Wireless Pers Commun
https://doi.org/10.1007/s11277-017-5110-6

Screening of Port Enterprise Value Chain Routines Based on Evolution Equilibrium

Bing Han[1,2] · Pengfei Zhang[1,2] · Haibo Kuang[1,2] · Min Wan[1,2]

Abstract In order to find the screening mechanism of port enterprises value chain routines, based on describing the selection of port enterprises value chain routines, an evolutionary game model is presented and constructed. Using this model, we analyze the strategy of port enterprises value chain routines when they achieve the stability of the evolution. The results show that port enterprise value chain routine selection is a dynamic and repeated game. The expected revenue and convention cost of routines taking part in the game playing directly correlate with the evolutionary stable strategy and the selection of port enterprises value chain routines tend to be conservative strategy. Introducing evolutionary game theory provides a new perspective for the study on the formation, search and selection of port enterprises value chain routines and provides favorable theoretical support for further research in related fields.

Keywords Evolutionary game · Port enterprises value chain routines · Routine selection

✉ Bing Han
hanbing0610@163.com

Pengfei Zhang
haerbinzpf@163.com

Haibo Kuang
khb@dlmu.edu.cn

Min Wan
15724527153@163.com

1 Shipping Economics and Management College, Dalian Maritime University, Dalian, China

2 Collaborative Innovation Center for Transport Studies, Dalian Maritime University, Dalian, China

Published online: 11 December 2017

1 Introduction

Due to the geographical limits and the lack of strong policy guidance, China's port industry layout is relatively scatted for a long-term and port resource use efficiency has not been effectively improved. Since the establishment of China (Shanghai) Pilot Free Trade Zone, the opening-up policy has promoted the principal part of China's port value chain to deal with the impact of international competition, such as repositioning, integrating and assigning, etc. The establishment of China (Shanghai) Pilot Free Trade Zone has brought opportunities for the development of port enterprises. At the same time, the new policy, service demand and environment have also brought challenges to the port enterprises. In the face of new opportunities and challenges, the port enterprise value chain urgently needs to make corresponding adjustment and innovation, so the mechanism of value chain routines selection will be of great significance to increasing the value of port enterprises, business model innovation, and assigning the source of port industry.

Based on the relevance of products and services, port managing entities (including port logistics, shipbuilding, manufacturing, shipping, finance, energy supply, etc.), according to a certain time and space order, form ports value chain by keeping a certain supply–demand relationship. The port enterprise value chain is an objectively existed set of entities with value flow and value-added, so the routines and game mechanism between different entities are great guidance to keeping the value chain working orderly. The concept of routine first appeared in the study of human organization problems and was considered by Steneas the core feature of human organization [1]. With the introduction of routine, it has become an important feature of business organizations and the main means to complete the task. In the definition of enterprise routine, based on the bounded rationality and knowledge dispersion, Nelson and Winter [2] put forward the routine is a fixed way of doing things and the carrier of enterprise knowledge and experience. The differences between the routines are the main features to identify different enterprises. Some scholars also put forward the concept of routine [3, 4].

Port enterprises has special properties, but also has general properties in common enterprises, so port enterprise routine is the carrier of special industry knowledge and experience in port enterprise itself. It's also the way of doing things formed in a long term. When port enterprise value chain adapts to the new environment of the free trade zone, the selecting mechanism of the value chain routine inevitably affects the promotion of the overall interest in the whole value chain. The selection of value chain is related to enterprise organizational structure, organizational goals and technological innovation, which is an important aspect of port enterprise value chain research. On the stimulating condition of free trade zone establishment affecting port industry adjustment, this paper uses the evolutionary game model as the main tool to study the pattern of selecting port enterprise value chain routine based on reviewing the connotation of enterprise routine and the methods of selecting enterprise routine. And then present the policies about the selection of port enterprise value chain routine, which provide decision-making reference for port enterprises and other enterprises to identify and choose the routine suitable for their own development.

2 Literature Review

2.1 Identification of Port Enterprise Value Chain Routine

Ports is the core part of port enterprise value chain, which forms a comprehensive enterprise alliance by integrating various types of providers and demanders and using the collaborative mechanism of sharing resource and exchanging information. So far, lots of scholars have studied the enterprise value chain and value net from different perspectives using various methods. Rasenyalo [5] proposed that the value chain is a value-added activity on supply chain. Liu and Yang [6] based on the analysis of the connotation and characteristics of port supply chain, summarize the integration and development path of port supply chain value-added service. Wei and Bin [7] and Gao [8] use the evolutionary game method to study the competition mechanism in the enterprise value chain, the focus of the research process is mainly reflected in the different stages and different agents of the value chain, through evolutionary analysis and numerical simulation, the competition of the enterprise value chain is clarified.

Routine as the gene of the port enterprise value chain evolution, it become the carrier of memory and store a great deal of enterprise information when a single enterprise value transforms to value nets [9]. Therefore, the characteristics of the routine itself, such as tacitness, inertia, learning, accumulating and memorizing etc. They are important features for recognizing the routine of port enterprise value chain. First, Drawing on Nelson and Winter’s point of view, the routine of port enterprise value chain is the memory of doing something for enterprise [10]. After a long period of time, it will form a regular or inherent way. Once the pattern exists for a long time, it will evolve into enterprise routine and will regulate and constrain the production and operation. Second, in the view of Feldman, port enterprise routine usually can guide the enterprise do something proficiently, its tacitness will become the core of enterprise memory effect and determines enterprise functions [11, 12]. Third, Levitt and March [13] pointed out that routine covers all kinds of enterprise phenomena, but the way of its existence is not fixed. The memory of routine should improve and update constantly, learning and accumulating are especially import in that process. The learning of port enterprise value chain routine is usually reflected in routine’s search and variation. Enterprise will continue to search the better routine, and adjust the structure and characteristics of itself to optimize the whole value chain.

2.2 The Essence of Port Enterprise Value Chain Routine Selection

The theory of enterprise value chain evolves with value form transforming from line to net, even to star [14]. No matter what the form and definition are, the essence of the value chain is unchanged. That is the value chain is an organic system constituted by a series of activities which create values. In increasingly competitive environment, Port enterprise value chain routine as a power exists in port enterprise and can not be neglected [15]. Port enterprise value chain routine determines the real structure of the enterprise. It is also the decisive factor for enterprise to join the competition using certain skills or programs. Routine become the target of enterprise not only because enterprise getting routine through special action, but also its negative feedback. Therefore, routine selection is important to locate enterprise development goals and is the vital way to obtain core competition and market advantages [16]. In the theoretical outcome of the process of routine selection and evolution the core problem is routine searching and optimizing no matter routine's endogenous view [17], exogenous view [18] or dynamic competence [19].

3 Mathematical Modeling

3.1 Model Construction for the Selection of Port Enterprise Value Chain Routine

Port enterprises value chain routine selection or optimization need to break through the traditional enterprise institutional mechanisms and public policy barriers with appropriate external environment and policy support. Meanwhile, China's free trade pilot area strategy provides the best international integration environment and innovation-driven development mechanism for enterprise transformation. The core part of free trade pilot zones construction in Shanghai, Tianjin, Guangdong and Fujian is port shipping. It provides the best conditions and stimulating elements for port and shipping enterprise to reconstruct and upgrade its value chain. Based on the review of lots of literature the research content of enterprise value chain routine mainly are its formation, reconstruction, evolution and synergy etc. the methods of those are focus on case analysis, evolutionary game etc. [20–23]. Therefore, using evolutionary game model to study port enterprise value chain routine selection in the context of free trade pilot zones has a certain theoretical and methodological basis.

The evolutionary game model was formed with the Evolutionary Stable Strategy formally proposed by Smith and Pierce [24], it is an important mathematical tool for economic analysis and communication medium [25]. The evolutionary game model does not focus on the static equilibrium, comparative static equilibrium and aimlessly dynamic analysis [26, 27]. It combines with the advantages of game theory's normative analysis and time irreversibility, regarding game process as a repetitive process, using "rational person" instead of "bounded rational person", so an important theory is formed to analyze the social habits, Institutional or institutional etc. Nonaka [19] proposed a routine evolution model, pointing out that convention evolution is a dynamic process based on interaction and learning. For this characteristic of the routine, Chen and Xu [28] used the evolutionary game model to study the mechanism of the interaction between the members of the network organization and the formation of the routine based on the hypothesis on the bounded rationality, heterogeneity and repeated game process of the game members. In view of the fact that port enterprise value chain routine screening has a dynamic evolution process on the time axis, combined with the nature of the port enterprise value chain routine and the characteristics of evolutionary game, port enterprise value chain routine selection model should make reasonable assumptions.

3.2 Basic Hypothesis

Hypothesis 1 The game-agent of port enterprise value chain has limited rationality. The routine of value chain practice can't obtain complete information, especially the port enterprises under the open policy in China's free trade pilot zones, so the process of value chain reconstruction has various uncertainties and the decision-making structure of the enterprise itself is also unpredictable. Therefore, the routine has two simple assumptions,

(1) the behavior of the routine is predicted by probability, (2) its revenue evaluated by expected value.

Hypothesis 2 Port business value chain routine selection process is a mixed strategy game process. Port enterprise value chain is an open system, with the basic characteristics of value nets, so the agents must have diversity in the game process. Different from the pure strategy game, mixed strategy game payment matrix as shown in Table 1.

From the pay matrix of mixed strategy, we can see that the revenue of the two agent is no longer the single revenue in the traditional game. To the expected revenue of mixed strategy, we need to consider the probability of each strategy. If agent 1 choose S_1 and the probability is p, agent 2 choose R_1 and the probability is ε, the probability of S_2 is $1 - p$, the probability of R_2 is $1 - \varepsilon$. So, the expected revenue of agent 1 is calculated as follows:

$$E_1 = p[\varepsilon a + (1-\varepsilon)b] + (1-p)[\varepsilon c + (1-\varepsilon)d] \quad (1)$$

Using the same method, we can calculate the expected revenue of agent 2.

Hypothesis 3 Free competition in the market determines the port enterprise value chain routine selection to game following the principle of random matching. The open policy of the free trade pilot zone provides a more open environment for the value increment of the port enterprises in our country. Therefore, we do not specify the routine gaming in the process, on the contrary, we take random sampling, so it can game with any routine in enterprise and populations.

Hypothesis 4 Optimized results of port enterprise value chain routine selection obtained by repeated game. As the agent of the game is random, the agent needs to adopt a variety of strategies, considering their own experience, and achieve the final equilibrium after several times of repeated game process.

3.3 Model Construction

Port enterprise value chain routine selection model describes the strategy selection process. In this game process enterprise routine categorized into old kind and new kind. To the old routine, the enterprise has inheriting and changing strategy. Otherwise, the new kind has resisting and accepting strategy, so in this paper we select two kinds of routine to game from port enterprise. Assuming that routine A can choose inheriting and changing strategy represented by A_1 and A_2 respectively. According to the strategy of routine B choosing routine A can choose resisting and accepting strategy represented by. B_1 and B_2 respectively.

Assuming that routine A can bring expected revenue R_0 for port enterprise value increment, expected revenue R_0 is also the loss of choosing routine B. The expected cost C of choosing changing strategy for routine A is also the conversion cost for routine B

Table 1 Payoff matrix of mixed strategy

	Agent 1	
	S_1	S_2
Agent 2		
R_1	a, r	c, d
R_2	b, f	d, m

choosing accepting strategy. We use symbol R_1 and R_2 to represent the revenue for routine A and routine B in current state respectively. The payoff matrix of Port enterprise value chain routine selection game model is as shown in Table 2.

The payoff matrix in Table 2 show the revenue respectively, when the routine selects inheriting strategy or changing strategy. The revenue of the agent in game process is related to the present revenue of routine A and routine B, the expected revenue of new routine for game agents, the expected loss of game behavior and the cost of agent changing.

4 Analysis on Evolutionary Stable Strategy of Port Enterprises Value Chain Routine Selection

Replicator dynamic is an important model in evolutionary game theory proposed by Taylor and Jonker [29] and has been widely developed and applied. Based on the bounded rationality of the agents, agents can't forecast its own strategies. They only can make decisions through imitation, replication, leaning etc. between the agents. Because of the dynamic of replicate process, the equation can predict the trend of the agents more comprehensively. Based on the single agent game model, assuming that the number of the population is N, the strategy set of all the agent is $s_i = (i = 1, 2, 3, \ldots, n)$, $x_i(t)$ denotes the proportion of individuals in the population at time t. So the individual evolution replicator equation is illustrated as follows.

$$\frac{dx_i(t)}{dt} = [f(s_i, x) - f(x, x)]x_i \tag{2}$$

where $dx_i(t)/dt$ is the proportion of individuals taking one strategy varying over time; $f(s_i, x)$ denotes the expected revenue function of choosing the ith strategy; $f(x, x)$ denotes the average expected revenue function of the population. The Evolutionary Stable Strategy (ESS) is an equilibrium analysis of the game. In the implementation of the present strategy the system comes to a stable state if the revenue of the strategy chosen by partial individuals bringing mutation to the population is lower than the revenue of the present strategy.

4.1 The Replicator Dynamic Equation of Port Enterprise Value Chain Routine Selection

Based on the basic hypothesis assuming that if port enterprise value chain routine A selects changing strategy with the probability x, the probability of inheriting strategy is $1 - x$; if the probability of resisting strategy for routine B is y, the probability of accepting strategy is $1 - y$.

Table 2 Payoff matrix of routine selection game

	Routine B	
	B_1 (resist)	B_2 (accept)
Routine A		
A_1 (change)	$R_1 + \frac{R_0}{2} - C$, $R_2 - \frac{R_0}{2} - C$	$R_1 + R_0 - C$, $R_2 - R_0$
A_2 (inherit)	$R_1 - R_0$, $R_2 + R_0 - C$	R_1, R_2

1. The replicator dynamic equation of routine A. To routine A the expected revenue of selecting two different strategies are U_{A1} and U_{A2}:

$$\begin{cases} U_{A1} = y \cdot \left(R_1 + \frac{R_0}{2} - C\right) + (1 - y) \cdot (R_1 + R_0 - C) \\ U_{A2} = y \cdot (R_1 - R_0) + (1 - y) \cdot R_1 \end{cases} \tag{3}$$

Solving Eq. (3) we can derive U_{A1} and U_{A2} illustrated as flows:

$$\begin{cases} U_{A1} = -\frac{R_0}{2} \cdot y + R_1 + R_0 - C \\ U_{A2} = -R_0 \cdot y + R_1 \end{cases} \tag{4}$$

Equation (5) is the expected revenue of routine A:

$$\overline{U}_A = x \cdot U_{A1} + (1 - x) \cdot U_{A2} \tag{5}$$

Here, plugging in U_{A1} and U_{A2} respectively, we can get the expected revenue of routine A:

$$\overline{U}_A = -\frac{3}{2} R_0 \cdot xy + x \cdot (R_0 - C) - R_0 y + R_1 \tag{6}$$

So the replicator dynamics of routine A is as shown in Eq. (7):

$$\frac{dx}{dt} = x(U_{A1} - \overline{U}_A) \tag{7}$$

Plugging in the certain parameters we can get Eq. (8):

$$\frac{dx}{dt} = x \cdot (R_0 xy + Cx - R_0 x + R_0 y + R_0 - C) \tag{8}$$

2. The replicator dynamics of routine B. using the same method, the replicator dynamics of routine B can be simply calculated:

$$\begin{cases} U_{B1} = x \cdot \left(R_2 - \frac{R_0}{2} - C\right) + (1 - x) \cdot (R_2 + R_0 - C) \\ U_{B2} = x \cdot (R_2 - R_0) + (1 - x) \cdot R_2 \end{cases} \tag{9}$$

Standardizing Eq. (9) into Eq. (10):

$$\begin{cases} U_{B1} = -\frac{3}{2} R_0 \cdot x + R_2 + R_0 - C \\ U_{B2} = -R_0 \cdot x + R_2 \end{cases} \tag{10}$$

Plugging in U_{B1}, U_{B2} here we can get the expected revenue of routine B:

$$\begin{aligned} \overline{U}_B &= y \cdot U_{B1} + (1 - y) \cdot U_{B2} \\ \overline{U}_B &= -\frac{R_0}{2} xy + y \cdot (R_0 - C) - R_0 x + R_2 \end{aligned} \tag{11}$$

The replicator dynamics of routine B is as flows:

$$\frac{dy}{dt} = y(U_{B1} - \overline{U}_B) \tag{12}$$

$$\frac{dy}{dt} = y \cdot (-R_0 xy + Cy - R_0 y + R_0 x + R_0 - C) \tag{13}$$

4.2 The Analysis of ESS (Evolutionary Stable Strategy)

1. The ESS of routine A. the replicator dynamics of routine A can be converted into Eq. (15):

$$\frac{dx}{dt} = x \cdot (1 - x) \cdot \left(\frac{R_0}{2} y + R_0 - C\right) \tag{14}$$

Solving Eq. (15) we get three stable points:

$$x_1^* = 0; \quad x_2^* = 1; \quad x_3^* = \frac{2(C - R_0)}{R_0} \tag{15}$$

taking derivative of replicator dynamic equation (Eq. 15) and $d^2x/dt^2 < 0$, the result is as flows:

$$\frac{d^2x}{dt^2} = (1 - 2x)\left(\frac{R_0}{2} y + R_0 - C\right) \tag{16}$$

According to the criterion we can get flowing conclusions:

1. If $2(C - R_0)/R_0, y > 2(C - R_0)/R_0$. According to the stability theorem of differential equation, only if $(1 - 2x) < 0$ Eq. (17) can get to the stable point. When $F'(1) < 0$, $x_2^* = 1$ is the ESS. Figure 1 is replicator dynamic phase diagram of routine A, it demonstrates that routine A will choose changing strategy.
2. If $0 < 2(C - R_0)/R_0 < 1$, the ESS is determined by y, the evolutionary stable points are illustrated in Eq. (18):

$$\begin{cases} y > \dfrac{2(C - R_0)}{R_0} & x_1^* = 0 \text{ is stable point} \\ y < \dfrac{2(C - R_0)}{R_0} & x_2^* = 1 \text{ is stable point} \end{cases} \tag{17}$$

At this moment the replicator dynamic phase diagrams of routine A are show in Figs. 2 and 3. In Fig. 3 it shows that through the game process routine A chooses inheriting strategy and the stable point is $x_1^* = 0$. In Fig. 4 it shows that through the game process routine A chooses inheriting strategy and the stable point is $x_1^* = 1$.
3. If $2(C - R_0)/R_0 > 1, C > 3R_0/2$. At this point the changing cost of routine A is higher than the expected revenue, so the best strategy is inheriting and the

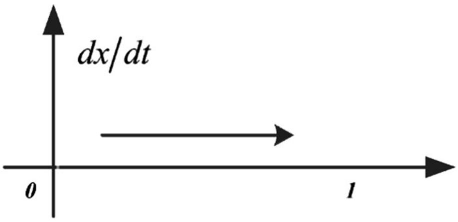

Fig. 1 Replicator dynamic phase diagram of routine A $(2(C - R_0)/R_0 < 0)$

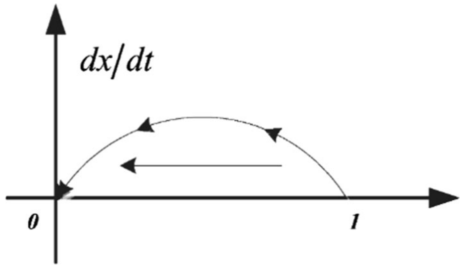

Fig. 2 Replicator dynamic phase diagram of routine A $(2(R_0 - C)/R_0 < 0)$

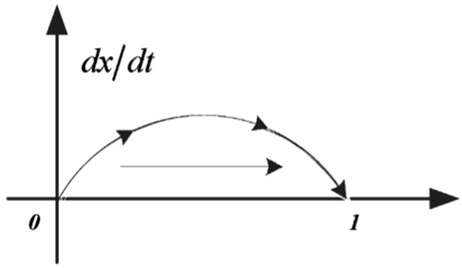

Fig. 3 Replicator dynamic phase diagram of routine A $(y < 2(C - R_0)/R_0)$

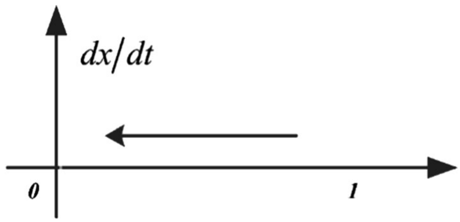

Fig. 4 Replicator dynamic phase diagram of routine A

stable point is $x_1^* = 0$. The replicator dynamic phase diagram is Fig. 4. From Fig. 4 we can explicitly see that only if the routine A selects inheriting strategy it can obtain maximum revenue.

2. The ESS of routine B. the replicator dynamics of routine A can be converted into Eq. (19):

$$\frac{dy}{dt} = y \cdot (1 - y) \cdot \left(-\frac{R_0}{2}x + R_0 - C\right) \tag{18}$$

Solving Eq. (19) we can get three stable points in the same way:

$$y_1^* = 0; \quad y_2^* = 1; \quad y_3^* = \frac{2(R_0 - C)}{R_0} \tag{19}$$

taking derivative of replicator dynamic equation (Eq. (20)) we can get Eq. (21):

$$\frac{d^2y}{dt^2} = (1 - 2y)\left(-\frac{R_0}{2}x + R_0 - C\right) \tag{20}$$

According to the criterion we can get three conclusions:

1. If $2(R_0 - C)/R_0 < 0, x < 2(C - R_0)/R_0$. It means that only if $(1 - 2y) > 0$ it can come to the stable point $y_2^* = 0$. By this moment the replicator dynamic phase diagram is Fig. 5. It shows that routine B will chooses accepting strategy no matter what strategy the routine A selects.
2. If $0 < 2(R_0 - C)/R_0 < 1$, the ESS is determined by y, the evolutionary stable points are illustrated in Eq. (22):

$$\begin{cases} x > \dfrac{2(R_0 - C)}{R_0} & y_2^* = 1 \text{ is the stable point} \\ x < \dfrac{2(R_0 - C)}{R_0} & y_1^* = 0 \text{ is the stable point} \end{cases} \tag{21}$$

   At this moment the replicator dynamic phase diagrams are illustrated in Figs. 6 and 7. Its dynamic game process is like the one of routine A. If $y_2^* = 1$ is the stable point after several rounds of game routine B will chooses resisting strategy finally. No matter what strategy the routine A selects routine B will resist; if the stable point is $y_2^* = 0$ routine B will take accepting strategy as the first choice. That is routine B will become the leading power and has enormous influence on the enterprise.

3. If $2(R_0 - C)/R_0 > 1, C < R_0/2$. Routine B will choose resisting strategy as its only choice because it can bring more expected revenue. Here, the stable point is $y_2^* = 1$ and the phase diagram is as show in Fig. 8.
   In summary, we use 2D coordinate plane to show the dynamic relations between routine A and routine B as is shown in Fig. 9.

From Fig. 9, we can see that point O and point C are ESS points. Point O denotes routine A selecting inheriting strategy and routine B selecting accepting strategy. Point C denotes routine A selecting changing strategy and routine B selecting resisting strategy. In the top right region of Fig. 9 agents converge to point C, that is the system converges to the Pareto optimal equilibrium. In the low left region of Fig. 9 agents converge to point O that is the system converges to the Pareto inferior equilibrium. Point D is the saddle point. Furthermore, the initial proportion of routines participating in the game determines the ESS. If the proportion is in BDAC region the stable point is C; If the proportion is in BDAO region, the stable point is O. The position of saddle point $D(x^*, y^*)$ affects the evolutionary feature of the system.

Fig. 5 Replicated dynamic phase diagram of routine B ($2(R_0 - C)/R_0 < 0$)

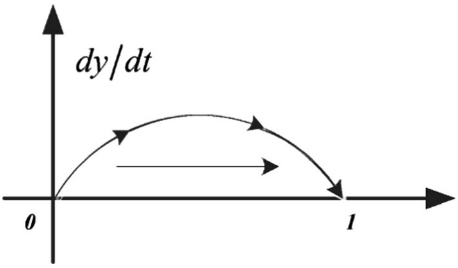

Fig. 6 Replicated dynamic phase diagram of routine B $(x > 2(R_0 - C)/R_0)$

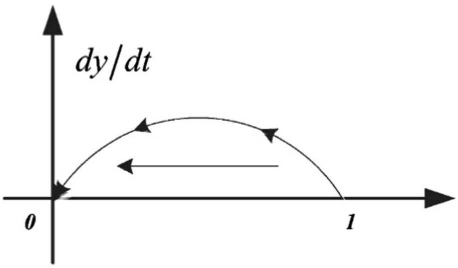

Fig. 7 Replicated dynamic phase diagram of routine B $(x < 2(R_0 - C)/R_0)$

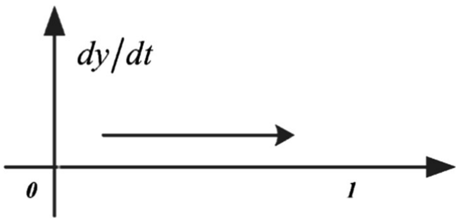

Fig. 8 Replicator dynamic phase diagram of routine B $(C < 1/2R_0)$

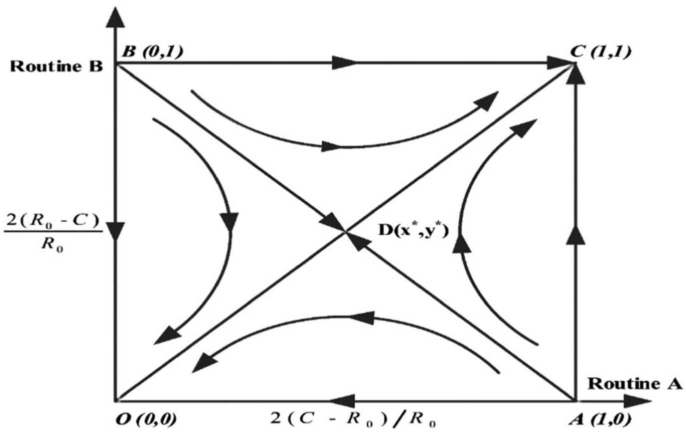

Fig. 9 Phase diagram of equilibrium points

5 Simulation Experiment

5.1 Basic Parameter Settings

This paper in order to verifying and analyzing the evolution state of port enterprise value chain routine, we use NetLogo software to simulate the dynamic evolution process of strategy selection under different initial conditions.

Setting a 25×25 double layer network with periodic boundaries, each layer network represents a kind of double homogeneous routines such as routine A or routine B. The agents of each kind of routines are distributed on each layer network. Every individual i only learn from its 4 nearest neighbors (von Neumann) and game with nearest neighbors of another kind of routines, so the fitness function f_i is the total revenue of individual i gaming with 4 neighbors. The fitness function can be simply calculated by:

$$f_i = \sum_{j=1}^{4} u(i,j) \tag{22}$$

where $u(i,j)$ is the revenue of individual i gaming with individual j.

Every individual is assigned a strategy randomly at the initial moment and changes their strategies by flowing rules: selecting one individual j from the 4 nearest neighbors of individual i, (1) if $f_i \geq f_j$, individual i keeps its own strategy and individual j chooses the strategy of individual i; (2) if $f_i \leq f_j$, individual i selects the strategy of individual j and individual j keeps its own strategy.

In Fig. 10 the dot denotes routine A. The red one denotes inheriting strategy and the blue one denotes changing strategy. The square represents routine B. The white one represents accepting strategy and the gray one represents resisting strategy. We set parameters as follows: $player1x \in [0, 1]$ denotes the initial proportion of routine A with changing strategy; $player2y \in [0, 1]$ denotes the initial proportion of routine B with resisting strategy; $R_0 \in [0, 100]$ denotes the revenue brought by routine A and the resistance loss of routine B; $R_1 \in [0, 100]$ denotes the revenue brought by routine A in current state; $R_2 \in [0, 100]$ denotes the revenue brought by routine B in current state; $C \in [0, 100]$

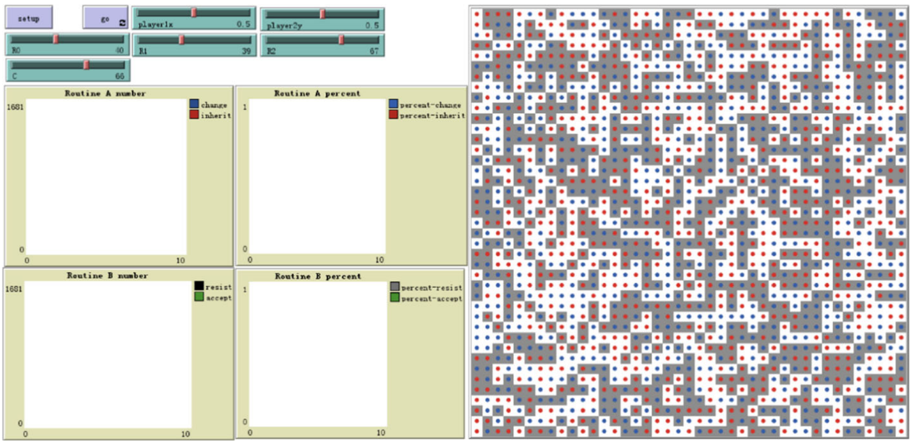

Fig. 10 NetLogo simulation interface

denotes the expected changing revenue of routine A and the convention cost of the enterprise accepting routine B.

5.2 Analysis of Simulation Results

Based on the replicator dynamic equation of routine A, routine B and relative parameters, we use simulation method to analyze the evolution of routine A and routine B. The results are illustrated as flows.

Evolution analysis of routine A

1. If $C < R_0$, keeping other parameters the same, adjusting the proportion of routine A selecting changing strategy, when the proportion is less than 0.5 the number and percent of routine A is changing all the time, but when the proportion is more than 0.5 after a period of time routine A comes to the equilibrium. That is the enterprise choose changing strategy finally as is show in Fig. 11.
2. If $R_0 < C < 3R_0/2$, $y > 2(C - R_0)/R_0$ and $x \neq 0$, routine A is always in unstable state as is shown in Fig. 12. Only if $x = 0$ it can achieve the equilibrium.

If $y < 2(C - R_0)/R_0$ and $x \neq 1$ routine A is also always in unstable state as is illustrated as flows. Only if $x = 1$ it can get to the equilibrium (Fig. 13).

3. if $C > 3R_0$ and $x \neq 0$ no matter what the parameters change routine A is always in unstable state until the $x = 0$ as is show in Fig. 14.

From the above simulation results, we can see that the simulation results are consistent with the previous analysis, and the simulation results of routine B can be obtained by the same method. It can be seen from the simulation results that the expected revenue R_0 and conversion costs C play a decisive role in the choice of the strategy for port enterprise value chain and determines the choice and state of routine A and routine B.

5.3 Determining Factor Analysis of Routine Selection

Through the modeling and analysis of port enterprise value chain routine selection game process, it is concluded that the evolutionary equilibrium is related to the expected revenue R_0 and convention costs of routine's strategies such as inheriting strategy, changing strategy.

1. Expected revenue R_0
   The expected revenue R_0 brought by routines is the first parameter the enterprise thinks about. If the expected revenue does not have enough attraction to the enterprise,

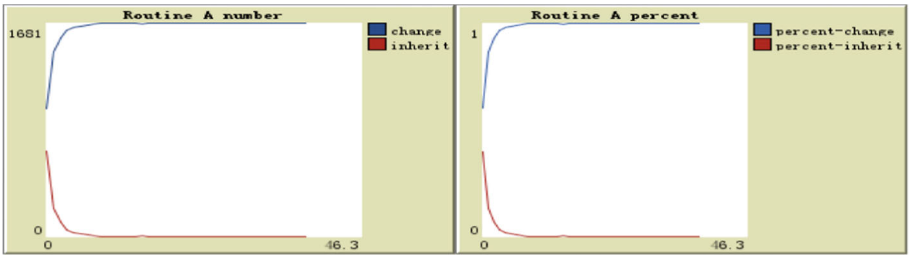

Fig. 11 Simulation results $(C < R_0, player1x < 0.5)$

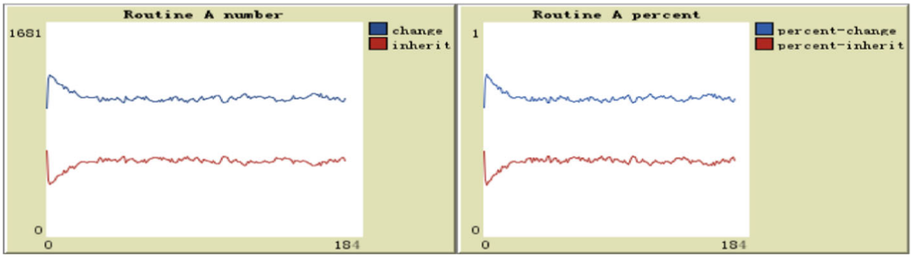

Fig. 12 Simulation results $(R_0 < C < 3R_0/2, y > 2(C - R_0)/R_0, x \neq 0)$

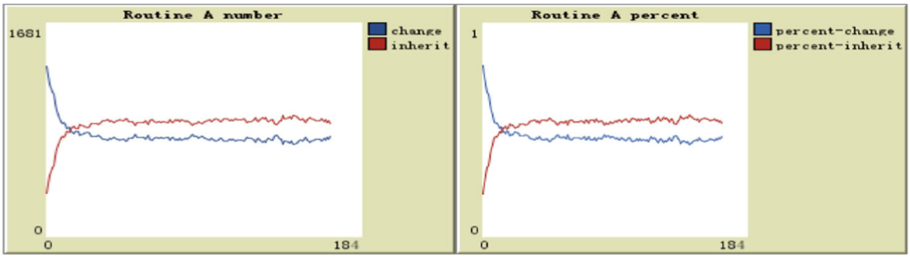

Fig. 13 Simulation results $(y < 2(C - R_0)/R_0, x \neq 1)$

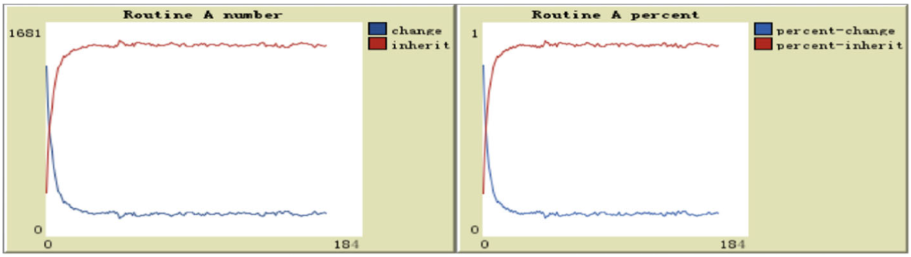

Fig. 14 Simulation results $(C > 3R_0, x \neq 0)$

the possibility of game interaction between routines is very low. In the actual game process, the expected revenue is the key factor for port enterprise value chain routine selection, because it is related to enterprise's success or failure in game process. As to the expected revenue, it not only measured by the growth of the enterprise's economic income, but also taking into account the economic, growth and social aspects of the enterprise.

2. Expected revenue C

   The cost of value chain routine selection is also an important factor. It has great influence on the game behavior. If routine A selects changing strategy the cost of abandoning routine A is a major factor in C. During the management of the enterprise, routine A occupy the whole sources and has Formed its own competitive advantages. If routine A changes or be substituted its advantage is no longer exist and may even bring irreversible loss to the enterprise. The selection of port enterprise value chain routine means that the enterprise should find its own role and take much of time to make changes and adapt to the new environment considering the key factor convention cost.

3. Time-lag effect
   As to the game process of routine selection, one routine replacing another routine needs a period of time, that is even one routine changes the major routine will also affect enterprise's behavior conducted by the new routine.

6 Conclusions

In this paper a quantitative tool is presented by introducing the theory of evolutionary game theory. It will guide the port enterprise to identify its routines affecting its development and to make strategy decisions. In the routine selection process, the expected revenue and expected cost mentioned above affects the selection behavior. Under the assumptions, this paper analyzes the process of routine selection where two kinds of routines participate in. Based on the whole analysis we get three conclusions as flows:

1. Port enterprise value chain routine selection is a dynamic evolution process. It is integrated with different kinds of evolutionary ways, so the routines have stability and flexibility.
2. The evolutionary equilibrium of port enterprise value chain routine selection shows that the routines tend to choose inheriting strategy. In the game model if the expected revenue R_0 is less than expecting cost C the enterprise will select inheriting strategy. This strategy can avoid many kinds of risks, such as the loss of routine changing, the risk of forming a new routine and the cost of routine convention etc.
3. The port enterprise value chain routine selection is not limited to enterprise inside. For the formation and evolution of the routine, it includes endogenous, exogenesis and dynamic views etc., but exogenesis perspective is the major view. In the evolution process of the port enterprise value chain routine, it is necessary to keep the interaction with the population all the time and there is also fierce competition in the population.

This study still contains limitations. For example, this study should further improve the indexes of the expected revenue R_0 and the expected cost C and build a scientific and comprehensive index system to sufficiently and reasonably describe the behavior of port enterprise value chain routine selection. The future study will focus on the application of the index system in enterprise and break through the limitation of routine numbers, this will make the theoretical model become a sufficient way to solving enterprise decisions.

Acknowledgements The authors would like to thank professors who give the valuable comments and constructive suggestions, which have greatly improved the quality of this paper. This research is supported by the National Natural Science Foundation for young scholars of China (71503029), Social Science Foundation of Liaoning (L13DJY055) and the Special Foundation for Connotative Development of Liaoning Higher Education (20110116203).

References

1. Stene, E. O. (1942). Legislative considerations in organizing regulatory agencies. *Annals of the American Academy of Political and Social Science, 221*(10), 49–55.

2. Nelson, R. R., & Winter, S. G. (1982). *An evolutionary theory of economic change*. Cambridge, MA: Harvard University Press.
3. Zollo, M., & Winter, S. G. (2002). Deliberate learning and the evolution of dynamic capabilities. *Organization Science, 13,* 339–351.
4. Liu, G. (2005). *Enterprise heterogeneity hypothesis*. Beijing: China Renmin University Press.
5. Rasenyalo, N. M. (2008). *Adding value through logistics: A value chain analysis of steel product handling in Durban Port*. Master's thesis. Durban: University of kwazulu-natal.
6. Liu, J., & Yang, J. (2014). A study on the path of expanding supply chain value-added service in China's port enterprises. *Port Economy, 12,* 9–11.
7. Wei, X., & Bin, H. (2014). Demand-driven simulation on the mobile value chain based on multi-stage game. *Chinese Journal of Management, 22*(4), 58–66.
8. Gao, J. (2014). Coordination coordination mechanism analysis of partners' behavior in plant variety right value chain based on evolutionary game theory. *Operations Research and Management Science, 23*(5), 205–212.
9. Wang, Y., & Ma, J. (2011). Research on the choice of enterprise technological innovation from the perspective of organizational practice and industry practice. *Nankai Business Review, 14*(3), 85–90.
10. Winter, S. G., & Nelson, R. R. (2009). An evolutionary theory of economic change. *American Journal of Agricultural Economics, 32*(2), 661–666.
11. Feldman, M. S., & Brian, T. P. (2003). Reconceptualizing organizational routines as a source of flexibility and change. *Administrative Science Quarterly, 48,* 94–118.
12. Feldman, M. S. (2000). Organizational routines as a source of continuous change. *Organization Science, 11,* 611–629.
13. Levitt, B., & March, J. G. (1988). Organizational learning. *Annual Review of Sociology, 14,* 314–340.
14. Wang, S., & Xiaodi, H. (2009). Research on business model innovation based on value chain evolution. *Market Modernization, 10,* 196–197.
15. Hage, J., & Aiken, M. (1969). Routine technology, social structure, and organization goals. *Administrative Science Quarterly, 14*(3), 366–376.
16. Pentland, B. T., & Rueter, H. H. (1994). Organizational routines as grammars of action. *Administrative Science Quarterly, 39*(3), 484–510.
17. Cyert, R. M., & March, J. G. (2004). Behavioral theory of the firm. *Systems Research & Behavioral Science, 4*(2), 81–95.
18. Winter, S. G., & Szulanski, G. (2001). Replication as strategy. *Organization Science, 12*(6), 730–743.
19. Nonaka I. (1994). A dynamic theory of organizational knowledge creation. *Organization Science, 5*(1), 14–37.
20. Shou, Y., Wang, W., & Dmitrij, S. (2016). Design and reconstruction of value chain of manufacturing product service system—case study of Hang oxygen. *Management Review, 28*(2), 230–240.
21. Man, Q., & Jin, J. (2013). Game chain mechanism of mobile value—added service based on game theory. *Journal of Industrial, 27*(2), 177–186.
22. Hong, J., & Huang, P. (2011). Dynamic decision model of collaborative knowledge innovation in enterprise value chain. *Chinese Journal of Management, 19*(4), 130–136.
23. Huang, M. (2010). Evolutionary game analysis of cooperation mechanism for collaborative product development in supply chain. *Chinese Journal of Management, 18*(6), 155–162.
24. Pierce, W., & Smith, R. (1974). Evaluation should be a welcomed experience. *Instructor, 83*(8), 34.
25. Sun, R., & Zhao, D. (2009). Evolutionary game analysis of knowledge sharing in dynamic alliance. *Operations Research and Management, 18*(1), 92–96.
26. Huang, K. (2009). Evolutionary game and evolutionary economics. *Economic Research, 2,* 154–158.
27. Huang, M. (2010). Research on cooperation mechanism of supply chain collaborative product development based on evolutionary game. *Chinese Journal of Management, 18*(6), 155–162.
28. Chen, X., & Xu, J. (2006). Formation of network organization and its routines: Based on the views of the evolutionary theory. *China Industrial Economy, 6*(4), 52–58.
29. Taylor, P. D., & Jonker, L. B. (2010). Evolutionarily stable strategies and game dynamics. *Mathematical Biosciences, 40*(2), 145–156.

Bing Han was born in Hunan, China in 1985. He received the Ph.D. degree in Management Science and Engineering from Harbin Engineer University in 2011. He is currently working as a lecture of Business Administration in Dalian Maritime University. His research interests include port sustainable development, port ecology, enterprise social responsibility management and Synergetic theory etc.

Pengfei Zhang was born in Shandong, China in 1988. He received the M.S. degree in Management Science and Engineering from Harbin Engineer University in 2014. He is currently studying as a Ph.D. candidate in Dalian Maritime University. His research interests include port enterprise value chain, complex adaptive system.

Haibo Kuang was born in Liaoning, China in 1965. He received the Ph.D. degree in Technical Economics and Management from Dalian University of Technology. He is currently a Professor of Transportation Management College and the Institute Director of ICSD. His research interests include macroeconomic management, transportation planning and management, logistics finance and green supply chain management etc.

Min Wan was born in Liaoning, China in 1992. He received the B.S. degree in Materials Science and Engineering from Northeastern University. He is currently studying as a M.S. candidate in Dalian Maritime University. His research interests include port enterprise value chain and business administration.