Evolutionary game of information sharing on supply chain network based on memory genetic algorithm

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ABSTRACT. *The topological structure of supply chain network directly bears on the efficiency of information sharing, which is the key to the profit-making of enterprises. Taking supply chain network as a complex network, this paper analyses the evolutionary game of information sharing, and explores how network topology, probability of chromosome mutation and degree of punishment affect the evolutionary results of the network. Through the numerical simulation, it is found that a plateau exists in the information sharing process of a random network but does not exist in that of the regular network, indicating that the random network is more favourable to information sharing between enterprises of the supply chain; the probability of chromosome mutation is positively correlated with the frequency increase of information sharing but negatively with frequency stability; the degree of punishment contributes to the information sharing between the said enterprises. In long-term coopetition, the enterprises may play multiple games of information sharing and interest coordination, and tend to adjust their current game strategies based on the outcome of the previous game. In other words, the nodes in the supply chain network usually have memories. Considering this, the author introduced the genetic algorithm with memory to analyse the evolutionary game of information sharing in supply chain network. The resulting model boasts profound practical significance to the solution of information sharing and interests coordination among enterprises in supply chain network.*

RÉSUMÉ. *La structure topologique du réseau de la chaîne d'approvisionnement influe directement sur l'efficacité du partage d'informations, qui est la clé de la rentabilité des entreprises. Considérant le réseau de la chaîne d'approvisionnement comme un réseau complexe, cet article analyse le jeu évolutionniste du partage d'informations et explore les effets de la topologie du réseau, de la probabilité de mutation du chromosome et du degré de punition sur les résultats évolutionniste du réseau. La simulation numérique révèle qu'il existe un plateau dans le processus de partage d'informations d'un réseau aléatoire mais* *n'existe pas dans celui du réseau classique, ce qui indique que le réseau aléatoire est plus favorable au partage d'informations entre entreprises de la chaîne d'approvisionnement; la probabilité de mutation du chromosome est positivement corrélée à l'augmentation de la fréquence de partage de l'information mais négativement à la stabilité de la fréquence; le degré de punition contribue au partage d'informations entre lesdites entreprises. Dans le cadre de la coopétition à long terme, les entreprises peuvent jouer à de multiples jeux de partage d'informations et de coordination des intérêts et ont tendance à ajuster leurs stratégies de jeu actuelles en fonction du résultat du jeu précédent. En d'autres termes, les nœuds du réseau de la chaîne d'approvisionnement ont généralement des mémoires. Considérant cela, l'auteur a introduit l'algorithme génétique avec mémoire pour analyser le jeu évolutionniste du partage d'informations dans le réseau de la chaîne d'approvisionnement. Le modèle qui en résulte a une profonde signification pratique pour la solution du partage d'informations et la coordination des intérêts entre les entreprises du réseau de la chaîne d'approvisionnement.*

KEYWORDS: *memory genetic algorithm, evolutionary game, supply chain network, information sharing.*

MOTS-CLÉS: *algorithme genetique de la memoire, jeu evolutionniste, reseau de la chaine d'approvisionnement, partage d'information.*

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1. Introduction

With the development of science and technology and the globalization of economy, social division of labor is becoming more and more sophisticated, more and more enterprises are in the supply chain, and their geographical distribution is also wider. Supply chain has gradually become a network composed of suppliers, manufacturers, distributors, logistics service providers and retailers all over the world. Many network members and their interdependence make the supply chain more complex, resulting in a supply chain network. Supply chain network can keep logistics, capital flow and information flow smooth and coordinated by controlling and coordinating the members and their behavior of each node in the network, so as to realize value added. Therefore, enterprises and relevant scholars expect to coordinate the network members of supply chain nodes by means of information sharing and supply chain management contracts. However, the members of each node have no motivation to realize information sharing because they aim to maximize their personal interests, which results in information delay and distortion in supply chain network. Through a certain contract and incentive system, private information sharing among members of supply chain network nodes can be realized, and then the cooperative operation goal of supply chain network can be achieved on the basis of information sharing.

The information sharing between supply chain network enterprises can promote cooperative development of the enterprises. When the enterprises share information mutually, the party obtaining and absorbing information gains direct gain, while the party sharing information needs to bear the cost of information sharing and the risk cost of information disclosure. Therefore, the information sharing on the supply chain network is essentially a game (Cachon and Netessine, 2004). The supply chain network is a complex network composed of manufacturers, distributors, customers and other entities. It integrates capital flow, logistics and information flow. Information sharing plays a very important role in the supply chain network: enterprise nodes in the supply chain network. There are often complementary information resources, through the sharing of information can produce synergies, promote the common development of both companies, and thus enhance competitiveness. In the actual supply chain network, because of the differences in scales, capacities, geographical locations and so forth among enterprises, different enterprises have different numbers of cooperation objects, and the supply chain network is not a fully connected network. The actual supply chain network is closer to a small, scale-free network. Under different topologies, the evolutionary game patterns of information sharing of the supply chain network are quite different. Therefore, it is of far reaching importance for information sharing of the supply chain network to study the complex network topologies of the supply chain.

With the dramatic developments in information and communication technologies, real-time information sharing has become increasingly easier to implement, information sharing is frequently cited as being the key to reducing supply chain cost. Rached *et al.* (2016) have studied a mono-product divergent supply chain composed of a supplier, a warehouse, retailers and customers in the context of decentralized and centralized decisions, the results have shown that incentives and revenue sharing contracts should be implemented to motivate and balance the benefits between supply chain partners. Huang *et al.* (2016) have analyzed the optimal degree of information sharing with consideration of the trade-off between the cost of collecting information and the benefits gained. Khan *et al.* (2016) studied an optimal shipment size and buyer's price are determined mathematically for the case of with- and without-sharing-information, It was observed that information sharing results in better annual profit with a drop in buyer's price. Fan *et al.* (2016) argued that a firm's capability in processing supply chain risk information, which comprises supply chain risk information sharing and supply chain risk information analysis, can improve operational performance, and this capability's effectiveness in improving performance is contingent on product-specific uncertainty characteristics and environment-related uncertainty characteristics. Huang *et al.* have considered a two-echelon supply chain with one supplier and one retailer for products with seasonal demand. Huang & Wang have analyzed the benefits of information sharing in a closed-loop supply chain with a manufacturer and adopt Stackelberg game to obtain equilibrium decisions of each remanufacturing scenario with/without information sharing, they have shown that information sharing always results in a profit increase to the manufacturer and the third party, whilst a profit loss to the distributor. Zhou *et al.* considered a supply chain composed of one GPO and two manufacturers competing in quantity, results show that under group purchasing, information sharing partially from the lower-precision manufacturer rather than both can benefit the supply chain. Firouzi *et al.* investigated the role of trust in supply forecast signaling in a supply chain with a supplier and a manufacturer in a one-shot game, the intuitive result indicated that the supplier has a tendency to deviate from reporting true forecast information. Zhao *et al.* extended the investigation of information sharing to the context where the manufacturer may have encroachment capability and may face production diseconomy or economy and found that information sharing improves the manufacturer profit and the supply chain performance if and only if the demand signal is very accurate and demand variable is relatively large. Zhang investigated the issue of demand forecast sharing in a supply chain, in which either the manufacturer or the retailer conducts demand-enhancing service. Wu *et al.* explored manufacturers' horizontal information sharing strategy under competition, they established manufacturers' information sharing strategies under different conditions and shows how supplier's pricing decision can shape manufacturers' information sharing incentives.

Information sharing in supply chain network is one of the important research contents. Jung & Matsumaru (2013) proposed a model on the feature of information sharing and load allocation in supply chain network. Navin *et al.* (2013) showed sharing of demand information between partnering echelons should not automatically be taken for granted as a direction for performance enhancement in alternative supply chain networks. Dev *et al.* (2013) concerned with the performance behavior of two different SC network structures given different design and control parameters adopted by the partnering echelons within the assumed SC configurations. Song *et al.* (2016) examined the effect of small and medium enterprises (SMEs)' supply chain network on influencing credit quality, or more specifically, whether bridging tie (structural network) or strong tie (relational network) of SMEs in the supply chain can improve the availability of equity and debt capital through information sharing.

The above related research has made important achievements in the information sharing mechanism of supply chain network, but considering the game relationship between supply chain enterprises, both sides of the game often consider the historical game records as a reference for making game strategies, that is, the nodes in the supply chain network usually have memory. However, there are few researches on the evolutionary game of information sharing in the supply chain network nodes with memory. In the process of game, the nodes usually compare the gains of their own and neighbor nodes, imitate the game behavior of the neighbor nodes with higher gain or integrate the game behaviors of some neighbor nodes, make the mutation of the comprehensive results under a certain probability and use them as their standards of conducts in formulating their own game strategies in the next game iteration. Such a game evolution mode can be described by the memory genetic algorithm. Therefore, in this dissertation, based on the above research results, the memory genetic algorithm is adopted to study the evolutionary game process on the supply chain network, describe the dynamic process of state change of the supply chain network by using the proportion of information sharing strategies in the supply chain network and then carry out the emulation analysis in allusion to different network types, different mutation possibilities and different punishment extents.

This model is of important practical significance to solve the problem of information sharing and benefit coordination among enterprises of different nodes in the supply chain network with different topologies. This paper consists of five parts, the first part is the introduction, the second part is the information sharing evolutionary game model, the third part is the expression of evolutionary game model with memory genetic algorithm, the fourth part is the numerical simulation, and the last part is the conclusion and outlook.

2. Evolutionary game model

Each node in the complex supply chain network represents an enterprise. If there is a connecting side between several nodes, it means that there is a cooperative relationship between two nodes and an information sharing game. In the iteration every time, all nodes are simultaneously in gaming with all their neighbors. The strategies adopted by both sides are related to those adopted in the recent three games between them. It is assumed that the total gain of each node on the complex supply chain network is the sum of the game proceeds with all neighboring nodes. When the two enterprises are in gaming, the proceeds can be divided into direct and cooperative gains. Direct gain is proportional to knowledge sharing K and knowledge absorption efficiency α. If both sides adopt the information sharing strategy, they may generate cooperative gains w. The cost of information sharing between enterprises on the complex supply chain network is λK, λ is a constant, which represents the proportional coefficient. When only one side shares the information, the enterprise not sharing the information should accept the punishment H. The bigger the H is, the stronger the punishment extent will be. The risk cost of the enterprise's information sharing is F. The gains of both sides are the sum of four parts: direct gain, synergetic gain, information sharing cost and penalty item, namely the gain matrix as shown in Table 1.

Table 1. Gain matrix

Suppliers	Manufacturer	
	Sharing	Non-sharing
Sharing	$K\alpha+w-\lambda K-F$, $K\alpha+w-\lambda K-F$	$\lambda K-F$, $K\alpha-H$
Non-sharing	$K\alpha-H$, $-\lambda K-F$	0,0

3. Memory genetic algorithm

In previous studies, the history of gaming may not be generally considered for the gaming between enterprises. In the process of actual cooperate gaming, not only current gain matrix but also historical gaming strategy should be taken into account during the selection of the strategies. It is assumed that each enterprise is in gaming with the enterprises having connecting edges with it and can remember three rounds of historical gaming of its own and opposite enterprises as the references for formulating the gaming strategy. The composition of the game strategy memory between two enterprises (A and B) is shown in the following memory table 2.

Table 2. Memory table of supply chain enterprises on complex network

Own strategy in last round	Opposite side's strategy in last round	Own strategy in penultimate round	Opposite side's strategy in penultimate round	Own strategy in antepenultimate round	Opposite side's strategy in antepenultimate round
b_A^1	b_B^1	b_A^2	b_B^2	b_A^3	b_B^3

where, $b_{alphabet}^i \in \{0,1\}, i = 1,2,3; alphabet = A, B$, 0 represents the strategy "without information sharing"; 1 represents the strategy "with information sharing". Assuming $B = (b_A^1, b_B^1, b_A^2, b_B^2, b_A^3, b_B^3)$, then the numeric range of B is (0,0,0,0,0,0)~(1,1,1,1,1,1), including 64 values, of which each corresponds to a memory state. Each memory state is numbered according to the rule of $N(B) = 2^5 b_A^1 + 2^4 b_B^1 + 2^3 b_A^2 + 2^2 b_B^2 + 2b_A^3 + b_B^3$. Actually, it is equivalent to map the binary member codes to decimal memory codes. For example, B=(0,0,0,0,0,0) corresponds to the code of 0; B=(1,1,1,1,1,1) to the code of 63.

When two enterprises A and B are in gaming on the supply chain network, the strategies selected in the historical gaming process of both sides should be firstly reviewed to establish a memory table (Table 2). The memory table contains a 6-digit binary number, totally including 2^6=64 different states. Each state represents a game history. In the history of each game, the enterprise can choose two strategies: share (expressed by 1) or not share the information (expressed by 0). The strategy selection of the enterprise in the different game histories constitutes the basis of its decision. It tells the enterprise to choose certain gaming strategy in certain gaming history. The 64 different decision-making behaviors corresponded by 64 game histories constitute a 64-dimension vector. The vector is a chromosome representing the decision model of the enterprise. The composition of the chromosome can be successively improved through the genetic algorithm, which can make the enterprise get higher expected gain in the game process.

The specific process of the memory genetic algorithm is as follows:

(1) Chromosome coding: the chromosome is coded into 64-digit 0 and 1 vectors, which correspond to strategies under 64 memories and are expressed in S=(s_1, s_2, …, s_{64}). For example, S=(0, 0, …, 0) means that the enterprise always holds the strategy of not sharing information in despite of historical gaming memory; and, S=(1, 1, …, 1) indicates that the enterprise always holds the strategy of sharing information in despite of historical gaming memory. There are totally 2^{64} chromosomes.

(2) Initialization: S value is randomly assigned to each enterprise node in the complex supply chain network. The previous three rounds of gaming history are randomly selected for all nodes in the network. The parameters of memory genetic algorithm are set up, including crossover probability, mutation probability, gain

matrix, iteration convergence condition and so on.

(3) Choice: The average gaming gain of each node in the network is calculated and regarded as the adaptability of the node. Two nodes are randomly selected according to the adaptability of each node and its neighbor nodes and the chromosomes of these two neighbor nodes are used as the parent chromosomes of the node.

(4) Cross and mutation: The parent node crosses and reconstructs with a certain probability to form two new chromosomes and one of the chromosomes is selected to carry out mutation operation with a certain probability and produce a new chromosome as the chromosome in the next iteration of the node.

(5) Record the current gaming strategy selection of each node and update the historical game table of each node in the next iteration process.

(6) If the iterative convergence condition is met (the change rate of adaptability is less than the threshold 0.001 or the number of iterations is greater than 1000), the genetic algorithm is tripped out, or otherwise Steps 3-6 are repeated.

To further explain the work process of memory genetic algorithm, a 5-node network is taken as an example in this dissertation and one iteration process is intercepted for description. The 5-node topology network is shown in Figure 1.

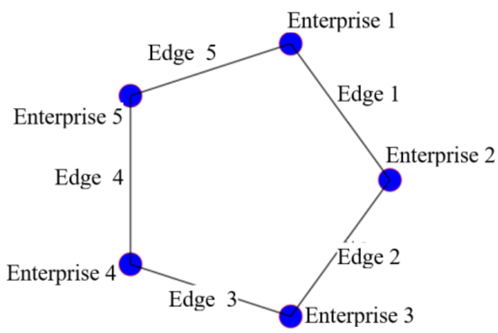

Figure 1. Network Topology Diagram

The chromosomes of 5 nodes are as follows:

$$S^1 = [1,0,1,0,1,1,1,1,1,1,1,1,0,0,0,0,0,0,1,1,1,1,1,1,0,0,0,0,1,1,1,1,1,0,0,0,0,0,1,1,1,1,1,0,0,0,0,0,1,1,1,1,1,0,0,0,0,0,1,1,1,1,1]$$

$$S^2 = [0,0,1,1,1,1,0,1,1,0,1,1,1,0,0,1,0,1,0,1,0,1,0,1,0,0,0,1,0,1,1,0,1,1,1,0,0,0,0,1,1,0,1,0,0,0,0,1,0,0,1,1,1,1,1,0,0,1,0,1,1,1,1,1]$$

$$S^3 = [0,0,1,0,0,0,1,0,0,1,1,1,1,0,1,0,1,0,1,1,1,1,1,1,1,0,0,0,0,1,1,1,1,1,0,0,0,0,0,1,1,1,1,1,0,1,0,1,0,1,1,1,1,1,0,1,0,1,0,1,1,1,1,0]$$

$$S^4 = [1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1]$$

$$S^5 = [1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0]$$

Enterprise 1 records the gaming history of Enterprise 2 and Enterprise 5, namely $B_{1,2}$=[1,1,0,0,1,0] and $B_{1,5}$=[0,0,0,1,1,1]; Enterprise 2 records the gaming history of Enterprise 1 and Enterprise 3, namely $B_{2,3}$=[0,0,1,1,0,1] and $B_{2,1}$=[1,1,0,0,0,1]; Enterprise 3 records the gaming history of Enterprise 2 and Enterprise 4, namely $B_{3,2}$=[0,0,1,1,1,0] and $B_{3,4}$=[1,1,1,1,1,1]; Enterprise 4 records the gaming history of Enterprise 3 and Enterprise 5, namely $B_{4,3}$=[1,1,1,1,1,1] and $B_{4,5}$=[0,0,0,0,0,0]; Enterprise 5 records the gaming history of Enterprise 4 and Enterprise 1, namely $B_{5,4}$=[0,0,0,0,0,0] and $B_{5,1}$=(0,0,1,0,1,1). The actual meaning of a chromosome is a set of strategies, which gives a specific game strategy for each game history: in the genetic algorithm, the game history B can be converted to a decimal number corresponding to a value in S, and the number should be the selected strategy. It is supposed that the gain matrix is as shown in Table 3.

Table 3. Example of Gain Matrix

Supplier	Manufacturer	
	Sharing	Non-sharing
Sharing	2,2	-1,3
Non-sharing	3,-1	0,0

When Enterprise 1 and Enterprise 2 are in gaming, they may firstly look at the game history of both sides and the game history seen by Enterprise 1 is $B_{1,2}$=[1,1,0,0,1,0]. According to the formula (1), $B_{1,2}$=[1,1,0,0,1,0] is converted to the number 50; then, according to the encoding method of the formula (1), the decimal encoding is done from 0, the number 50 corresponds to the order of 51, and so, the 51st number: 1, e.g. sharing information, in the S^1, should be the strategy adopted by Enterprise 1 during the gaming with Enterprise 2. Similarly, $B_{2,1}$=[1,1,0,0,0,1] is converted to thee number 49, which means that the strategy adopted by Enterprise 2 is the 50th number 0, e.g. not-sharing information, in S^2, during the gaming with Enterprise 1. It can been seen from the gain matrix that the gain of Enterprise 1 is -1 and that of Enterprises 2 is 3 in the game between Enterprise 1 and Enterprise 2. Similarly, in the game between Enterprise 2 and Enterprise 3, the gains of both sides are -1 and 3, respectively; in the game between Enterprise 3 and Enterprise 4, the gains of both sides are -1 and 3, respectively; in the game between Enterprise 4 and Enterprise 5, the gains of both sides are 2 and 2, respectively; in the game between Enterprise 5 and Enterprise 1, the gains of both sides are 2 and 2, respectively. In the game with Enterprise 2 and 5, the gains of Enterprise 1 are -1 and 2, respectively, and the adaptability of Enterprise 1 is defined as the mean of all gains, namely (-1+2) /2=0.5. In the same methods, the adaptabilities of other four enterprises can be calculated. Through calculation, the adaptabilities of Enterprise 1-5 are 0.5, 1, 1, 2.5 and 2, respectively. Because there are negative values for the adaptabilities, the values of adaptabilities are sorted out from small to big in this dissertation. Then, the probability that a node is selected is proportional to the sequence number when the parent chromosome is selected. For example, the probabilities of Enterprise 1-5 selected as the parent chromosome of Enterprise 1 are 1/15, 2/15, 3/15, 5/15 and 4 /15, respectively.

4. Numerical simulation

Three-term numerical simulations are carried out in this dissertation. In each numerical simulation experiment, the parameters are set as risk cost F=1, corporate sharing information K=10, proportional factor of information sharing cost λ=0.2, synergetic gain w=2, cross probability cp=0.3, number of mutation probability network nodes N=100, fixed punishment H=8 and mutation probability mp=0.1, and the topological structure is a randomly-reconnected network (reconnection probability is 0.2). In this dissertation, the proportion of information-sharing individuals to overall number is adopted to measure the dynamic change process of the evolutionary game of information sharing. The gain matrix in the gaming of each pair of individuals is calculated according to the parameters set in the simulation experiment and the expressions of the gain matrix in Table 1.

4.1. Effect of network topology on evolutionary game

The simulation experiment is to study the effect of topological structure on the evolutionary game of information sharing on the supply chain network. Under the condition that other parameters are fixed, the regular network and the randomly-reconnected network (the reconnection probability is 0.2) are adopted for the parameters of the topological structure. The topological diagram of the regular network is shown in Figure 2, of which each node is connected to two adjacent points at the left and right sides and the mean value is 4. For the randomly-reconnected network, a node is randomly selected at each side with the probability 0.2 for reconnection on the basis of a regular network and the network topology diagram is as shown in Figure 3. The randomly-reconnected network has small-world properties and the average value of the network node is 4.

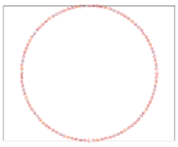

Figure 2. Regular network

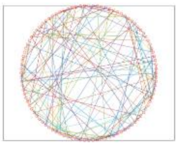

Figure 3. Randomly-reconnected network

In each round of the game, there are totally 200 games in the complex network, including 400 pure-game strategies (sharing information or not-sharing information). The proportion of the information-sharing strategy in the iteration is recorded and 1000 iterations are totally carried out to get the change diagram of information-sharing frequency as shown in Figure 4. Figure 4A shows the frequency change diagram of the regular network; Figure 4B represents the frequency change diagram of the randomly-reconnected network. It can be seen from comparison of Figure 4A and 4B that the frequency variation on the regular network is approximately a straight line, while there are many "plateaus" in the frequency change of the randomly-reconnected network. The information-sharing frequencies on both networks are approaching to 1, indicating that more and more cooperative strategies are adopted on the network. The fluctuation of frequency variation curve is caused by chromosome mutation. The true supply chain network is always not a regular network, but a network structure with the small-world properties of the randomly-reconnected network. Therefore, in the process of promoting information sharing by some measures, it is likely to fall into the similar "plateau" found in the simulation experiment. When trapping in the "plateau", we should continuously insist on the original policy and push forward the development of information sharing cooperation.

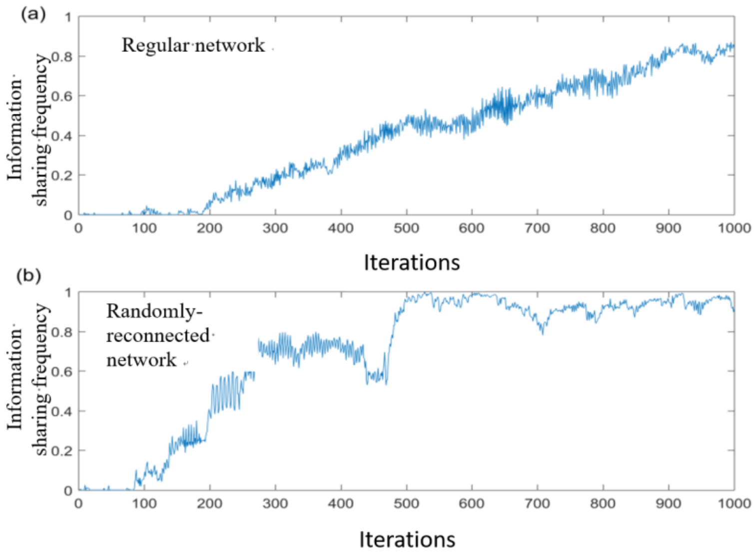

Figure 4. Comparison diagram for evolution of supply chain network under different network topology

4.2. Effect of chromosome mutation probability on evolutionary game

The simulation experiment is to study the effect of chromosome mutation probability on the evolutionary game of information sharing. Under the condition that other parameters are fixed, the chromosome mutation probabilities are set as 0.1 and 0.3, respective. The simulation results are shown in Figure 5. The convergence rate of frequency in Figure 5A (mutation probability 0.1) is obviously slower than that in Figure 5B (mutation probability 0.3), while it is more stable after convergence in the curve of Figure 5A. It can be understood that, in a group of non-cooperative individuals, some cooperators may always be generated by mutation. They are waiting for the right time to survive and the higher chromosome mutation probability can more quickly produce an environment suitable for the survival of the cooperators. In the supply chain network, mutation means the reform of the enterprise and the probability of mutation indicates the willingness of the enterprise to reform. In order to promote cooperation, the enterprise should be actively encouraged to change the original policies of information non-sharing. When the enterprise adopting information-sharing strategy is up to a certain initial proportion, the advantage of information sharing will appear, and the proportion of sharing-information strategy in the supply chain network will also be developed rapidly.

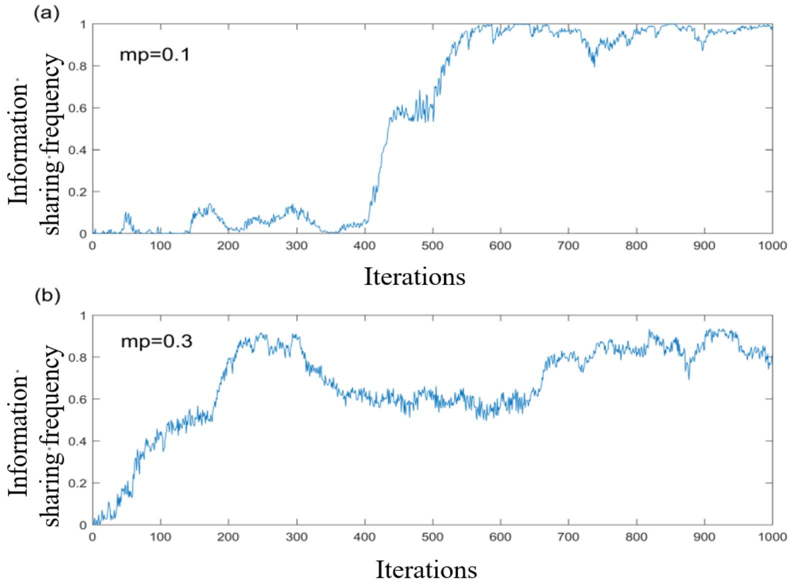

Figure 5. Comparison diagram for evolution of supply chain network under different mutation frequencies

4.3. Effect of punishment extent on evolutionary game

The simulation experiment is to study the effect of punishment extent on the evolutionary game of information sharing. Under the condition that other parameters are fixed, the punishment extent is set as 0 and 8, respectively. Figure 6A shows the information sharing frequency curve at punishment extent 0 and Figure 6B the information sharing frequency curve at punishment extent 8. It can be seen from comparison of Figure 6a and Figure 6B that the improvement of the punishment extent is beneficial to generate the cooperation in complex supply chain network.

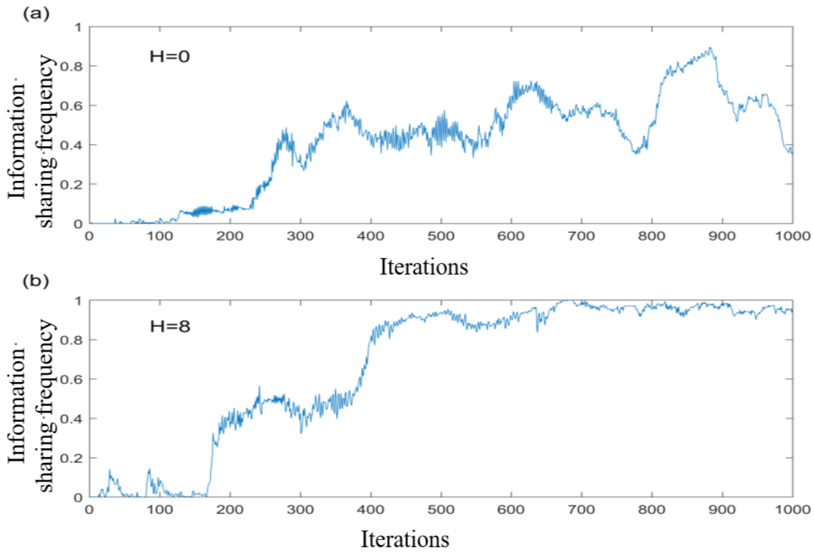

Figure 6. Comparison diagram for evolution of supply chain network under different punishment extents

5. Conclusion and expectation

In this dissertation, the memory genetic algorithm is adopted to analyze the evolutionary game of information sharing on the complex supply chain network. In combination with the numerical simulation, the research results indicate: the topological structure of the complex network has certain effect on the evolutionary game of information sharing, and the randomly-reconnected network is more propitious to raise the cooperation than the regular network; the chromosome mutation probability has certain effect on the evolutionary game of information sharing, and the cooperation emerges more quickly and the network cooperation frequency is more stable in case of high mutation rate; the punishment extent has certain effect on the evolutionary game of information sharing as well and the greater punishment extent is more propitious to generate cooperation in a complex network. Besides the above conclusions, the dissertation still has more aspects to be studied further. Besides the above regular network on the circle, the effects of regular network on two-dimensional square lattice, scale-free network and so forth on the evolutionary game should be further analyzed.

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