Evolutionary Game Analysis of the Transformation from Traditional Logistics to Green Logistics under the Background of Dual Carbon

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Abstract. Green logistics is an important measure in response to national energy conservation and emission reduction policies, and in the long run, it is also a necessary measure to save costs for enterprises. This article aims to address the obstacles in the transition from traditional logistics to green logistics, and constructs a four party evolutionary game model of government, environmental NGOs, logistics enterprises, and consumers. The model consists of top-down transportation, bottom-up circulation, forward logistics, and reverse logistics to form a green logistics loop; Several Equant are solved by establishing duplicate dynamic equations, Jacobian matrix and determinant, etc., and the local stability of Equant is analyzed by using Lyapunov's first rule.By analyzing the evolutionary game model, this study explores the impact of government policies on corporate behavior, thereby providing reference for the formulation of relevant policies by government departments.

Keywords: double carbon target; Green logistics; Reverse logistics; Evolutionary game

1 Introduction

With the 18th National Congress of the Communist Party of China bringing the construction of ecological civilization into the overall layout of Socialism with Chinese characteristics modernization, green industries with energy conservation, environmental protection and low-carbon as the theme have flourished and become the new driving force of economic growth. The "14th Five Year Plan" clearly proposed the "double carbon" goal[1]. Up to the 20th National Congress of the Communist Party of China, accelerating the green transformation of the development mode can show the urgency of the rise of green industries[2]. According to 2021 statistics, the total logistics cost accounts for 14.6% of GDP, and green logistics needs to be developed. However, green logistics is still in its infancy and development stage in China. The green and low-carbon transformation of the logistics industry faces insufficient research on green logistics theory, difficulties in implementing green logistics related policies and standards, and obstacles to the development of green logistics due to short-term benefits and long-

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term development goals. Mechanisms cannot be established[5]. Many scholars have proposed solutions to this problem, and Yan Shuli[3]argues the necessity of implementing green logistics from the perspective of the high-quality prospects brought by green logistics; Sun Supeng[4] and others demonstrated the feasibility of green emission reduction of enterprises by establishing a tripartite game among government, enterprises and environmental NGOs; Dai Dongfang[5],Lian Jie[7]and others analyzed the obstacles and proposed corresponding strategies for the government and enterprises to promote the development of green logistics; Zhou Qilei[6], Shu Hui[9]and others, starting from the characteristics of logistics, put forward the concept of negative Externality, called on the government to intervene, give subsidies and guide the transformation; Starting from the prominent issues in the current development of green logistics, Liu Zhanyu and others[8] proposed relevant technical suggestions for the development of green logistics to ensure its development; Yu Lijing and others [10]analyzed the asymptotic stability of green innovation diffusion in logistics enterprises by establishing a tripartite evolutionary game model of logistics enterprise groups, government regulators, and consumers. They concluded that government regulatory participation is a booster for green innovation diffusion in enterprises, and government entities can withdraw from regulatory participation at any time. This study is based on scholars' research and aims to construct a four party evolutionary game model for green logistics cooperation. The four main entities are the government, environmental NGOs, logistics enterprises, and consumers. In the model, the government is the key factor in the development of green logistics[11], controlling the direction of the main body, and logistics enterprises are the core affiliated entities that are indispensable. The role of independent organizations - environmental NGOs is mainly as supervisors during the transformation process, and the last party is consumers. The participation of consumers in the government and enterprises plays a certain supervisory role[12], and can cooperate to complete the recycling of green materials, thus forming a green logistics closed-loop, It has a positive effect on the effectiveness of environmental governance[13]. The four party game model is shown in Fig 1.

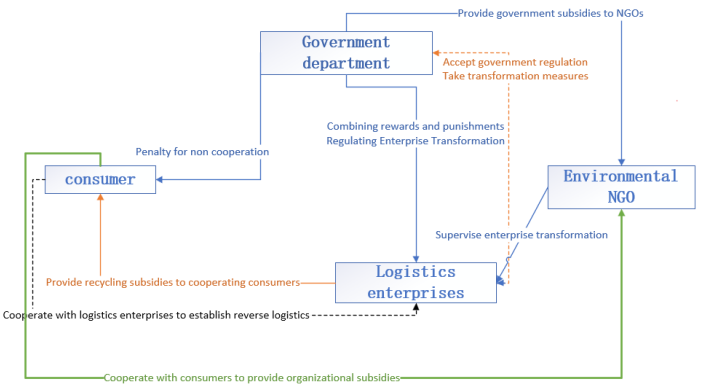

Fig. 1. Relationship diagram of multi-agent game model

2 Model construction and analysis

2.1 Basic Assumptions of Evolutionary Game Models

The four parties mentioned above interact and influence each other during the evolution of the game. Based on this model, the following basic assumptions are proposed:

Assumption 1: All the players in the game are Bounded rationality[14], including the government, enterprises, environmental NGOs and consumers.

Assumption 2: The government's behavioral strategy set is S_1={G_1 regulation, G_2 non regulation}. "Regulation" refers to the government investing a certain amount of manpower, financial resources, and material resources with a probability of x (0<x<1) to regulate the logistics of related enterprises, providing subsidies to enterprises implementing green logistics transformation. On the contrary, enterprises that do not implement will be punished, and environmental NGOs that implement supervision will also be given certain subsidies, and consumers who do not cooperate will be punished, 'Non regulation' refers to the government not taking any policy measures with a 1-x probability and allowing the market to develop;

Assuming that the behavioral strategy set of Enterprise 3 is S_2={K_1 adopts, K_2 does not adopt}, "adopt" refers to the regulated enterprise paying the corresponding cost to introduce relevant equipment or carry out technological innovation with a probability of y (0<y<1), transforming traditional logistics into green logistics, and the enterprise will provide certain recycling subsidies to cooperate with consumers. "do not adopt" refers to the enterprise paying the original cost with a probability of 1-y to adopt traditional logistics, and the enterprise operates with high carbon;

Assuming that the strategy set of 4 environmental NGOs is S_3={N_1 supervision, N_2 not supervision}, "supervision" refers to the cost incurred by environmental NGOs to supervise relevant enterprises with a probability of z (0<z<1) after the regulatory policy is issued. Enterprises that do not transform into green logistics are exposed, and relevant enterprises are not supervised with a probability of 1-z;

Assuming that the strategy set of 5 consumers is S_4={P_1 cooperation, P_2 non cooperation}, "cooperation" refers to the probability that consumers participate in the establishment of a green logistics system with a probability of m (0<m<1) during the transformation process, and "non cooperation" refers to the probability that consumers do not cooperate with the establishment of a green logistics system with a probability of 1-m, x, y, z, m $\in$ [0,1].

Assumptions and meanings of relevant parameters in evolutionary game models, as shown in Table1.

Table 1. Main parameters and their meanings

parameter	meaning
E_1	**Benefits obtained by enterprises adopting green logistics**
E_2	**Benefits obtained by enterprises adopting traditional logistics (without adopting green logistics)**

E_3	**The potential benefits of green logistics adopted by enterprises to the government**
E_4	**Benefits brought to consumers by enterprises adopting green logistics (such as reduced logistics costs**
C_1	**The replacement equipment and other costs that enterprises need to pay for adopting green logistics**
C_2	**The cost that enterprises need to pay for adopting traditional logistics (without adopting green logistics)**
C_3	**The cost (management, manpower, etc.) that the government needs to pay for selecting regulatory strategies**
C_4	**The cost of government not adopting green logistics to govern the environment and management in enterprises**
C_5	**The cost of environmental NGOs supervising enterprises**
S_1	**Subsidies for green logistics enterprises during government regulation**
S_2	**Environmental NGOs supervise enterprises receiving government funding**
S_3	**Enterprises receive funding from participating consumers during environmental NGO supervision**
S_4	**Adopting green logistics enterprises to actively recycle and reward participating consumers**
G_1	**Fines imposed on traditional logistics enterprises during government regulation**
G_2	**Fines imposed on non participating consumers during government regulation**
G_3	**Environmental NGO supervision causes losses for traditional logistics enterprises**

2.2 Establishment of a Four Party Evolutionary Game Model

According to the behavioral strategies of the government, enterprises, environmental NGOs, and consumers, there are a total of 16 game combinations among the four, namely:

$(\mathrm{G}_1,\mathrm{K}_1,\mathrm{N}_1,\mathrm{P}_1)(\mathrm{G}_1,\mathrm{K}_1,\mathrm{N}_1,\mathrm{P}_2)(\mathrm{G}_1,\mathrm{K}_1,\mathrm{N}_2,\mathrm{P}_1)(\mathrm{G}_1,\mathrm{K}_2,\mathrm{N}_1,\mathrm{P}_1)(\mathrm{G}_1,\mathrm{K}_1,\mathrm{N}_2,\mathrm{P}_2)(\mathrm{G}_1,\mathrm{K}_2,\mathrm{N}_1,\mathrm{P}_2)(\mathrm{G}_1,\mathrm{K}_2,\mathrm{N}_2,\mathrm{P}_1)$

$(\mathrm{G}_1,\mathrm{K}_2,\mathrm{N}_2,\mathrm{P}_2)(\mathrm{G}_2,\mathrm{K}_1,\mathrm{N}_1,\mathrm{P}_1)(\mathrm{G}_2,\mathrm{K}_1,\mathrm{N}_1,\mathrm{P}_2)(G_2,K_1,N_2,P_1)(\mathrm{G}_2,\mathrm{K}_2,\mathrm{N}_1,\mathrm{P}_1)(\mathrm{G}_2,\mathrm{K}_1,\mathrm{N}_2,\mathrm{P}_2)(\mathrm{G}_2,\mathrm{K}_2,\mathrm{N}_2,\mathrm{P}_1)$

$(\mathrm{G}_2,\mathrm{K}_2,\mathrm{N}_1,\mathrm{P}_2)(\mathrm{G}_2,\mathrm{K}_2,\mathrm{N}_2,\mathrm{P}_2)$

Taking (G_1, K_1, N_1, P_1) as an example, according to the parameters given in Table 1, it can be seen that the government needs to spend costs such as human and financial resources to regulate enterprises. The transformation of green logistics by enterprises will bring potential benefits to them; The cost that the enterprise will spend on equipment introduction, technological innovation, etc. will receive subsidies from the

government to obtain the benefits of transforming into green logistics; Environmental NGOs will incur supervision costs and receive funding from the government and consumers; Consumers will benefit from the transformation of enterprises into green logistics (reducing logistics costs), as well as receive proactive recycling subsidies from enterprises. Other combinations can yield corresponding returns similarly, as shown in Table 2.

Table 2. Government, Enterprise, Environmental NGOs, and Consumer Behavior Strategy Combination and Benefit Matrix

strategy combination	Government benefits	business income	NGO Benefits	Consumer benefits
(G_1, K_1, N_1, P_1)	$E_3 - C_3 - S_1 - S_2$	$E_1 - C_1 + S_1 - S_4$	$-C_5 + S_2 + S_3$	$E_4 - S_3 + S_4$
(G_1, K_1, N_1, P_2)	$E_3 - C_3 - S_1 - S_2 + G_2$	$E_1 - C_1 + S_1$	$-C_5 + S_2$	$E_4 - G_2$
(G_1, K_1, N_2, P_1)	$E_3 - C_3 - S_1$	$E_1 - C_1 + S_1 - S_4$	0	$E_4 + S_4$
(G_1, K_2, N_1, P_1)	$-C_3 - C_4 - S_2 + G_1$	$E_2 - C_2 - G_1 - G_3$	$-C_5 + S_2 + S_3$	$-S_3$
(G_1, K_1, N_2, P_2)	$E_3 - C_3 - S_1$	$E_1 - C_1 + S_1$	0	$E_4 - G_2$
(G_1, K_2, N_1, P_2)	$-C_3 - C_4 - S_2 + G_1 + G_2$	$E_2 - C_2 - G_1 - G_3$	$-C_5 + S_2$	$-G_2$
(G_1, K_2, N_2, P_1)	$-C_3 - C_4 + G_1$	$E_2 - C_2 - G_1$	0	0
(G_1, K_2, N_2, P_2)	$-C_3 - C_4 + G_1 + G_2$	$E_2 - C_2 - G_1$	0	$-G_2$
(G_2, K_1, N_1, P_1)	$E_3 - S_2$	$E_1 - C_1 - S_4$	$-C_5 + S_2 + S_3$	E_4-S_3+S_4
(G_2, K_1, N_1, P_2)	$E_3 - S_2$	$E_1 - C_1$	$-C_5 + S_2$	E_4
(G_2, K_1, N_2, P_1)	E_3	$E_1 - C_1 - S_4$	0	$E_4 + S_4$
(G_2, K_2, N_1, P_1)	$-C_4 - S_2$	$E_2 - C_2 - G_3$	$-C_5 + S_2 + S_3$	$-S_3$
(G_2, K_1, N_2, P_2)	E_3	$E_1 - C_1$	0	E_4
(G_2, K_2, N_2, P_1)	$-C_4$	$E_2 - C_2$	0	0
(G_2, K_2, N_1, P_2)	$-C_4 - S_2$	$E_2 - C_2 - G_3$	$-C_5 + S_2$	0
(G_2, K_2, N_2, P_2)	$-C_4$	$E_2 - C_2$	0	0

2.3 An Analysis of the Evolutionary Game Model of Quadripartite Subjects

The two core categories of evolutionary game theory are "replication dynamics" and "evolutionary stability strategies". "Replication dynamics" is a dynamic description and analysis of the process of Bounded rationality participants' strategy adjustment[15]. Below are the replication dynamic equations for the behavior strategies of enterprises, governments, environmental NGOs, and consumers. Assuming that the expected return of the government choosing the "regulation" strategy is V_{11}, the expected return of the "non regulation" strategy is V_{12}, and the average expected return is V_1, Then there are formulas (1)(2)(3)(4)

$$V_{11} = yzm(E_3 - C_3 - S_1 - S_2) + yz(1-m)(E_3 - C_3 - S_1 - S_2 + G_2) + y(1-z)m(E_3 - C_3 - S_1) + (1-y)zm(-C_3 - C_4 - S_2 + G_1) + y(1-z)(1-m)(E_3 - C_3 - S_1) + (1-y)z(1-m)(-C_3 - C_4 - S_2 + G_1 + G_2) + (1-y)(1-z)m(-C_3 - C_4 + G_1) + (1-y)(1-z)(1-m)(-C_3 - C_4 + G_1 + G_2) \quad (1)$$

$$V_{12} = yzm(E_3 - S_2) + yz(1-m)(E_3 - S_2) + y(1-z)mE_3 + (1-y)zm(-C_4 - S_2) + y(1-z)(1-m)E_3 + (1-y)(1-z)m(-C_4) + (1-y)z(1-m)(-C_4 - S_2) + (1-y)(1-m)(1-z)(-C_4) \quad (2)$$

$$V_1 = xV_{11} + (1-x)V_{12} \quad (3)$$

Constructing a replication dynamic equation for government behavior strategies is：

$$F(x) = dx/dt = x(V_{11} - V_1) =$$

$$x(x-1)(C_3 - G_1 - G_2 + G_2m + G_1y + G_2y + S_1y - G_2my - G_2yz + G_2myz) \quad (4)$$

Similarly, if the expected return of a company choosing the "adopt" strategy is V_{21}, the expected return of a company choosing the "unregulated" strategy is V_{22}, and the average expected return is V_2, Then there are formulas (5)(6)(7)(8)

$$V_{21} = xzm(E_1 - C_1 + S_1 - S_4) + xz(1-m)(E_1 - C_1 + S_1) + x(1-z)m(E_1 - C_1 + S_1 - S_4) + x(1-z)(1-m)(E_1 - C_1 + S_1) + (1-x)zm(E_1 - C_1 - S_4) + (1-x)z(1-m)(E_1 - C_1) + (1-x)(1-z)m(E_1 - C_1 - S_4) + (1-x)(1-z)(1-m)(E_1 - C_1) \quad (5)$$

$$V_{22} = xzm(E_2 - C_2 - G_1 - G_3) + xz(1-m)(E_2 - C_2 - G_1 - G_3) + x(1-z)m(E_2 - C_2 - G_1) + x(1-z)(1-m)(E_2 - C_2 - G_1) + (1-x)zm(E_2 - C_2 - G_3) + (1-x)(1-z)m(E_2 - C_2) + (1-x)z(1-m)(E_2 - C_2 - G_3) + (1-x)(1-z)(1-m)(E_2 - C_2) \quad (6)$$

$$V_2 = yV_{21} + (1-y)\,V_{22} \quad (7)$$

The replication dynamic equation for constructing enterprise behavior strategies is:

$$F(y) = dy/dt = y(V_{21} - V_2) = -y(y-1)(C_2 - C_1 + E_1 - E_2 + G_1x - S_4m + G_3z + S_1x) \quad (8)$$

The expected return of environmental NGOs choosing the "supervision" strategy is V_{31}. The expected return on choosing the "unsupervised" strategy is V_{32}, with an average expected return of V_3, Then there are formulas (9)(10)(11)(12)

$$V_{31} = xym(-C_5 + S_2 + S_3) + xy(1-m)(-C_5 + S_2) + x(1-y)m(-C_5 + S_2 + S_3) + x(1-y)(1-m)(-C_5 + S_2) + (1-x)ym(-C_5 + S_2 + S_3) + (1-x)y(1-m)(-C_5 + S_2) + (1-x)(1-y)m(-C_5 + S_2 + S_3) + (1-x)(1-y)(1-m)(-C_5 + S_2) \quad (9)$$

$$V_{32} = 0 \quad (10)$$

$$V_3 = zV_{31} + (1-z)V32 \quad (11)$$

$$F(z) = dz/dt = z(V_{31} - V_3) = -z(z-1)(S_2 - C_5 + S_3 m) \quad (12)$$

The expected return for consumers to choose the "cooperation" strategy is V_{41}. The expected return on choosing the 'non cooperation' strategy is V_{42}, with an average expected return of V_4, Then there are formulas (13)(14)(15)(16):

$$V_{41} = xyz(E_4 - S_3 + S_4) + xy(1-z)(E_4 + S_4) + x(1-y)z(-S_3) + (1-x)yz(E_4 - S_3 + S_4) + (1-x)y(1-z)(E_4 + S_4) + (1-x)(1-y)z(-S_3) \quad (13)$$

$$V_{42} = xyz(E_4 - G_2) + xy(1-z)(E_4 - G_2) + x(1-y)z(-G_2) + x(1-y)(1-z)(-G_2) + (1-x)yzE_4 + (1-x)y(1-z)E_4 \quad (14)$$

$$V_4 = mV_{41} + (1-m)V_{42} \quad (15)$$

$$F(m) = dm/dt = m(V_{41} - V_4) = -m(m-1)(G_2 x + S_4 y - S_3) \quad (16)$$

2.4 Equant and Stability Analysis of Quadripartite Evolutionary Game

The strategy that participants constantly adjust their strategies according to their vested interests to pursue improvement of their own interests and ultimately achieve Dynamic equilibrium is called evolutionary stability strategy (ESS). The Equant of the evolutionary game is required before determining the evolutionary stability strategy. By making F (x)=0, F (y)=0, F (z)=0, and F (m)=0, we can obtain that the equation has 24=16 pure strategy solutions and 22 mixed strategy solutions. It can be seen that the stable solution in multi group evolutionary games is a strict Nash equilibrium, which is a pure strategy solution[16]. The 16 pure strategy solutions are (0,0,0,0), (0,0,0,1), (0,0,0,1,0), (0,0,0,1,1), (0,1,0,0), (0,1,1), (0,1,1), (1,0,0,0), (1,0,0,0,1) 1,1,0,1), (1,1,1,0), and (1,1,1,1).

Friedman's research results indicate that by solving the local stability of the Jacobian matrix of the replicated dynamical system, the evolutionary stable equilibrium solution of the replicated dynamical system can be obtained. The Jacobian matrix of the four party evolutionary game system is[4]:

$$J = \begin{bmatrix} J_1 & J_2 & J_3 & J_4 \\ J_5 & J_6 & J_7 & J_8 \\ J_9 & J_{10} & J_{11} & J_{12} \\ J_{13} & J_{14} & J_{15} & J_{16} \end{bmatrix} = \begin{bmatrix} \partial F(x)/\partial x & \partial F(x)/\partial y & \partial F(x)/\partial z & \partial F(x)/\partial m \\ \partial F(y)/\partial x & \partial F(y)/\partial y & \partial F(y)/\partial z & \partial F(y)/\partial m \\ \partial F(z)/\partial x & \partial F(z)/\partial y & \partial F(z)/\partial z & \partial F(z)/\partial m \\ \partial F(m)/\partial x & \partial F(m)/\partial y & \partial F(m)/\partial z & \partial F(m)/\partial m \end{bmatrix} \tag{17}$$

Using Lyapunov's first method: if all eigenvalues of the Jacobian matrix have negative real parts, then the Equant is an asymptotically stable point; If at least one of the eigenvalues of the Jacobian matrix has a positive real part, then the Equant is an unstable point; In addition to the eigenvalues whose real part is zero, the other eigenvalues of Jacobian matrix have negative real parts, so the Equant is in a critical state, and the stability cannot be determined by the eigenvalue symbol.

Analyze the 16 sets of corresponding eigenvalues corresponding to the pure strategy solution according to the Lyapunov rule to determine whether it is stable.

1. Firstly, the parameters set in this paper are all positive values, so eigenvalues with positive real parts can be directly excluded, as follows:

$E_2(1,0,0,0), E_3(0,1,0,0), E_6(1,1,0,0), E_{11}(0,0,1,1), E_{13}(1,1,0,1), E_{16}(1,1,1,1)$, These six Equant are unstable points;

2. Discussion $E_1(0,0,0,0)$,if the characteristic value $G_1 - C_3 + G_2 < 0$, which means that in the case of government regulation, if enterprises and consumers do not cooperate, the government's revenue will be less than 0. Therefore, there will be problems with the government's operation, so it is necessary to ensure that it is greater than 0 at this time. Therefore, $E_1(0,0,0,0)$ is an unstable fixed point, and similarly, can be obtained $E_4(0,0,1,0)$,eigenvalues $G_1 - C_3 + G_2$ must also be greater than 0, which is also an unstable fixed point;
3. Discussion $E_5(0,0,0,1)$, eigenvalues $S_2 - C_5 + S_3$. Correspondingly, the cost of benefits for environmental NGOs needs to be greater than 0, otherwise supervision cannot be exercised. Therefore, $E_5(0,0,0,1)$ is an unstable fixed point, similarly, $E_9(1,0,0,1), E_{10}(0,1,0,1)$, eigenvalues $S_2 - C_5 + S_3$ is also greater than 0, which is also an unstable fixed point;
4. Discussion $E_7(1,0,1,0)$, eigenvalues $C_2 - C_1 + E_1 - E_2 + G_1 + S_1 + G_3$, corresponding to respectively $E_1 - C_1$ and $E_2 - C_2$. The profit minus cost should be greater than 0, and adding three parameters greater than 0 will inevitably be greater than 0. Therefore, $E_7(1,0,1,0)$ is an unstable fixed point;
5. Discussion $E_8(0,1,1,0)$, eigenvalues $S_4 - S_3$, The direct benefits of consumption need to be greater than the subsidies provided by consumers, otherwise consumers will not cooperate based on their interest orientation. Similarly, $E_{12}(1,1,1,0)$, eigenvalues$S_4 - S_3 + G_2$,must be greater than 0, which is also an unstable fixed point;
6. Discussion $E_{14}(1,0,1,1)$, eigenvalues$C_2 - C_1 + E_1 - E_2 + G_1 + G_3 + S_1 - S_4$, By organizing it, $(E_1 - C_1 + S_1 - S_4) - (E_2 - C_2 - G_1 - G_3)$ it can be concluded that under government regulation and environmental NGO supervision, the benefits of transforming green logistics for enterprises are inevitably greater than those of continuing traditional logistics. Therefore, $E_{14}(1,0,1,1)$ is an unstable fixed point;

7. Discussion $E_{15}(0,1,1,1)$, eigenvalue$C_1 - C_2 - E_1 + E_2 - G_3 + S_4$. After sorting, it is $(E_2 - C_2 - G_3) - (E_1 - C_1 - S_4)$, which cannot directly determine the positive or negative eigenvalues and needs to reach a stable state. Its meaning is that when the government does not regulate the enterprise, that is, when the logistics enterprise adopts green logistics reform without subsidies, and when the logistics enterprise does not adopt green logistics reform with fines that can be used for government regulation costs ($G_1 > n$), Logistics enterprises will be able to achieve a balance between the total revenue of green logistics development and the original total revenue of traditional logistics. This is in line with the background of global low-carbon and sustainable development, as well as China's development policies. Green logistics will become an important part of enterprise competitiveness in the future environment. Therefore, $E_{15}(0,1,1,1)$may be a stable point.

From the above seven points of discussion, the following Table 3 can be obtained.

Table 3. Stability Analysis of Equant

equilibrium	Jacobian matrix eigenvalues		stability
	$\lambda_1, \lambda_2, \lambda_3, \lambda_4$	real part of symbol	
$E_1(0,0,0,0)$	$G_1 - C_3 + G_2, C_2 - C_1 + E_1 - E_2, S_2 - C_5, 0$	$(+, +, \times, 0)$	Instability point
$E_2(1,0,0,0)$	$C_3 - G_1 - G_2, C_2 - C_1 + E_1 - E_2 + G_1 + S_1, S_2 - C_5, G_2$	$(-, +, \times, +)$	Instability point
$E_3(0,1,0,0)$	$-C_3 - S_1, C_1 - C_2 - E_1 + E_2, S_2 - C_5, S_4$	$(-, -, \times, +)$	Instability point
$E_4(0,0,1,0)$	$G_1 - C_3 + G_2, C_2 - C_1 + E_1 - E_2 + G_3, C_5 - S_2, -S_3$	$(+, +, \times, -)$	Instability point
$E_5(0,0,0,1)$	$G_1 - C_3, C_2 - C_1 + E_1 - E_2 - S_4, S_2 - C_5 + S_3, 0$	$(+, \times, +, 0)$	Instability point
$E_6(1,1,0,0)$	$C_3 + S_1, C_1 - C_2 - E_1 + E_2 - G_1 - S_1, S_2 - C_5, G_2 + S_4$	$(+, -, \times, +)$	Instability point
$E_7(1,0,1,0)$	$C_3 - G_1 - G_2, C_2 - C_1 + E_1 - E_2 + G_1 + G_3 + S_1, C_5 - S_2, G_2 - S_3$	$(-, +, \times, +)$	Instability point
$E_8(0,1,1,0)$	$G_2 - C_3 - S_1, C_1 - C_2 - E_1 + E_2 - G_3, C_5 - S_2, S_4 - S_3$	$(+, \times, \times, +)$	Instability point
$E_9(1,0,0,1)$	$C_3 - G_1, C_2 - C_1 + E_1 - E_2 + G_1 + S_1 - S_4, S_2 - C_5 + S_3, -G_2$	$(-, \times, +, -)$	Instability point
$E_{10}(0,1,0,1)$	$-C_3 - S_1, C_1 - C_2 - E_1 + E_2 + S_4, S_2 - C_5 + S_3, -S_4$	$(-, \times, +, -)$	Instability point
$E_{11}(0,0,1,1)$	$G_1 - C_3, C_2 - C_1 + E_1 - E_2 + G_3 - S_4, C_5 - S_2 - S_3, S_3$	$(+, \times, -, +)$	Instability point
$E_{12}(1,1,1,0)$	$C_3 - G_2 + S_1, C_1 - C_2 - E_1 + E_2 - G_1 - G_3 - S_1, C_5 - S_2, G_2 - S_3 + S_4$	$(-, -, \times, +)$	Instability point

$E_{13}(1,1,0,1)$	$C_3+S_1, C_1-C_2-E_1+E_2-G_1-S_1+S_4, S_2-C_5+S_3, -G_2-S_4$	$(+,-,+,-)$	Instability point
$E_{14}(1,0,1,1)$	$C_3-G_1, C_2-C_1+E_1-E_2+G_1+G_3+S_1-S_4, C_5-S_2-S_3, S_3-G_2$	$(-,+,-,-)$	Instability point
$E_{15}(0,1,1,1)$	$-C_3-S_1, C_1-C_2-E_1+E_2-G_3+S_4, C_5-S_2-S_3, S_3-S_4$	$(-,\times,-,-)$	indeterminacy
$E_{16}(1,1,1,1)$	$C_3+S_1, C_1-C_2-E_1+E_2-G_1-G_3-S_1+S_4, C_5-S_2-S_3, S_3-G_2-S_4$	$(+,-,-,-)$	Instability point

3 Conclusion

Aiming at the realization of dual carbon goals in the sustainable development of China's economy, this paper constructs a four party evolutionary game model that includes government, enterprises, environmental NGOs and consumers in the process of traditional logistics transformation and green logistics, establishes a replication dynamic equation, solves the 16 pure strategy Equant of the model, and obtains the equilibrium value by constructing a Jacobian matrix and determinant, Then the asymptotic stability of the Equant is analyzed using Lyapunov's first method, and the stable point is obtained. Finally, Matlab tools were used to numerically simulate the evolution process of interaction behavior among government, enterprises, environmental NGOs, and consumers, analyzing the impact of parameter changes on the system evolution results, and then exploring the influencing factors and mechanisms that affect the system's evolution to an ideal state. The main conclusions of this article are as follows:(1) The transformation of enterprises from traditional logistics to green logistics does not require government subsidies, and excessive government regulation costs will lead to enterprises being more willing to adopt traditional logistics. The government can accelerate the transformation of enterprises into green logistics by adjusting subsidies, fines, and changes in cost control; This conclusion is based on the fact that the benefits brought by green logistics exceed the required costs and are greater than the benefits brought by traditional logistics. Compared to traditional logistics, green logistics can better concentrate resources, improve resource utilization, reduce circulation costs, and promote enterprise performance improvement. For high-cost transformation in the early stage, transformation costs can be reduced through methods such as technological innovation, supply chain management, and digital logistics technology. Of course, the huge cost investment in the early stage is still a challenge. We can negotiate with the government to open green credit, allowing enterprises to make a transition and support them in completing the transformation of green logistics. (2) Environmental NGOs need to adjust the cost of supervision so that the four parties can tend towards the optimal direction for trend evolution. The supervision cost of environmental NGOs should not be too high, as excessive supervision costs can lead to government pressure and consumer pressure, ultimately leading to the failure of environmental NGO supervision functions; At the same time, it should not be too low, as low supervision costs will lead to a trend towards zero in the evolution of consumer participation probability. It is worth mentioning that introducing consumers as the main body has a positive impact on the final

evolutionary trend. The addition of reverse logistics can make the entire evolutionary game process smoother and more complete.

4 Enlightenment

In the context of "dual carbon", government departments not only need to issue regulatory policies for enterprises, but also need to open up some green channels to reduce the cost of enterprise transformation. At the same time, a series of standards and evaluation systems related to green logistics need to be developed for standardized management; The primary consideration for the transformation of logistics enterprises is still cost. It should be combined with sustainable, green and low-carbon development strategies, and strengthen the foundation of green logistics application step by step through technological innovation, green supply chain management, etc., in order to ultimately successfully complete the transformation and enhance the competitiveness of future enterprises; The recycling behavior of consumers directly affects the logistics costs of enterprises. On the basis of consumers' willingness to actively recycle and use green materials, consumers can also use social groups and media news to promote the reduction of logistics costs, becoming another external push to promote the rapid transformation of logistics enterprises. The recycling path of consumers is also a major difficulty, and there are many logistics companies, corresponding to the high cost of recycling to a certain company, So, Cainiao Baobao can launch a unified recycling site, establish an integrated system, and form a relatively standardized recycling model. According to the proportion of recycled materials entering the system, an equal proportion can be given. Of course, it is also allowed to set up recycling points by oneself, such as enterprises with sufficiently large systems such as JD.com, SF Express, and Tmall, which can provide a certain guarantee for the recycling rate; The participation of environmental NGOs has made this system more complete, but the types of environmental NGOs vary across regions. For large cities, environmental NGOs are mostly advocacy oriented. Although they are independent third-party organizations, they can operate in a policy oriented manner, attract public participation, provide financial support from all parties, regulate, promote, and other functions, and achieve maximum effect through various external resources, such as government support, various public welfare organization negotiations, and media promotion; For medium-sized cities, environmental NGOs are mostly supervision oriented, with relatively little material and human support. The rules and regulations are not yet perfect, but they can achieve basic operation. The main direction of their work is based on pollution control work, and they can supervise the actions of the government and enterprises related to pollution control; For small cities, environmental NGOs are mostly propaganda oriented, with fewer participants and no established system nature. Of course, there is also assistance and support from various parties, and their work mainly focuses on environmental publicity and public environmental education to enhance public environmental awareness. Therefore, large and medium-sized cities can be used as pilot projects, and in this process, the development of propaganda oriented NGOs can be driven, with a dual line parallel approach, in order to accelerate the progress of logistics enterprise transformation. At the

same time, relatively speaking, there is still a lack of strong institutionalized rules within the organization, which can easily lead to the phenomenon of shielding. It is necessary to replace positions in a timely manner to ensure the maximization of supervisory power.

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