial condition is $s_i(t_i) = s$, the cluster innovation network will eventually evolve to a small world and scale-free network（as shown in Figure 1）, figure 1 shows degree distribution of the evolution of industrial cluster innovation network: $N = n_0 + t = 3000$.The three curves in the figure1 represent degree distribution of the following three stats $n_0 = s = 3$, $n_0 = s = 5$, $n_0 = s = 7$.

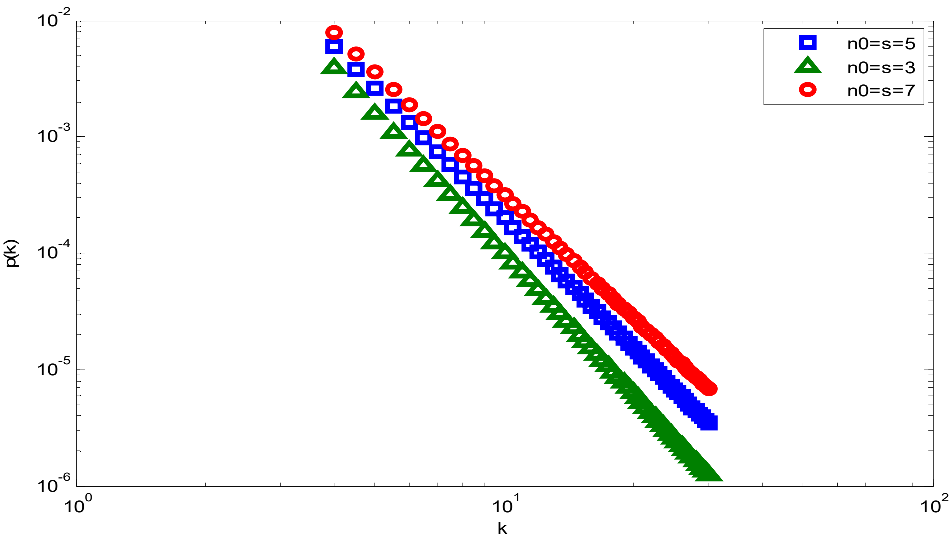

Figure.1. The power-law distribution of Institution evolution

According to the formula (3), when $k \leq 2$, the scale s of agents engaging in technological innovation is all subjects with the same goal of technological innovation and cooperation. When $k \to \infty$, the subject is lack of coordination, and there exists no cooperation with each other, and the scale of the technological innovation is 0. If the K is moderate, the entire network system will reach the state of self-organized Critical. Therefore, it also shows that the strategic emerging industry clusters have the characteristics of small world and scale free.

3. The dynamic analysis of the trust relationship among the cooperative enterprises in the strategic emerging industry cluster

For the sake of simplicity, we call the enterprises in the cluster as the behavior agent, and the relationship among the enterprises is called the trust relationship. Because the change of the trust relationship among the agents is a gradual process, so it is assumed that the state of the relationship among the agents contains two states of benign trust relationship H_1 and H_2, and there are m malignant trust relationship status $W_1,\cdots,W_m$. The state of trust relationship among the agents transfers among these states. We call the state of trust relationship transferring between H_1 and H_2 is the positive transfer of trust relationship among the agents. The transferring of the trust relationship with H_1 or H_2 to $W_1,\cdots,W_m$ is called malignant transfer.

Order the time interval is (t_1,t_2), $0 \leq t_1 < t_2 < \infty$, At the time t_1, the agent is in the state H_α, and state of the agent will change between H_α and H_β, and may be up to W_δ at the time interval (t_1,t_2). The transition from one state to another depends on the benign strength $v_{\alpha\beta}$ and malignant intensity $u_{\alpha\delta}$ on the transformation of the trust relationship among the agents, and for $v_{\alpha\beta}$ and $u_{\alpha\delta}$, we make the following definition in this paper.

Definition1. For any ε, $t_1 \leq \varepsilon \leq t_2$

$v_{\alpha\beta}\Delta + o(\Delta)$ =Pr{the state of agent at the time ε is H_α and its state is H_β at the time $\varepsilon+\Delta$}, $\alpha \neq \beta; \alpha,\beta = 1,2$.

$u_{\alpha\delta}\Delta + o(\Delta)$ =Pr{the state of agent at the time ε is H_α and its state is W_δ at the time $\varepsilon+\Delta$}, $\alpha = 1,2; \delta = 1,2,\cdots,m$.

Definition2. $P_{\alpha\beta}(t_1,t_2)=\Pr\{$the state of agent at the time ε is H_α and its state is H_β at the time $\varepsilon+\Delta\}$, $\alpha\neq\beta;\alpha,\beta=1,2$ is benign transition probability of the trust relationship among the agents.

Definition3. $Q_{\alpha\delta}(t_1,t_2)=\Pr\{$the state of agent at the time ε is H_α and its state is W_δ at the time $\varepsilon+\Delta\}$, $\alpha=1,2;\delta=1,2,\cdots,m$ is malignant transition probability of the trust relationship among the agents.

Therefore, according to the state transition equation of probability theory, the evolution process of transition probability of the state of the trust relationship among the agents can be expressed by the following differential equation:

$$\frac{\partial}{\partial t}P_{\alpha\alpha}(t_1,t_2)=P_{\alpha\alpha}(t_1,t_2)v_{\alpha\alpha}+P_{\alpha\beta}(t_1,t_2)v_{\beta\alpha}$$

$$\frac{\partial}{\partial t}P_{\alpha\beta}(t_1,t_2)=P_{\alpha\alpha}(t_1,t_2)v_{\alpha\beta}+P_{\alpha\beta}(t_1,t_2)v_{\beta\beta},\quad \alpha\neq\beta;\alpha,\beta=1,2 \tag{4}$$

$$Q_{\alpha\delta}(t_1,t_2)=\int_{t_2}^{t_1}P_{\alpha\alpha}(t_1,t_2)u_{\alpha\delta}\,dt+\int_{t_2}^{t_1}P_{\alpha\beta}(t_1,t_2)u_{\beta\delta}\,dt \tag{5}$$

For the equation (4), we order:

$$P_{\alpha\alpha}(t_1,t_2)=K_{\alpha\alpha}e^{\gamma(t_2-t_1)}\quad P_{\alpha\beta}(t_1,t_2)=K_{\alpha\beta}e^{\gamma(t_2-t_1)} \tag{6}$$

According to formula (6) and formula (4), we can get the following equations:

$$(\lambda-v_{\alpha\alpha})K_{\alpha\alpha}-v_{\beta\alpha}K_{\alpha\beta}=0\qquad(\lambda-v_{\alpha\alpha})K_{\alpha\alpha}-v_{\beta\alpha}K_{\alpha\beta}=0$$

(7)

To solve $K_{\alpha\alpha}$ and $K_{\alpha\beta}$, only the following determinant is satisfied:

$$\begin{vmatrix}\lambda-v_{\alpha\alpha} & -v_{\beta\alpha}\\ -v_{\beta\alpha} & \lambda-v_{\beta\beta}\end{vmatrix}=0$$

(8)

So we can get:

$$\lambda_1=\frac{1}{2}[v_{11}+v_{22}+\sqrt{(v_{11}-v_{22})^2+4v_{12}v_{21}}]\qquad\lambda_2=\frac{1}{2}[v_{11}+v_{22}-\sqrt{(v_{11}-v_{22})^2+4v_{12}v_{21}}]$$

(9)

According to the formula (4), formula (8) and formula (9), we can solve transition probability of the trust relationship between state H_α and H_β:

$$P_{\alpha\alpha}(t_1,t_2)=\sum_{i=1}^{2}\frac{\lambda_i-v_{\beta\beta}}{\lambda_i-\lambda_j}e^{\lambda_i(t_2-t_1)}$$

(10)

$$P_{\alpha\beta}(t_1,t_2)=\sum_{i=1}^{2}\frac{v_{\alpha\beta}}{\lambda_i-\lambda_j}e^{\lambda_i(t_2-t_1)} \qquad \alpha\neq\beta, i\neq j;\alpha,\beta=1,2$$

(11)

According to the formula (10), formula (11) and formula (5), we can get:

$$Q_{\alpha\delta}(t_1,t_2)=\sum_{i=1}^{2}\frac{e^{\lambda_i(t_2-t_1)}-1}{\lambda_i(\lambda_i-\lambda_j)}[(\lambda_i-v_{\beta\beta})u_{\alpha\delta}+v_{\alpha\beta}u_{\beta\delta}]\alpha\neq\beta, i\neq j;\alpha,\beta=1,2,\delta=1,2,\cdots,m$$

(12)

For the sake of simplicity, we order t_1 =0 and t is the interval length, so the formula (7), formula (8) and formula (9) can be expressed as:

$$P_{\alpha\alpha}(0,t)=\sum_{i=1}^{2}\frac{\lambda_i-v_{\beta\beta}}{\lambda_i-\lambda_j}e^{\lambda_i t}$$

(13)

$$P_{\alpha\beta}(0,t)=\sum_{i=1}^{2}\frac{v_{\alpha\beta}}{\lambda_i-\lambda_j}e^{\lambda_i t} \quad \alpha\neq\beta, j\neq i; j,\alpha,\beta=1,2 \tag{14}$$

$$Q_{\alpha\delta}(0,t)=\sum_{i=1}^{2}\frac{e^{\lambda_i t}-1}{\lambda_i(\lambda_i-\lambda_j)}[(\lambda_i-v_{\beta\beta})u_{\alpha\delta}+v_{\alpha\beta}u_{\beta\delta}] \tag{15}$$

Theorem1. For any $\tau,\tau\in(0,t)$, the benign transfer process of the trust relationship state among agents is a Markov process, and the following equation was established:

$P_{\alpha\alpha}(0,t)=P_{\alpha\alpha}(0,\tau)P_{\alpha\alpha}(\tau,t)+P_{\alpha\beta}(0,\tau)P_{\beta\alpha}(\tau,t)$ (16)

$$P_{\alpha\beta}(0,t)=P_{\alpha\alpha}(0,\tau)P_{\alpha\beta}(\tau,t)+P_{\alpha\beta}(0,\tau)P_{\beta\beta}(\tau,t) \quad \alpha\neq\beta, j\neq i; j,\alpha,\beta=1,2 \tag{17}$$

Proof: According to the formula (13), formula (14) and formula (16), we can get:

$$\sum_{i=1}^{2}\frac{\lambda_i-v_{\beta\beta}}{\lambda_i-\lambda_j}=[\sum_{i=1}^{2}\frac{\lambda_i-v_{\beta\beta}}{\lambda_i-\lambda_j}e^{\lambda_i\tau}][\sum_{i=1}^{2}\frac{\lambda_i-v_{\beta\beta}}{\lambda_i-\lambda_j}e^{\lambda_i(t-\tau)}]+[\sum_{i=1}^{2}\frac{v_{\alpha\beta}}{\lambda_i-\lambda_j}e^{\lambda_i\tau}][\sum_{i=1}^{2}\frac{v_{\beta\alpha}}{\lambda_i-\lambda_j}e^{\lambda_i(t-\tau)}] \tag{18}$$

Expanding the first item of the formula (18) on the right, we can get:

$$\begin{aligned}&[\sum_{i=1}^{2}\frac{\lambda_i-v_{\beta\beta}}{\lambda_i-\lambda_j}e^{\lambda_i\tau}][\sum_{i=1}^{2}\frac{\lambda_i-v_{\beta\beta}}{\lambda_i-\lambda_j}e^{\lambda_i(t-\tau)}]=[\frac{\lambda_1-v_{\beta\beta}}{\lambda_1-\lambda_2}e^{r_1\tau}+\frac{\lambda_2-v_{\beta\beta}}{\lambda_2-\lambda_1}e^{\lambda_2\tau}][\frac{\lambda_1-v_{\beta\beta}}{\lambda_1-\lambda_2}e^{\lambda_1(t-\tau)}+\frac{\lambda_2-v_{\beta\beta}}{\lambda_2-\lambda_1}e^{r_2(t-\tau)}]\\&=\sum_{i=1}^{2}(\frac{\lambda_i-v_{\beta\beta}}{\lambda_i-\lambda_j})^2e^{\lambda_i t}-\frac{(\lambda_1-v_{\beta\beta})(\lambda_2-v_{\beta\beta})}{(\lambda_1-\lambda_2)^2}\sum_{\substack{i=1\\i\neq j}}^{2}e^{\lambda_i\tau+\lambda_j(t-\tau)}\end{aligned} \tag{19}$$

Expanding the second item of the formula (19) on the right, we can get:

$$[\sum_{i=1}^{2}\frac{v_{\alpha\beta}}{\lambda_i-\lambda_j}e^{\lambda_i\tau}][\sum_{i=1}^{2}\frac{v_{\beta\alpha}}{\lambda_i-\lambda_j}e^{\lambda_i(t-\tau)}]=(\frac{v_{\alpha\beta}}{\lambda_1-\lambda_2}e^{\lambda_1\tau}+\frac{v_{\alpha\beta}}{\lambda_2-\lambda_1}e^{\lambda_2\tau})(\frac{v_{\beta\alpha}}{\lambda_1-\lambda_2}e^{\lambda_1(t-\tau)}+\frac{v_{\beta\alpha}}{\lambda_1-\lambda_2}e^{\lambda_2(t-\tau)})$$

$$=\frac{v_{\alpha\beta}v_{\beta\alpha}}{(\lambda_1-\lambda_2)^2}e^{\lambda_1 t}+\frac{v_{\alpha\beta}v_{\beta\alpha}}{(\lambda_1-\lambda_2)(\lambda_2-\lambda_1)}e^{\lambda_1\tau+\lambda_2(t-\tau)}+\frac{v_{\alpha\beta}v_{\beta\alpha}}{(\lambda_2-\lambda_1)(\lambda_1-\lambda_2)}e^{\lambda_2\tau+\lambda_1(t-\tau)}+\frac{v_{\alpha\beta}v_{\beta\alpha}}{(\lambda_2-\lambda_1)^2}e^{\lambda_2 t} \quad (20)$$

$$=\sum_{i=1}^{2}\frac{v_{\alpha\beta}v_{\beta\alpha}}{(\lambda_i-\lambda_j)^2}e^{\lambda_i t}-\frac{v_{\alpha\beta}v_{\beta\alpha}}{(\lambda_1-\lambda_2)^2}\sum_{\substack{i=1\\i\neq j}}^{2}e^{\lambda_2\tau+\lambda_j(t-\tau)}$$

So merging the formula (19) and formula (20)， the right of formula (18) is：

$$\sum_{i=1}^{2}(\frac{\lambda_i-v_{\beta\beta}}{\lambda_i-\lambda_j})^2e^{\lambda_i t}-\frac{(\lambda_1-v_{\beta\beta})(\lambda_2-v_{\beta\beta})}{(\lambda_1-\lambda_2)^2}\sum_{\substack{i=1\\i\neq j}}^{2}e^{\lambda_i\tau+\lambda_j(t-\tau)}+\sum_{i=1}^{2}\frac{v_{\alpha\beta}v_{\beta\alpha}}{(\lambda_i-\lambda_j)^2}e^{\lambda_i t}-\frac{v_{\alpha\beta}v_{\beta\alpha}}{(\lambda_1-\lambda_2)^2}\sum_{\substack{i=1\\i\neq j}}^{2}e^{\lambda_2\tau+\lambda_j(t-\tau)}$$

$$=\sum_{i=1}^{2}\frac{(\lambda_i-v_{\beta\beta})^2+v_{\alpha\beta}v_{\beta\alpha}}{(\lambda_i-\lambda_j)^2}e^{\lambda_i t}-\frac{(\lambda_1-v_{\beta\beta})(\lambda_2-v_{\beta\beta})+v_{\alpha\beta}v_{\beta\alpha}}{(\lambda_1-\lambda_2)^2}\sum_{\substack{i=1\\i\neq j}}^{2}e^{\lambda_i\tau+\lambda_j(t-\tau)}$$

$$=\sum_{i=1}^{2}\frac{(\lambda_i-v_{\beta\beta})^2+v_{\alpha\beta}v_{\beta\alpha}}{(\lambda_i-\lambda_j)^2}e^{\lambda_i t}=\sum_{i=1}^{2}\frac{\lambda_i-v_{\beta\beta}}{\lambda_i-\lambda_j}e^{\lambda_i t} \quad （(\lambda_i-v_{\beta\beta})^2+v_{\alpha\beta}v_{\beta\alpha}$$

So the formula (16) is proved. Similarly, the formula (17) can be proved.

Theorom2. For any $\tau, \tau \in (0,t)$, the malignant transfer process of the trust relationship state among agents is a Markov process, and the following equation was established:

$$Q_{\alpha\delta}(0,t)=Q_{\alpha\delta}(0,\tau)+P_{\alpha\alpha}(0,\tau)Q_{\alpha\delta}(\tau,t)+P_{\alpha\beta}(0,\tau)Q_{\beta\delta}(\tau,t)\ \alpha\neq\beta;\alpha,\beta=1,2$$

Proof: we assume that the probability of benign state of trust relationship of agent at time $t=0$ is in a malignant state of trust relationship at time t is $Q_{\alpha\delta}(0,t)$. Then, there will appear three possible situations in the process of transferring:

(1) if we set τ is any point within the interval (0, t), the trust relationship state among the agents may has transfer from benign trust relationship to malignant trust relationship at the time τ or before the time τ. We assume that the state transition probability of trust relationship in such a case is $Q_{\alpha\delta}$.

If the trust relationship state among the agents at time τ is H_α or H_β, and the trust relationship state is W_δ in the interval (τ,t), and this is the other two situations behind:

(2) When the trust relationship state among the agents at time τ is H_α, and the trust relationship state is W_δ in the interval (τ,t). So the state transition probability of trust relationship in such a case is $P_{\alpha\alpha}(0,\tau)Q_{\alpha\delta}(\tau,t)$.

(3) When the trust relationship state among the agents at time τ is H_β , and the trust relationship state is W_δ in the interval (τ, t). So the state transition probability of trust relationship in such a case is $P_{\alpha\beta}(0,\tau)Q_{\beta\delta}(\tau,t)$.

Therefore, combing the probability of the above three conditions together, we can get the following equation:

$$Q_{\alpha\delta}(0,t) = Q_{\alpha\delta}(0,\tau) + P_{\alpha\alpha}(0,\tau)Q_{\alpha\delta}(\tau,t) + P_{\alpha\beta}(0,\tau)Q_{\beta\delta}(\tau,t) \ \alpha \neq \beta; \alpha, \beta = 1,2$$

So the theorem 2 is proved.

From the theorem 1 and theorem 2, we can get the following conclusion:

Conclusion1. The future state transition of trust relationship among the agents is independent of the transfer of the trust relationship state in the past. That is to say, the future state transition of trust relationship mainly depends on a series of behavior happed among agents regardless of the state transfer of trust relationship among the agents in the past is benign transfer or malignant transfer, and these behaviors may lead to benign transfer of the trust relationship among the agents, and it is also likely to lead to malignant transfer of trust relationship among the agents.

4. The influence of the network structure of strategic emerging industry cluster on the dynamics of the trust relationship

4.1Establishment of the model

From the above analysis, we have known that the strategic emerging industry cluster has features of "small world" and scale-free, and the trust itself among agents is embedded in the cluster network, so whether the network topological structure will affect the trust relationship among the enterprises? It respectively will produce what kind of impact ff it has an impact? So we discuss the influence the features of the cluster network structure on the evolution of trust mechanism of the industrial cluster mainly from the factors of agglomeration factor (c_i), center degree (d_i) and average path length (l_{ij}).

To reflect the heterogeneity of the enterprises and the difference of the trust state in different time, we use the symmetrical scale $\{-N, -N+1, \cdots, 0, \cdots, N-1, N\}$ to represent the degree of mutual trust among enterprises, among them, $-N$ represents the completely distrust among enterprises, 0 represents the neutral trust among enterprises, and N indicates the high trust among enterprises, or even completely trust. And we used $x_{ij}(t)$ to represent the trust state of enterprise i to enterprise j at time t in the network. And we used $x_{ij}^n(t)$ to represent the probability of the trust degree of enterprise i to enterprise j which is n at time t , $\sum_{n=-N}^{N} x_{ij}^{n}(t)=1$, $E(x_{ij}(t))=\sum_{n=-N}^{N} n x_{ij}^{n}$ represents the expectation of trust state of enterprise i to enterprise j at time t. Here, we assume that the influence of variable $x_{ij}^{n}(t)$ only from $x_{ij}^{n-1}(t), x_{ij}^{n+1}(t)$, without considering the influence of $x_{ij}^{n-2}(t), x_{ij}^{n+2}(t)$. There is no doubt that the trust degree of enterprise i to enterprise j which is n at time t is from the changes of the following two aspects: one is the increase of the trust degree n, that is the trust degree turned from $n-1$ and $n+1$ to n; The second is decrease the trust degree n, that is the trust degree turned from n to $n-1$ and $n+1$, but the trust shift probability is not the same.

Therefore, we can draw the evolution model of trust mechanism among enterprises in industrial cluster after defining the above concepts and variables by using the state transition equation:

$$\dot{x}_{ij}^{n}(t)=p_{ij}(n\mid n-1)x_{ij}^{n-1}+p_{ij}(n\mid n+1)x_{ij}^{n+1}-p_{ij}(n-1\mid n)x_{ij}^{n}-p_{ij}(n+1\mid n)x_{ij}^{n} \tag{21}$$

Among them, $p_{ij}(n\mid n-1)$ represents the transfer probability of enterprise i to enterprise j from $n-1$ to n , and the other definitions is similar.

And for the calculation of the above four transition probability, we can calculate the transition probability of the evolution model based on the results of research by scholars Tan Zhengda:

$$p_{ij}(n+1\mid n)=c_i e^{-(a_{ij}-(n+1))^2/2}+(1-c_i)\Pi e^{-l_{ij}((n+1)-E(x_{ij}))^2/d_i}$$

$$p_{ij}(n-1\mid n)=c_i e^{-(a_{ij}-(n-1))^2/2}+(1-c_i)\Pi e^{-l_{ij}((n-1)-E(x_{ij}))^2/d_i}$$

$$p_{ij}(n\mid n-1)=c_i e^{-(a_{ij}-n)^2/2}+(1-c_i)\Pi e^{-l_{ij}(n-E(x_{ij}))^2/d_i}$$

$$p_{ij}(n\mid n+1)=c_i e^{-(a_{ij}-(n-2))^2/2}+(1-c_i)\Pi e^{-l_{ij}((n-2)-E(x_{ij}))^2/d_i}$$

Among them, a_{ij} is the expectations of trust state among enterprises at the initial state, and it won't change in the whole process once it is determined.

4.2 Model simulation and result analysis

(1) Initialization of parameters

For simplicity, we consider a network constituted by four enterprises in the industrial cluster, and each enterprise is connected with each other. The design of trust value among enterprises is similar to the research of scholar Tan Zhengda, assuming $N = 2$, the degree of trust state among enterprises is divided into five degrees which are $\{-2,-1,0,1,2\}$. In addition, it is assumed that there are only two kinds of trust states in the initial state $x_{ij1}^{n}(0) = \{0.55, 0.4, 0.05, 0, 0\}$ and $x_{ij2}^{n}(0) = \{0, 0, 0.05, 0.4, 0.55\}$.

And the initial value of the trust state among the 4 enterprises is shown in table 1. We assume that the trust state value of the enterprise 1 is higher than the other enterprises at the initial state, and the trust state value of the enterprise 4 is lower than the other enterprises at the initial state.

Table1. The initial value of the trust state among enterprises

j / i	Enterprise1	Enterprise2	Enterprise3	Enterprise4
Enterprise1	_	$x_{ij2}^{n}(0)$	$x_{ij2}^{n}(0)$	$x_{ij2}^{n}(0)$
Enterprise2	$x_{ij2}^{n}(0)$	_	$x_{ij1}^{n}(0)$	$x_{ij2}^{n}(0)$
Enterprise3	$x_{ij1}^{n}(0)$	$x_{ij2}^{n}(0)$	_	$x_{ij1}^{n}(0)$
Enterprise4	$x_{ij1}^{n}(0)$	$x_{ij1}^{n}(0)$	$x_{ij1}^{n}(0)$	_

According to the data in table1， we can work out the value of a_{ij} (as it is shown in Table 2)：

Table2. Expectations of trust state among enterprises in initial state

j / i	Enterprise1	Enterprise2	Enterprise3	Enterprise4
Enterprise1	_	1.5	1.5	1.5
Enterprise2	1.5	_	-1.5	1.5
Enterprise3	-1.5	1.5	_	-1.5
Enterprise4	-1.5	-1.5	-1.5	_

(2) Simulation and result analysis

It should be noted here that the simulation results in this paper reflect the change of the expectations of the trust state in the network. That is $x_{ij}(t) = \sum_{n=-N}^{N} n x_{ij}^{n}$.

Firstly, we assume that $c_i = 0.7$ 、 $d_i = 4$ and $l_{ij} = 3$, so we can get the first simulation figure about the change of expectations of the trust state among enterprises with time(as it is shown in figure2).

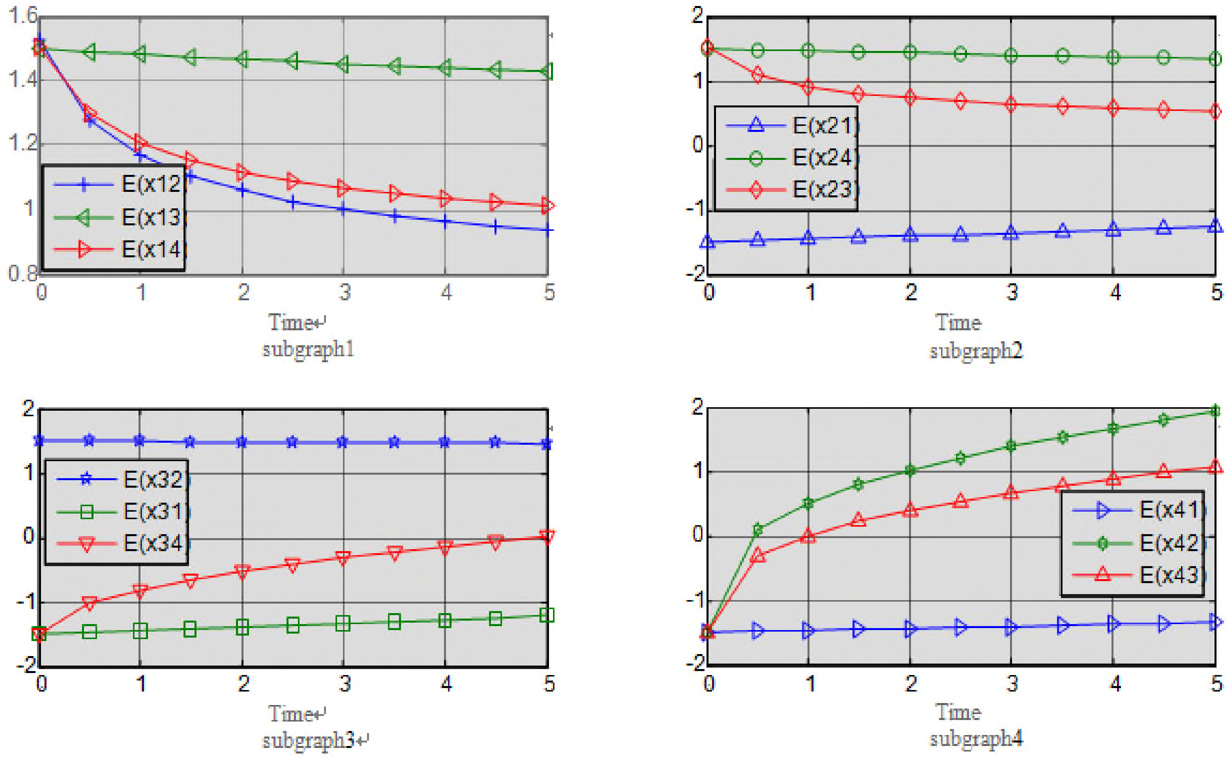

Figure.2. The fist simulation result

As it can be seen from the figure 2, the subgraph1 reflects the expectations of trust status of enterprise 1 to enterprise 2, enterprise 3, enterprise 4 all decreased; subgraph2 reflects the expectations of trust status of enterprise 2 to enterprise 1 and enterprise 4 remained largely unchanged, but the expectations of trust status of enterprise 2 to enterprise 3 decreased; subgraph3 reflects the expectations of trust status of enterprise 3 to enterprise 1 and enterprise 2 remained largely unchanged, but the expectations of trust status of enterprise 3 to enterprise 4 improved; subgraph4 reflects the expectations of trust status of enterprise 4 to enterprise 2, enterprise 3, enterprise1 all improved.

Secondly, on the basis of the first simulation, we change the center degree of enterprise 4 in the cluster social network, $d_4 = 8$, and other parameters are the same as the first simulation, so we can get the following second simulation diagram (as it is shown in figure 3).

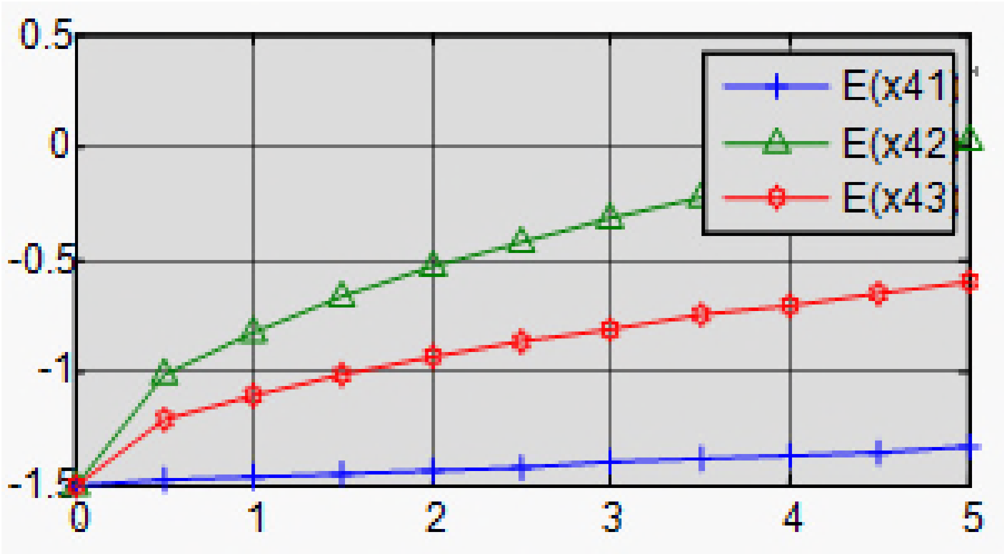

Figure.3. The second simulation result

Compared figure 3 with figure 2, we can find that the expectations of trust state among enterprises in the overall network has fallen after improving the center degree of enterprise 4 in cluster social networks. This is because the trust status value of enterprise 4 to the other three companies at initial state is low, and with the promotion of enterprise's 4 influence in the network, the behavior of enterprises 4 has a very important influence on the other enterprises' behavior, and it lead to the fall of trust degree of the whole cluster network, and it also suggests that the trust state of the enterprise with a high influence in the cluster network plays a positive role for the trust degree of the whole industrial cluster. Thus, we can get the following conclusion:

Conclusion2. The increase of the center degree of enterprises in the cluster network will improve the expectations of trust state of the whole industrial cluster.

Again, on the basis of the first simulation, we change the path length among enterprises, $c_i = 0.8$, and the other parameters are the same as the first simulation, so we can get the following simulation diagram (as it is shown in figure 4).

Compared figure 4 with figure 2, we found that the change degree of the expectations of trust status of industrial cluster weaken after the expansion of network distance among enterprises. So we can get the following conclusion:

Conclusion3. The expansion of average path length among enterprises in the cluster network will make the change degree of the expectations of trust status weaken.

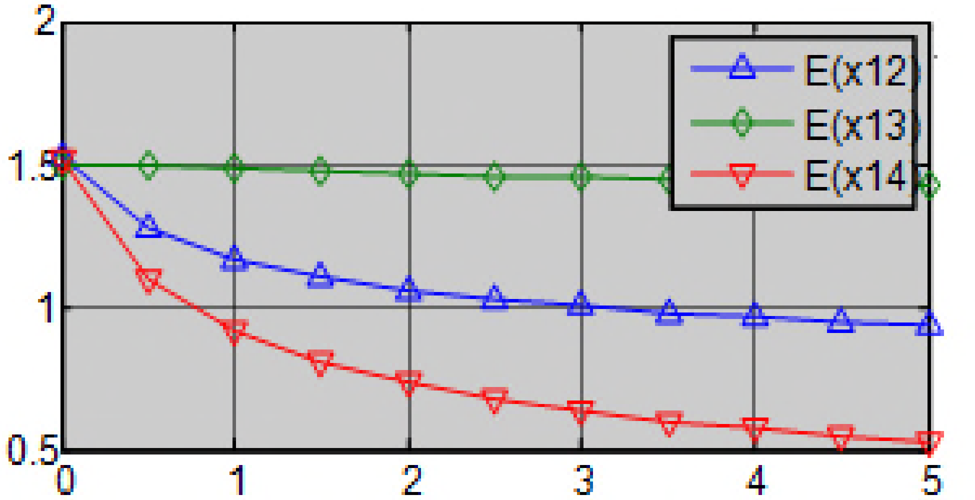

Figure.4. The third simulation result

Finally, on the basis of the first simulation, and we change the concentration coefficient of the cluster network, $c_i = 0.8$, and other parameters are the same as the first simulation, so we can get the following fourth simulation diagram (as it is shown in figure 5).

Compared figure 5 with figure 2, we can find that the expectations of state trust of the overall cluster has obvious improvement after improving the cluster coefficient of the cluster network. So we can draw the following conclusion:

Conclusion4. The greater the concentration coefficient of the cluster network, it can improve the expectations of state trust of the overall cluster.

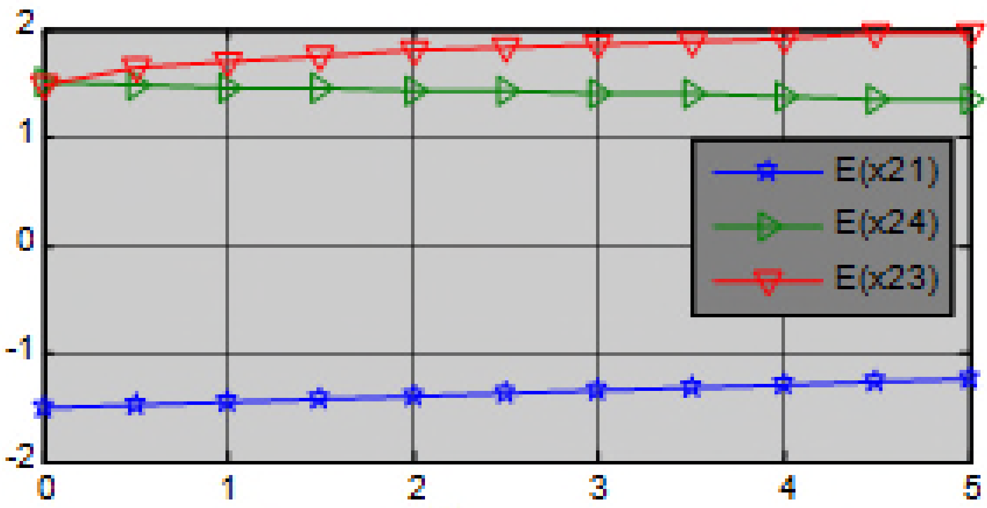

Figure.5. The forth simulation result

Discussion

According to the analysis process above, we can know that the strategic emerging industrial cluster as a complex social network with multiple levels also has the characteristics of small world and scale free. As we all know, in the strategic emerging industry cluster, it contains many innovative behavior agents such as the science and technology enterprises, universities and research institutions, intermediary organizations, financial institutions and the government. Enterprise is the core unit of strategic emerging industrial cluster, and it is the behavior agent who plays the direct role in the process of cluster innovation. Universities or research institutions can not only produce the new knowledge and new technology, and provide various knowledge and skills for innovation activities, but also it can promote the diffusion of new knowledge and new technology in the cluster network or the implementation of market value by education and training. Intermediary service agencies as an intermediate organization providing related services for the enterprises in the cluster, it mainly includes the cluster agent institutions, such as various types of industry associations, Chambers of commerce, entrepreneurs association and so on, but also includes those law firms, accounting firms and other intermediary organizations. These institutions would help enterprises use the innovation resources in the process of innovation effectively. The government here is mainly refers to the local government and the public sector of the cluster, unlike the enterprises and research institutions in the cluster, it mainly create a good environment for the transmission of internal knowledge and information in the cluster, and provide mechanisms to promote the various links between enterprises and other behavior agents in the cluster, so as to improve the efficiency of the cooperation among enterprises. Financial institutions in the strategic emerging industry cluster includes local state-owned Banks, local commercial Banks, various forms of capital fund and lending institutions, risk investment institutions and there exists all kinds of relationship among these behavior agents; they constitute an effective network organization. The cluster network promotes the agents to work together, and realize the share of resources and the complementary advantages, thus making enterprises in the cluster obtain the scale economy and scope economy.

At the same time, the trust relationship among enterprises in the cluster will change dynamically, and the characteristics of network structure of the cluster have important influence for the change of trust relationship among enterprises. On the one hand, in the industrial cluster, when the distance among the enterprise grows, it will undoubtedly lead to the inconvenience of communication among enterprises, and it also will lead to the understanding of enterprise operating state and information, and it will be difficult to let entrepreneurs to trust each other, so as to make the trust among enterprises will not change. On the other hand, in the industrial cluster, the interpersonal trust is the premise of knowledge exchange supporting the cluster innovation network. The enterprises showed height confidence of the intention and behavior each other when trust exists, and it makes the enterprises creatively carry out and implement their own task and achieve the goal of innovation through exchanges and sharing of knowledge and technology. Therefore, when the cluster coefficient of the cluster network strengthen, the information among enterprises will more transparent, and it will help to the mutual understanding among the enterprises, and thus promoting the mutual cooperation among enterprises and enhance each other's trust in the process of cooperation.

In summary, we should consider the feature of the strategic emerging industrial cluster as a complex social network and its influence on the behavior of agents in the industrial cluster.

Conclusions

We used the related theory about complex network and probability to analyze the characteristics of network structure of the strategic emerging industry cluster and the dynamics of trust relationship among enterprises in the strategic emerging industry cluster, and we used the simulation method to analyze the influence of network structure characters on the transformation of trust relationship among enterprises. Through the research, we concluded that the strategic emerging industrial cluster as a complex social network with multiple levels also has the characteristics of small world and scale free. And the future state transition of trust relationship among the agents is independent of the transfer of the trust relationship state in the past. That is to say, the future state transition of trust relationship mainly depends on a series of behavior happed among agents regardless of the state transfer of trust relationship among the agents in the past is benign transfer or malignant transfer, and these behaviors may lead to benign transfer of the trust relationship among the agents, and it is also likely to lead to malignant transfer of trust relationship among the agents. In addition, the characteristics of network structure of the cluster has important influence for the change of trust relationship among enterprises, and the enhancing of the center degree of the enterprise in the cluster network will improve the expectation of trust state of the whole industrial cluster. And the expansion of the average path length among the enterprises in the cluster network will make the expectation of trust state of the whole cluster change weakly. And the enlarging of the clustering coefficient of the cluster network will promote the expectation value of the trust state of the whole cluster.

In a word, the above research method and relevant conclusion has good theoretical and practical value, it better reflects the structure characteristics of strategic emerging industry cluster network, but also reflects the effect mechanism of this kind of network structure the characteristic on the trust mechanism of cluster. Of course, this article research also is just a start, we will consider the impact of complexity of the cluster network system evolution, such as robustness and fragility on the trust mechanism.

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