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Dynamic Evolutionary Game Analysis of Symbiosis System in E-commerce Industrial Park

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Abstract: Based on the evolutionary game theory and the bounded rational and asymmetric information assumptions, we construct the dynamic evolutionary game model between the three game players and analyze the replication dynamic equations. Furthermore, we analyze the strategy of three symbiosis units and the evolution mechanism of E-commerce industrial park symbiosis system. Finally, two conclusions are drawn: Conclusion 1, the probability that three symbiosis units of E-commerce Industrial Park choosing the symbiosis strategy increases with increase of the probability that the other two symbiosis units selecting the symbiosis strategy. Conclusion 2, the probability of the symbiosis unit to choose the symbiosis strategy increase with the increase of the benefit and decrease with the increase of the cost, risk and loss.

Keywords: E-commerce industrial park, Symbiosis system, Evolutionary game

1. INTRODUCTION

Evolutionary game, combined traditional game theory and dynamic evolution, is a game model which is about interaction and iterative process of behavioral strategies of behavioral subjects. The research object is not the simple behavioral subject but ‘population’, focusing on the evolution of population structure instead of the utility analysis of simple behavioral subject. The basic idea of evolutionary game theory is that the game players are searching ‘Evolutionary Stable Strategy (ESS)’ by repetitively imitation and improving own optimal strategy under the bounded rational and asymmetric information assumptions, which is a long-term and dynamic process. In fact, such imitation and improvement is a process of adaption.

As an emerging economy which includes ‘internet plus and the real economy’ and ‘internet plus and industrial park’, e-commerce industrial park is a spatial concentration about the regional e-commerce industries. Coordination and interaction between various of e-commerce enterprises and organizations, which aims to pursue harmonious and mutually beneficial development, can promote the network and prosperity of the e-commerce industry. The coupling process of the evolution of e-commerce industrial park symbiosis system are double couplings including the relationships between enterprises and the relationships between the environment and enterprises. The coupling among enterprises is the outward manifestation and the coupling between the environment and enterprises is the interior impetus. In the embryonic stage of the symbiosis system of e-commerce industrial park, the enterprise to adapt itself to environment by being coupled with other enterprises and establishment a symbiotic and cooperative relationship through the intermittent point symbiosis model. Coordination seems formation of symbiotic network, which is a process of game for enterprises. The symbiotic stabilization strategy selection process of units in e-commerce industrial park is similar to a process named 'searching stable strategy’ mentioned in evolutionary game.

Therefore, from the perspective of evolutionary game, the paper studies the evolutionary mechanism of symbiosis behavior strategy of the three game subjects such as the core unit, the supporting unit and the derivative unit in the symbiosis system of e-commerce industrial park. Further the paper analyzes the reasons of the selection of ‘symbiosis’ and ‘no symbiosis’ in the three game subjects. We build the payoff matrix of the

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core unit, the supporting unit and the derivative unit and format replicated dynamic equation to search evolutionary stable strategy. Finally, we analyze the evolutionary game model.

2. SYMBIOSIS SYSTEM OF E-COMMERCE INDUSTRIAL PARK

The study of e-commerce industrial park system requires the application of symbiosis theory, industrial ecosystem theory and industrial cluster theory. In a certain symbiotic environment, upstream and downstream firms and institutions form symbiotic relationship, symbiosis network and symbiosis mechanism based on the value chain of information flow, logistics and capital flow to attain increment of value[1]. In order to save costs, access to external economy of scale, easier communication and sharing infrastructure, e-commerce key enterprises, e-commerce services enterprises, e-commerce derivative enterprises aggregate spatially. These behavioral agents establish virtual value chain and real value chain by social communication, material exchanging, knowledge spillovers and information sharing and so on, and then form a community with relatively stable symbiotic partnership to obtain long-tern competitive advantage. That can finally promotes the optimization and upgrade of e-commerce industrial structure, elevates resource allocation efficiency and accelerates the formation of innovation network[2]-[3].

Hu[4]-[5] divided the 'species' of system into leading species, key species, supporting species and derivative species based on the definition of various 'species' in e-commerce ecosystem, and pointed out that the evolution of e-commerce ecosystem includes four main stages: exploration, expansion, coordination and evolution. Ji[6]analyzed the four evolution stages of e-commerce ecosystem and pointed out the characteristics of each evolution stage. Sun[7] divided ecological community into universities and research institutions, financing institutions, intermediaries, e-commerce enterprises, affiliated enterprises and government agencies according to the differences of functions of organizations in e-commerce industry. Four types of e-commerce enterprise in e-commerce industrial park such as e-commerce transaction service platforms, the enterprises using the third-party platform to carry out business (network business enterprise), e-commerce supporting service enterprises and e-commerce derivative service enterprises are divided by Ministry of Commerce. These 4 types of e-commerce enterprises are in the same e-commerce system, but with different strategic choices, so that enterprises constantly adjust their strategies in competition and cooperation[8]. E-commerce industrial park combines enterprises with different business to consolidate cooperation between them. And the symbiotic system is a process of dynamic equilibrium realization and maintenance so that we can adopt evolutionary game method to study it[9]. Evolutionary game theory assumes that all players are finite rational and studies the strategic choices of different players[10]. From the perspective of industrial symbiosis, Feng[11] studied the influencing factors of industrial symbiosis behavior based on evolutionary game theory. Li [12] believed that a reasonable cost allocation ratio and effective reward and punishment mechanism could effectively enhance the value of collaborative innovation, and has built the evolutionary game model of industry-university-research collaborative innovation to demonstrate it.

The paper divides the symbiosis system of e-commerce industrial park into core system, supporting system and derivative system, which is based on the results of the other scholars, combined with the characteristic of e-commerce industrial park and according to the differences of the delivering and exchanging energies of different organizations in symbiosis system of e-commerce industrial park. These three subsystems also include several tiny systems[2],[6],[9]. Figure 1 shows the symbiosis system of e-commerce industrial park.

(1) Core system includes e-commerce service platforms and e-commerce transaction enterprises (network business enterprise such as manufacturer, supplier and merchant and so on), which is the leading population of the ecosystem in e-commerce industrial park. The growth of central population guide the development of the entire e-commerce industrial park.

(2) Supporting system includes operation and management enterprise of industrial park, logistics company, financial institutions, network operators, government agencies, research institutions, which is the supporting population of ecosystem in e-commerce industrial park and the organization that e-commerce industry park business transactions must be attached to. Supporting population is the key element to guarantee the operation and development of e-commerce industrial park. And the supporting system is also the safeguard population in e-commerce industrial park.

(3) Derivative system includes network marketing service providers, technology outsourcing service providers, e-commerce consulting service providers, application service providers, which is the supplier providing value-added service for e-commerce. Derivative is the dependent population of the ecosystem in e-commerce industrial park.

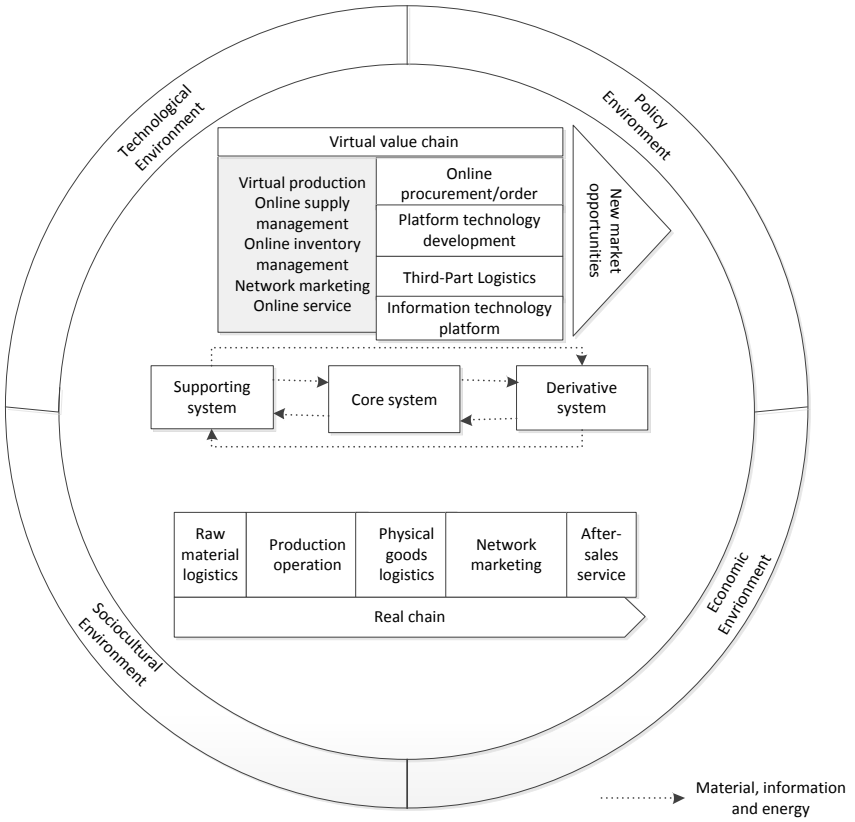

Figure 1. Symbiosis system of e-commerce industrial park

3. THE DYNAMIC EVOLUTIONARY GAME ANALYSIS OF THE SYMBIOTIC SYSTEM OF E-COMMERCE INDUSTRIAL PARK

There are two adaptive paths that formed the process of development and evolution of e-commerce industrial park, the first path stemmed from the core unit, the support unit and the derivative unit, and the other one from those units and the symbiosis environment, two paths work together to promote the development of the symbiotic system of e-commerce industry park. In the infancy of e-commerce industrial park, the core system unit, support unit and derivative unit attempted to establish intermittent point symbiotic relationship with other enterprises or organizations for adapting the change of environment. The process of establishing the symbiotic relationship between the three symbiotic units is the process of the game, and interact cooperation of three manifests the formation of the symbiosis network. The strategy selection process of three symbiotic units is the process of ‘seeking stable strategy’ that is concerned by evolutionary game theory.

This section focus on the core units, support units and derivative unit of e-commerce industrial park symbiotic system, builds the dynamic evolutionary model of three game subject under the condition of limited rationality and the asymmetric information hypothesis, and analyzes the replicated dynamic equation. Then we analyze which strategies (independent strategy or symbiosis strategy) can be chosen by three symbiotic units and how the strategy influence the overall evolution of the symbiotic system of e-commerce industrial park.

3.1 The basic assumptions

Assumption 1: the three symbiotic units of the game are limited rational, information asymmetry and aim to maximize their own interests.

Assumption 2: both the core unit, the supporting unit and the derived unit can choose the two strategies of symbiosis and independence.

Assumption 3: the core unit, support unit and derivative unit take independent strategy can earn π1,π2,π3 respectively, the proportion of taking symbiosis strategy is x, y and z. When take the symbiosis strategy, the cost of three units is c1, c2, c3, and the revenue is r1, r2, r3. Meanwhile, the revenue risk that these units face is α1, α2, α3.

Assumption 4: if the core unit chooses the symbiotic strategy, one of other two units choose independence strategy, the core unit will suffer loss i1; In the same way, the support unit and the derived unit will suffer loss i2, i3 respectively if the core unit chooses independence strategy.

3.2 Model specification

On the basis of the above assumptions, the symbiotic evolutionary game payoff matrix of e-commerce industrial park is shown in table 1, the game strategy and the profit value in the table corresponding to the core units, support units and derived unit.

Table 1. Information system levels

Game strategy	Profit value
（symbiosis，symbiosis，symbiosis）	$(\alpha_1\gamma_1 - c_1, \alpha_2\gamma_2 - c_2, \alpha_3\gamma_3 - c_3)$
（symbiosis，symbiosis，independence）	$(\alpha_1\gamma_1 - c_1 - i_1, \alpha_2\gamma_2 - c_2 - i_2, \pi_3)$
（symbiosis，independence，symbiosis）	$(\alpha_1\gamma_1 - c_1 - i_1, \pi_2, \alpha_3\gamma_3 - c_3 - i_3)$
（symbiosis，independence，independence）	$(\alpha_1\gamma_1 - c_1 - i_1, \pi_2, \pi_3)$
（independence，symbiosis，symbiosis）	$(\pi_1, \alpha_2\gamma_2 - c_2 - i_2, \alpha_3\gamma_3 - c_3 - i_3)$
（independence，symbiosis，independence）	$(\pi_1, \alpha_2\gamma_2 - c_2 - i_2, \pi_3)$
（independence，independence，symbiosis）	$(\pi_1, \pi_2, \alpha_3\gamma_3 - c_3 - i_3)$
（independence，independence，independence）	(π_1, π_2, π_3)

3.3 Solution method for model

(1) The dynamic replication equation of the core unit

The expected revenue of the core unit when it choose the symbiotic strategy is:

$$E(A_1) = yz(\alpha_1\gamma_1 - c_1) + y(1-z)(\alpha_1\gamma_1 - c_1 - i_1) + z(1-y)(\alpha_1\gamma_1 - c_1 - i_1) + (1-y)(1-z)(\alpha_1\gamma_1 - c_1 - i_1) = \alpha_1\gamma_1 - c_1 - i_1 + yzi_1 \quad (3\text{-}1)$$

The expected revenue of the core unit when it choose the independent strategy is:

$$E(A_2) = yz\pi_1 + y(1-z)\pi_1 + (1-y)z\pi_1 + (1-y)(1-z)\pi_1 = \pi_1 \quad (3\text{-}2)$$

The dynamic replication equation of the core unit is:

$$F(x) = \frac{dx}{dt} = x(1-x)(\alpha_1\gamma_1 - c_1 - i_1 + yzi_1 - \pi_1) \tag{3-3}$$

（Ⅰ）When $y = \frac{-\alpha_1\gamma_1 + c_1 + i_1 + \pi_1}{zi_1}$, $F(x) = 0$, whatever the value of x is, we will get the same answer that means these units can obtain a stable state;

（Ⅱ）When $y \neq \frac{-\alpha_1\gamma_1 + c_1 + i_1 + \pi_1}{zi_1}$, we set $F(x) = 0$, and in this time both *x*=0 and *x*=1 will acquire the same answer and those units can gain a stable state;

We can make a derivative of F(*x*) : $\frac{dF(x)}{dx} = (1-2x)(\alpha_1\gamma_1 - c_1 - i_1 + yzi_1 - \pi_1)$

The influence of the probability y that the support unit chooses the symbiotic strategy to the probability x that the core unit choose symbiotic strategy:

①When $y > \frac{-\alpha_1\gamma_1 + c_1 + i_1 + \pi_1}{zi_1}$, $\frac{dF(x)}{dx}|x = 0 > 0$, $\frac{dF(x)}{dx}|x = 1 < 0$, x =1 will become the evolutionary stable point, that means symbiosis is the stable strategy of the core unit;

②When $y < \frac{-\alpha_1\gamma_1 + c_1 + i_1 + \pi_1}{zi_1}$, $\frac{dF(x)}{dx}|x = 0 < 0$, $\frac{dF(x)}{dx}|x = 1 > 0$, x =0 will become the evolutionary stable strategy, that means independence is the stable strategy of the core unit;

In the same way, we can acquire the influence of the probability z that the derivative unit choose the symbiotic strategy to the probability x that the core unit choose symbiotic strategy.

When $z > \frac{-\alpha_1\gamma_1 + c_1 + i_1 + \pi_1}{yi_1}$, the stable strategy of the core unit is symbiosis;

When $z < \frac{-\alpha_1\gamma_1 + c_1 + i_1 + \pi_1}{yi_1}$, the stable strategy of the core unit is independence.

(2) The dynamic replication equation of the support unit

The expected revenue that the support unit choose the symbiotic strategy is:

$$E(B_1) = xz(\alpha_2\gamma_2 - c_2) + x(1-z)(\alpha_2\gamma_2 - c_2 - i_2) + z(1-x)(\alpha_2\gamma_2 - c_2 - i_2) + (1-x)(1-z)(\alpha_2\gamma_2 - c_2 - i_2) = \alpha_2\gamma_2 - c_2 - i_2 + xzi_2 \tag{3-4}$$

The expected revenue that the support unit choose the independence strategy is:

$$E(B_2) = xz\pi_2 + x(1-z)\pi_2 + (1-x)z\pi_2 + (1-x)(1-z)\pi_2 = \pi_2 \tag{3-5}$$

The dynamic replication equation of the support unit is:

$$F(y) = \frac{dy}{dt} = y(1-y)(\alpha_2\gamma_2 - c_2 - i_2 + xzi_2 - \pi_2) \tag{3-6}$$

（Ⅰ）When $z = \frac{-\alpha_2\gamma_2 + c_2 + i_2 + \pi_2}{xi_2}$, $F(y) = 0$, whatever the value of y is, we will get the same answer that means these units can obtain a stable state;

（Ⅱ）When $z \neq \frac{-\alpha_2\gamma_2 + c_2 + i_2 + \pi_2}{xi_2}$, we set $F(y) = 0$, and in this time both y=0 and y=1 will acquire the same answer and those units can gain a stable state;

Calculating the derivative of *F*(*y*): $F(y) = \frac{dy}{dt} = y(1-y)(\alpha_2\gamma_2 - c_2 - i_2 + xzi_2 - \pi_2)$

We can get that $\frac{dF(y)}{dy} = (1-2y)(\alpha_2\gamma_2 - c_2 - i_2 + xzi_2 - \pi_2)$. In this time, there are two situations:

①When $z > \frac{-\alpha_2\gamma_2+c_2+i_2+\pi_2}{xi_2}$, $\frac{dF(y)}{dy}|y=0>0$, $\frac{dF(y)}{dy}|y=1<0$, y =1, will become the evolutionary stable point, that means symbiosis is the stable strategy of the support unit;

②When $z < \frac{-\alpha_2\gamma_2+c_2+i_2+\pi_2}{xi_2}$, $\frac{dF(y)}{dy}|y=0<0$, $\frac{dF(y)}{dy}|y=1>0$, y =0, will become the evolutionary stable strategy, that means independence is the stable strategy of the support unit.

(3) The dynamic replication equation of the derivative unit

The expected revenue of the derivative unit when it choose the symbiotic strategy is:

$$E(C_1) = xy(\alpha_3\gamma_3 - c_3) + x(1-y)(\alpha_3\gamma_3 - c_3 - i_3) + y(1-x)(\alpha_3\gamma_3 - c_3 - i_3) + (1-x)(1-y)(\alpha_3\gamma_3 - c_3 - i_3) = \alpha_3\gamma_3 - c_3 - i_3 + xyi_2 \quad (3\text{-}7)$$

The expected revenue of the derivative unit when it choose the independent strategy is:

$$E(C_2) = xy\pi_3 + x(1-y)\pi_3 + y(1-x)\pi_3 + (1-x)(1-y)\pi_3 = \pi_3 \quad (3\text{-}8)$$

The dynamic replication equation of the derivative unit is:

$$F(z) = \frac{dz}{dt} = z(1-z)(\alpha_3\gamma_3 - c_3 - i_3 + xyi_3 - \pi_3) \quad (3\text{-}9)$$

（Ⅰ）When $x = \frac{-\alpha_3\gamma_3+c_3+i_3+\pi_3}{yi_3}$, $F(z)=0$, whatever the value of z is, we will get the same answer that means these units can obtain a stable state;

（Ⅱ）When $x \neq \frac{-\alpha_3\gamma_3+c_3+i_3+\pi_3}{yi_3}$, we set $F(z)=0$, and in this time both $z=0$ and $z=1$ will acquire the same answer and those units can gain a stable state;

Calculating the derivative of *F*(z): $F(z) = \frac{dz}{dt} = z(1-z)(\alpha_3\gamma_3 - c_3 - i_3 + xyi_3 - \pi_3)$

We can get that $\frac{df(z)}{dz} = (1-2z)(\alpha_3\gamma_3 - c_3 - i_3 + xyi_3 - \pi_3)$. In this time, there are two situations:

①When $x > \frac{-\alpha_3\gamma_3+c_3+i_3+\pi_3}{yi_3}$, $\frac{df(z)}{dz}|z=0>0$, $\frac{df(z)}{dz}|z=1<0$, z =1 will become the evolutionary stable point, that means symbiosis is the stable strategy of the derivative unit;

②When $x < \frac{-\alpha_3\gamma_3+c_3+i_3+\pi_3}{yi_3}$, $\frac{df(z)}{dz}|z=0<0$, $\frac{df(z)}{dz}|z=1>0$, z =0 will become the evolutionary stable strategy, that means independence is the stable strategy of the derivative unit.

(4) Comprehensive model analysis

Set $\frac{dx}{dt} = \frac{dy}{dt} = \frac{dz}{dt} = 0$, in the set $M\{(x,y,z); 0 \le x,y,z \le 1\}$ of three-dimensional linear space R^3, the correlation points between core units, support units, and derived units are $O(0, 0, 0)$, $E_1(1, 0, 0)$, $E_2(0, 1, 0)$, $E_3(0, 0, 1)$, $E_4(1, 1, 0)$, $E_5(1, 0, 1)$, $E_6(0, 1, 1)$, $E_7(1, 1, 1)$ and 9 partial balance points of saddle point $S(x^*, y^*, z^*)$.

$$\begin{cases} x^* = \dfrac{\sqrt{\frac{i_3c_2c_1+i_3c_2i_1+i_3c_2\pi_1+i_3\pi_2c_1+i_3\pi_2i_1+i_3\pi_2\pi_1+i_3c_1i_2+i_3i_1i_2+i_3\pi_1i_2-i_3c_2\alpha_2r_1-i_3\pi_2\alpha_2r_1-i_3\alpha_1r_1i_2-i_3\alpha_2r_2c_1-i_3\alpha_2r_2i_1-i_3\alpha_2r_2\pi_1+i_3\alpha_2r_2\alpha_1r_1}{c_3i_1i_2+i_3i_1i_2+\pi_3i_1i_2-\alpha_3r_3i_1i_2}}}{i_3c_1+i_3i_1+i_3\pi_1-i_3\alpha_1r_1} \\ \quad *(c_3i_1+i_3i_1+\pi_3i_1-\alpha_3r_3i_1) \\ y^* = \dfrac{\sqrt{\frac{i_3c_2c_1+i_3c_2i_1+i_3c_2\pi_1+i_3\pi_2c_1+i_3\pi_2i_1+i_3\pi_2\pi_1+i_3c_1i_2+i_3i_1i_2+i_3\pi_1i_2-i_3c_2\alpha_2r_1-i_3\pi_2\alpha_2r_1-i_3\alpha_1r_1i_2-i_3\alpha_2r_2c_1-i_3\alpha_2r_2i_1-i_3\alpha_2r_2\pi_1+i_3\alpha_2r_2\alpha_1r_1}{c_3i_1i_2+i_3i_1i_2+\pi_3i_1i_2-\alpha_3r_3i_1i_2}}}{i_3c_2+i_3i_2+i_3\pi_2-i_3\alpha_2r_2} \\ \quad *(c_3i_2+i_3i_2+\pi_3i_2-\alpha_3r_3i_2) \\ z^* = \sqrt{\frac{i_3c_2c_1+i_3c_2i_1+i_3c_2\pi_1+i_3\pi_2c_1+i_3\pi_2i_1+i_3\pi_2\pi_1+i_3c_1i_2+i_3i_1i_2+i_3\pi_1i_2-i_3c_2\alpha_2r_1-i_3\pi_2\alpha_2r_1-i_3\alpha_1r_1i_2-i_3\alpha_2r_2c_1-i_3\alpha_2r_2i_1-i_3\alpha_2r_2\pi_1+i_3\alpha_2r_2\alpha_1r_1}{c_3i_1i_2+i_3i_1i_2+\pi_3i_1i_2-\alpha_3r_3i_1i_2}} \end{cases}$$

In 9 partial balance points, balance point $O(0, 0, 0)$ and $E_7(1, 1, 1)$ are stable point, and it is the evolutionary stable strategy of the symbiotic unit of e-commerce industrial park. These two points correspond to two strategies of core unit, support unit and derived unit respectively. One is the (independence, independence, independence) and the other is (symbiosis, symbiosis, symbiosis). Figure 2 shows the dynamic evolution path of the three-way game of three symbiotic units.

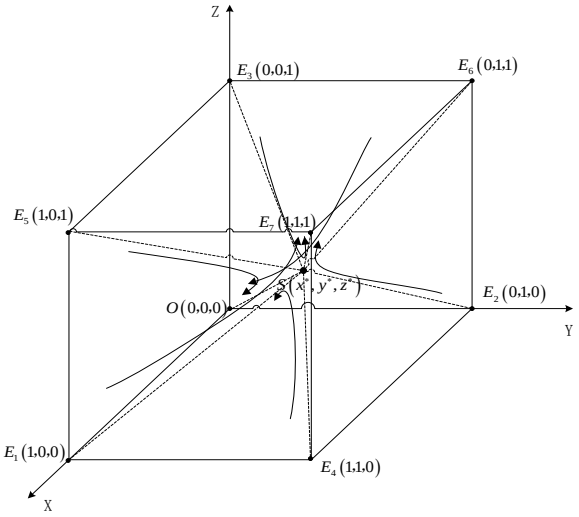

Figure 2. The web of system performance

According to figure 2, three symbiotic units of e-commerce industrial park symbiotic system will eventually converge to point $O(0, 0, 0)$ or point $E_7(1, 1, 1)$ in the evolutionary game, in other words, the core units, support units, derivative units will gradually become fully independent or completely symbiosis. When the three symbiotic units converge to point $O(0,0,0)$, the symbiotic units within the e-commerce industrial park will present a completely independent relationship; when units converge to point $E_7(1, 1, 1)$, it present a entirely collaborative relationship. According to the figure 2, we can find that point $O(0, 0, 0)$, $E_1(1, 0, 0)$, $E_2(0, 1, 0)$, $E_3(0, 0, 1)$, $E_4(1, 1, 0)$, $E_5(1, 0, 1)$, $E_6(0, 1, 1)$ and saddle point $S(x^*, y^*, z^*)$ can form three tetrahedron, that are $S\text{-}OE_1E_4E_2$, $S\text{-}OE_1E_5E_3$ and $S\text{-}OE_2E_6E_3$, and the sum of three tetrahedral volume is the probability that the ecosystem evolutionary process of e-commerce industry park converges to complete independence. We can also find that point $E_1(1, 0, 0)$, $E_2(0, 1, 0)$, $E_3(0, 0, 1)$, $E_4(1, 1, 0)$, $E_5(1, 0, 1)$, $E_6(0, 1, 1)$, $E_7(1, 1, 1)$and the saddle point $S(x^*, y^*, z^*)$ can form the other three tetrahedron, that is $S\text{-}E_7E_5E_1E_4$, $S\text{-}E_7E_5E_3E_6$, and $S\text{-}E_7E_4E_2E_6$, and the sum of three tetrahedral volume is the probability that the ecosystem evolutionary process of e-commerce industry park converges to complete symbiosis.

4. CONCLUSIONS

Conclusion 1: the probability that three symbiotic units of the e-commerce industrial park choose the symbiotic strategy increases follow the augment of the probability that other two symbiotic units choose the symbiosis strategy.

Proof: based on calculation of the dynamic replication equation of the core unit, we can find that symbiosis is the stability strategy of the core unit when $y > \frac{-\alpha_1\gamma_1+c_1+i_1+\pi_1}{zi_1}$. When $z > \frac{-\alpha_1\gamma_1+c_1+i_1+\pi_1}{yi_1}$, the stability strategy of the core unit is symbiosis, then we can find that the probability that the core unit choose the symbiotic strategy increases follow the augment of the probability that other two symbiotic units choose the symbiosis strategy. Similarly, we can prove other units.

Conclusion 2: the probability that the core units choose the symbiotic strategy will increase when the revenue that choosing symbiosis strategy soars, and when costs, risks and losses that choosing symbiosis strategy increase, the probability will decrease.

Proof: On the basis of the above known, when $y > \frac{-\alpha_1\gamma_1+c_1+i_1+\pi_1}{zi_1}$, the stable strategy of the core unit is symbiosis, then we can get $\pi < -\alpha_1\gamma_1 + c_1 - (1-yz)i_1$. Therefore, we can prove the conclusion 2 undoubtedly. Similarly, we can prove other units.

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