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RESEARCH ARTICLE

The Influence Mechanism of a Self-Governing Organization in the Logistics Industry Based on the Tripartite Evolutionary Game Model

CHI ZHANG[1], GUANGHUI YUAN[2], SHUAIWU LI[3], AND JUN HE[1,4]

[1]Center for Political and Social Security Studies, Shanghai University of Political Science and Law, Shanghai 201701, China
[2]School of Economics and Management, Shanghai University of Political Science and Law, Shanghai 201701, China
[3]School of Politics and International Relations, East China Normal University, Shanghai 200062, China
[4]Shanghai Research Center for Students' Safety Education, Shanghai 200032, China

Corresponding author: Jun He (12110170023@fudan.edu.cn)

ABSTRACT As a bridge of cooperation between enterprises and the government, the logistics association fully promotes logistics management and improves resource allocation. However, because China's logistics association is still in its initial stage, it is difficult for it to effectively unite the government and enterprises to solve the market monopoly, the incomplete system, and other problems. An evolutionary game model among the government, associations, and enterprises is constructed in order to develop a sustainable governance mechanism for the logistics industry to realize cooperative supervision and healthy competition among relevant participants. Based on the bounded rationality and expected payoff of the participants, the main determinants of the optimal strategy are analyzed, and the evolution path and equilibrium state of the three game groups are studied by numerical simulation. The results show that strengthening the independence of the association, increasing the government's reward to the association, and highlighting the positive social effects of industry independence are important factors for the healthy development of the logistics industry. In addition, the association must play its role in submission, distribution, and communication with the government and enterprises, constantly strengthen its own construction, improve industry standards, and create a favorable market environment for logistics enterprises.

INDEX TERMS Tripartite evolutionary game, self-governing organization, logistics, enterprises and associations, numerical simulation.

I. INTRODUCTION

Logistic associations are social intermediary organizations between the government and enterprises that provide services, consultation, communication, supervision, justice, self-discipline, and coordination for the two and are the bridge between the government and enterprises [1]. Since China's reform and with the continuous development of the market economy, associations have gradually become an important force in promoting economic construction and social progress. In the field of logistics, there are various levels of logistics associations and logistics management activities. These have yielded significant academic results, demonstrating that digital self-governing organizations can gain autonomy in non-market operations while remaining unconstrained by traditional hierarchies [2]. In addition, the relationship between logistics enterprises and the government is strengthened in the social aspect, which indirectly improves the efficiency of logistics management and plays an important role in promoting the development of the logistics industry. Because logistics associations in China are still in their initial stages and their functions of self-discipline and independence are not perfect, the problems they face are mainly concentrated on the following three aspects:

First, the unfair competition and monopoly behavior of logistics enterprises are outstanding. It is necessary to carry

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out macro-control on logistics enterprises, formulate laws and industry norms, and adjust the relationship between the government and logistics enterprises. At present, the Chinese government's macro-control of the logistics market is mainly focused on anti-unfair competition and anti-monopoly. Based on the ''Anti-Unfair Competition Law'' and the ''Anti-Monopoly Law'', the Chinese government aims to purify the market environment and promote orderly competition and healthy development of the logistics market. However, there is still much to be desired in terms of the legal construction. For example, the lack of uniform industry regulations to restrain the improper behavior of enterprises will inevitably weaken supervision.

Second, the self-discipline mechanism of the logistics association is insufficient. At present, China's logistics associations are not independent, lacking a certain regulatory function and legal status. In China, except for the ''Regulations on the Registration and Management of Social Organizations'', there are no specific laws and regulations to explain the nature, functions, powers, and responsibilities of logistics associations. Therefore, for better performance of social supervision functions, the logistics association's legal status needs to be improved, and its nature, functions, powers, and responsibilities need to be specified by formulating the basic related regulations of logistics.

Third, the government's standards for the logistics industry are insufficient. The conflicts and contradictions in the logistics industry standards need to be formulated and modified at the government level with reference to international standards so as to reduce the possible obstacles in the connection of logistics links.

At present, most of the studies on logistics industry governance mainly start from the separate perspectives of the government, enterprises, or associations, and a small number of literatures consider the cooperative supervision between the government and logistics enterprises. However, there are few reports on the relationship among the government, associations, and enterprises. In fact, the order of the logistics industry should not only rely on the market competition mechanism and the government's forced intervention to maintain it, but should make the participants voluntarily implement supervision and comply with the rules. It is of great significance for the sustainable development of the logistics industry to develop a reasonable and effective mechanism to promote cooperation and mutual supervision between the government, associations, and enterprises. Therefore, this paper starts from the interaction of the government, associations, and enterprises, comprehensively considers the management objectives of the government, the expected benefits of the association, and the development strategy of the enterprise, and explores how to make the logistics industry's governance mechanism carry out smoothly under the cooperation of these three subjects.

In view of the limitations of current statistical methods on the logistics market in terms of data acquisition and calculation accuracy, this paper uses game theory to analyze the main factors affecting industry governance from the perspective of expected benefits of participants. At the same time, because each participant cannot obtain all the information needed to make the optimal decision in practice, that is, they are all bounded rational, this paper adopts the evolutionary game theory that satisfies this prerequisite to analyze the behavior relationships of the participants in the logistics industry. In addition, the goal of the evolutionary game is to find a systematic evolutionarily stable strategy for a certain group of players that conforms to the industry governance mechanism sought in this paper. Under this mechanism, the association can cooperate with the government to implement effective regulation and supervision of the logistics industry, while enterprises can achieve self-discipline and healthy competition.

The rest of this paper is arranged as follows: In Section 1, this paper reviews the current literature in terms of the logistics industry, associations, and evolutionary games theory. In Section 2, this paper designs a three-party evolutionary game model, including the government, enterprises, and associations, and analyzes the model parameters, behavior strategies, payment matrix, and expected returns in detail. In Section 3, this paper explains the evolutionary game model through three parts: copying dynamic equations and equilibrium solutions; copying dynamic equations' evolutionary stability strategy analysis; and equilibrium point stability analysis. In Section 4, under the framework of the three-party evolutionary game, the simulation analysis of different parameter changes was carried out, and the results of the evolutionary game are discussed in detail. In the last section, research conclusions, improvement suggestions, and future research directions are explored.

II. LITERATURE REVIEW

Against the background of the information network era, logistics has gradually become an important pillar for promoting economic development and maintaining social order by virtue of business flow, guaranteeing production and facilitating life. An increasing number of scholars have paid attention to the logistics field and conducted research mainly from two perspectives: the industry's macro perspective and the enterprise's micro perspective [3], [4].

In terms of the logistics industry, Yao et al. [5] analyzed the green performance of the logistics industry in 30 provinces in China from 2008 to 2017 and adopted the functional clustering method funHDDC to show that the level of green efficiency was closely related to geographic location. Li and Wang [6] constructed an information sharing system and a sharing model between the manufacturing and the logistics industry, using blockchain technology to break the information flow barriers in the linkage of manufacturing and logistics, and achieved efficient coordination and management between the two industries. Centobelli et al. [7] constructed an emerging green practice information system suitable for the logistics industry and divided the proposed green initiative strategies into four types: sustainable development lead-

ers, green practice adopters, information system adopters, and sustainable followers.

In terms of logistics companies, Hsiao et al. [8] took Taiwanese logistics companies as the research object and found that both increasing the number of goods or reducing the number of workers would promote the company's performance through empirical analysis. Ef et al. [9], explored the main challenges faced by international logistics companies, such as the pick-up time window and delivery delay, and proposed a solution for an Italian shipping company, thus shortening the delivery time and improving the level of cargo security based on the principle of lean thinking and the concept of Industry 4.0. Stadnicka and Katarzyna [10] pointed out that fuel consumption was the most important operating cost of logistics enterprises and concluded that the human factor was an important factor affecting fuel consumption through the implementation of the Six Sigma project.

From the above analysis, it can be seen that the research focus in the logistics field includes information sharing, environmental protection, operating costs and management efficiency. However, there is little literature on the comprehensive supervision of individual enterprises and the industry as a whole. At the same time, because there are few studies related to logistics associations, it is possible to deepen the understanding of industry operation mechanisms by analyzing recognized association cases and industry management measures.

In terms of associations, Wenge et al. [11] collected sample data from 567 entrepreneurial companies in nine emerging industries in China and used a hierarchical regression model to analyze the impact of association members on corporate innovation and their potential moderating effects. The results showed that becoming a member of an association has a positive impact on corporate innovation. Wang et al. [12] pointed out that the rapid development of blockchain technology has prompted the emergence of decentralized self-governing organizations and smart contracts based on blockchain could make the organization's management rules operate automatically, thereby significantly reducing the cost of the organization's communication, management, and collaboration. Meng [13] recognized that the China Tourism association failed to fulfill its regulatory role and proposed that the social contract relationship between the government and associations, the cooperative relationship between various associations at all levels, and the management of members by associations could be handled better.

In terms of industry management, Ramoa et al. [14] adopted a nonprobabilistic sampling method to conduct a quantitative survey on ports, environmental protection experts, and ocean cruise companies and proposed a cruise industry management model that met environmental standards, which was conducive to maintaining a friendly company image to add the intangible value of tourism products. Batikas et al. [15] studied the effect of the self-regulatory agreement formulated by the European Commission on reducing the revenue of infringing content in the advertising industry, which showed that large advertisers could better comply with the initiative and reduce the connection with pirated websites. Kjr et al. [16] studied the effectiveness of building pockets of effectiveness (POEs) to manage natural resources in the extractive industries of African countries, and the study showed that this management model can increase the income of private enterprises, while ensuring the rationality of government supervision.

Although there have been many studies on industry regulatory measures in different countries and fields, qualitative discussions are mainly conducted through questionnaire surveys and empirical analysis, and there is a lack of objective characterization and quantitative research through mathematical models. Therefore, this paper chose evolutionary game theory, which reflects the subject's bounded rationality, to analyze the operation mechanism of the logistics industry.

Evolutionary games can be understood as repeated games through random pairings between groups by employing the dynamic mechanism of replication to continuously optimize strategies and finally reach the evolutionary stable state of the system [17], [18]. In recent years, applied research on evolutionary game theory has developed, involving environmental resource protection [19], [20], financial and trade development [21], [22], transportation management [23], [24], and public administrative supervision [25], [26]. Because the research of this paper is about the logistics industry and regulatory measures, the analysis of evolutionary game research in these two aspects is the focus.

In terms of logistics, Xing et al. [27] studied how to enable cold chain companies to voluntarily share their logistics information with the government based on evolutionary game theory, and simulation experiments showed that increasing subsidies and reducing costs were beneficial to ensuring the transparency and retrievability of cold chains. Zhang et al. [28] established a two-level supply chain evolutionary game model based on suppliers and manufacturers, and research showed that effective logistics information collaboration strategies were conducive to the establishment of new partnerships in the supply chain. Gu et al. [29] analyzed the cooperation between resource-intensive and energy-intensive enterprises applying two types of reverse logistics strategies, namely, self-operated and cooperative, and analyzed the evolution of the game model based on data from the steel industry.

In terms of supervision, Chen et al. [30] constructed an evolutionary game model to analyze the optimal decision of the government and enterprises in the reuse of waste products, and the study showed that if the profit of pollution production was higher than the profit of remanufacturing production, the enterprise would maintain its production mode, although it might face government penalties. Sun and Zhang [31] divided enterprises into superior and inferior ones centering on heterogeneity, constructed a green innovation strategy evolution model affected by the government's punishment mechanism and tax subsidy mechanism, and analyzed the evolution and stability of the model and the evolution of the two types of

enterprises. Liang et al. [32] studied the systematic relationship between government regulatory agencies and corporate behaviors in the use of electronic seals through the compensation matrix and evolutionary game model. The research showed that simply increasing the fines by the government was not an effective solution because electronic seals could not regulate the illegal use of credit rating factors.

In summary, the existing research takes a single perspective view of enterprises, markets, and governments. There is a lack of multidimensional systematic research on the logistics industry. Research on the operation mechanism of the logistics industry should, not only consider the long-term and dynamic nature of the mechanism, but also involve multiagent behavior factors. This paper extends the game subjects of traditional logistics and transportation issues from two parties to three parties and constructs an evolutionary game model of the ''association-enterprise-government'' operating mechanism. With model derivation and numerical simulation, the evolutionary stability strategy and ideal state of each subject are studied to realize the benign and effective development of the logistics industry.

III. CONSTRUCTION OF THE EVOLUTIONARY GAME MODEL OF LOGISTICS INDUSTRY OPERATION MECHANISM

A. HYPOTHESIS ANALYSIS OF THE MODEL

Based on the analysis of the logistics industry's operations and the behavior of the entities, this paper makes the following assumptions:

1) In this game system, there are only three game subjects: government regulatory agencies (short as ''the government''), logistics associations (short as ''associations'') and logistics enterprises (short as ''enterprises'').

2) Because people cannot obtain all the information in practice, each game subject cannot achieve complete rationality and cannot make profit maximization strategies. However, each subject has the ability to learn and imitate and can continuously adjust strategies to make it better through actual conditions.

3) The orderly operation of the logistics industry can only be ensured when associations and enterprises adopt active strategies.

Table 1 shows the model parameters and related meanings.

B. STRATEGIC ANALYSIS OF THREE-PARTY ENTITIES

The two strategies of the government are direct supervision and indirect supervision. The former means that the government supervises enterprises and associations at the same time through its own supervisory mechanism, thereby rewarding associations that implement independence and penalizing enterprises that implement vicious competition and nonindependent associations. The latter means that the government punishes the vicious competition behavior of enterprises through the investigation and reporting of the association and does not supervise the association. In addition, when there is vicious competition in the enterprise and the association is not independent, the government needs to implement governance on the poorly functioning logistics industry.

The two strategies of enterprises are healthy competition and vicious competition. The healthy one refers to the orderly operation and management of enterprises, in accordance with industry norms and regulations. The vicious one refers to the unfair competition and monopolistic behavior of enterprises. Among them, the profits obtained by enterprises under healthy competition are lower than those under vicious competition, but they may face penalties for violation when implementing vicious competition.

The two strategies of the association are complete and incomplete independence. The strategy of full independence means that the association, not only performs conventional duties, such as industry service and industry coordination, but also performs special duties, such as industry self-discipline and rights protection. The strategy of incomplete one means that the association only performs industry services and industry coordination and other conventional duties. When the association implements complete independence and discovers the vicious competition behavior of the enterprise, the association can take disciplinary measures, including warnings, criticism in the industry, expulsion of membership, etc., and report to the government in a timely manner. When the association implements incomplete independence and vicious competition among enterprises, the association suffers certain losses.

C. PAYOUT MATRIX AND EXPECTED RETURN OF THE THREE-PARTY GAME

The payment matrix of three-party entities in the logistics industry is shown in Table 2, where a_i, b_i and c_i represent the profit decisions of the government, enterprises and associations, respectively.

Because the actual revenues of each subject can be affected by the strategies of the other two subjects, there are eight combinations of strategies for the three subjects of government, enterprises and associations including: (direct supervision, healthy competition, complete independence); (direct supervision, vicious competition, complete independence); (indirect regulation, healthy competition, complete independence); (indirect regulation, vicious competition, complete independence); (direct regulation, healthy competition, incomplete independence); (direct regulation, vicious competition, incomplete independence); (indirect supervision, healthy competition, incomplete independence); and (indirect supervision, vicious competition, incomplete independence). The revenue decision for each combination is as follows:

$$\begin{aligned}(a_1, b_1, c_1) &= (-C_1 - B + E, R_1 - M + \delta E,\\ &\quad M - \alpha M - \beta M + B + \gamma E)\\ (a_2, b_2, c_2) &= (-C_1 - B + P_1, R_2 - M - P_1 - P_2,\\ &\quad M - \alpha M - \beta \mathrm{M} + B)\\ (a_3, b_3, c_3) &= (E, R_1 - M + \delta E, M - \alpha M - \beta M + \gamma E)\end{aligned}$$

TABLE 1. Model parameters and definitions.

Parameter	Connotation
R_1	The benefits that companies get when they implement healthy competition
R_2	The benefits obtained by the enterprise when it implements vicious competition ($R_1 < R_2$)
M	Membership fee paid by enterprises
αM	The cost paid by the association to perform industry services, industry coordination and other conventional duties (α is the cost coefficient)
βM	The cost paid by the association to perform special duties, such as industry self-discipline and rights protection (β is the cost coefficient, $\alpha < \beta, \alpha + \beta \leq 1$)
C_1	The cost of direct supervision by the government
B	Rewards given by the government to associations that implement independence (including decentralization of management functions, policy support, participation in and discussion of politics, and offer of financial support, etc.)
P_1	Government fines for companies engaged in vicious competition($P_1 > R_2 - R_1$)
P_2	Association's punishment for companies engaging in vicious competition (including warnings, industry criticism, expulsion of membership, etc.)
P_3	The government's punishment for associations that have not implemented self-government (including downgrading penalties, ordering rectification, etc.,$p_3 > \beta M$)
C_2	Governance costs paid by the government when enterprises compete viciously and the association is not independent
C_3	The loss paid by the association when the enterprise competes viciously and the association is not independent (including public influence, social reputation, etc., $C_3 > \beta M$)
E	The positive social effects obtained when the logistics industry operates in an orderly manner
γ	The positive social effect on the welfare coefficient of the association (for example, increase the social influence of the association, etc.)
δ	The positive social effect on the enterprise's welfare coefficient (for example, expanding the enterprise's market share, etc.)

TABLE 2. Payment matrix of three-party entities in the logistics industry.

Government	Direct supervision (x)		Indirect supervision (1-x)	
Enterprise	Healthy competition (y)	Vicious competition (1-y)	Healthy competition (y)	Vicious competition (1-y)
Association with full independence (z)	$(a1, b1, c1)$	$(a2, b2, c2)$	$(a3, b3, c3)$	$(a4, b4, c4)$
Association with incomplete independence (1-z)	$(a5, b5, c5)$	$(a6, b6, c6)$	$(a7, b7, c7)$	$(a8, b8, c8)$

$$(a_4, b_4, c_4) = (P_1, R_2 - M - P_1 - P_2, M - \alpha M - \beta M)$$
$$(a_5, b_5, c_5) = (-C1, R1 - M, M - \alpha M - P3)$$
$$(a_6, b_6, c_6) = (-C_1 + P_1 - C_2, R_2 - M - P_1, M - \alpha M - C_3 - P_3)$$
$$(a_7, b_7, c_7) = (0, R_1 - M, M - \alpha M)$$
$$(a_8, b_8, c_8) = (-C_2, R_2 - M, M - \alpha M - C_3)$$

In the initial stage of the evolutionary game of three-party entities in the logistics industry, assuming that the government's choice of direct supervision is a proportion x, then the proportion of indirect supervision is $1 - x$. Assuming that the proportion of enterprises choosing healthy competition is y, then the proportion of enterprises choosing vicious competition is $1 - y$. Assuming that the proportion of the association choosing full independence is z, then the

proportion of choosing incomplete independence is $1-z$. Obviously, $0<x<1, 0<y<1, 0<z<1$.

Suppose U_{A1} represents the expected revenues of the government's direct regulatory decision-making, U_{A2} represents the expected revenue of the government's indirect regulatory decision-making, and $\overline{U}_A$ represents the average expected revenue of the government, as shown in (1) - (3).

$$U_{A1} = yza_1+(1-y)\,za_2+y\,(1-z)\,a_5+(1-y)\,(1-z)\,a_6 \tag{1}$$

$$U_{A2} = yza_3+(1-y)za_4+y(1-z)a_7+(1-y)(1-z)a_8 \tag{2}$$

$$\begin{aligned}\overline{U}_A = {} & xyza_1+x\,(1-y)\,za_2+x\,(1-z)\,ya_5\\ & +x\,(1-y)\,(1-z)\,a_6+(1-x)\,yza_3\\ & +\,(1-x)\,(1-y)\,za_4+(1-x)\,(1-z)\,ya_7\\ & +\,(1-x)\,(1-y)\,(1-z)\,a_8\end{aligned} \tag{3}$$

Suppose U_{B1} represents the expected return of the enterprise making a healthy competitive decision, U_{B2} represents the expected return of making a vicious competitive decision, and $\overline{U}_B$ represents the average expected return of the enterprise, as shown in (4) – (6).

$$U_{B1} = xzb_1+x(1-z)b_5+(1-x)zb_3+(1-x)(1-z)b_7 \tag{4}$$

$$U_{B2} = xzb_2+x(1-z)b_6+(1-x)zb_4+(1-x)(1-z)b_8 \tag{5}$$

$$\begin{aligned}\overline{U}_B = {} & xyzb_1+xy(1-z)b_5+(1-x)yzb_3\\ & +y(1-x)(1-z)b_7+x(1-y)zb_2\\ & +x(1-y)(1-z)b_6+(1-x)(1-y)zb_4\\ & +(1-x)(1-y)(1-z)b_8\end{aligned} \tag{6}$$

Suppose U_{C1} represents the expected benefits of the association adopting full independence, U_{C2} represents the expected benefits of the association adopting incomplete independent decision-making, and $\overline{U}_c$ represents the average expected benefits of the association, as shown in (7) – (9).

$$U_{C1} = xyc_1+x(1-y)c_2+(1-x)yc_3+(1-x)(1-y)c_4 \tag{7}$$

$$U_{C2} = xyc_5+x(1-y)c_6+(1-x)yc_7+(1-x)(1-y)c_8 \tag{8}$$

$$\begin{aligned}\overline{U}_C = {} & xyzc_1+x\,(1-y)\,zc_2+(1-x)\,yzc_3+(1\\ & -x)\,(1-y)\,zc_4+xy\,(1-z)\,c_5+x(1-y)(1-z)c_6\\ & +(1-x)y(1-z)c_7+(1-x)(1-y)(1-z)c_8\end{aligned} \tag{9}$$

IV. THE EVOLUTIONARY GAME EQUILIBRIUM ANALYSIS OF THE LOGISTICS INDUSTRY OPERATION MECHANISM

A. REPLICATION OF DYNAMIC EQUATIONS AND EQUILIBRIUM SOLUTIONS

The dynamic equation of the government's replication is shown in (10).

$$\begin{aligned}F(x) = dx/dt &= x(U_{A1}-U_A) = x(1-x)(U_{A1}-U_{A2}\\ &= x(1-x)[yz(-p_1)+z(p_1-B)-C_1+p_1]\end{aligned} \tag{10}$$

The dynamic equation of enterprise replication is shown in (11).

$$\begin{aligned}G(y) = dy/dt &= y(U_{B1}-U_B) = y(1-y)(U_{B1}-U_{B2})\\ &= y(1-y)[xz(-p_1)+z(\delta E+p_1+p_2)\\ &\quad +xp_1+R_1-R_2]\end{aligned} \tag{11}$$

The dynamic equation of the association's replication is shown in (12).

$$\begin{aligned}H(z) = dz/dt &= z(U_{c1}-U_c) = z(1-z)(U_{c1}-U_{c2})\\ &= z(1-z)[x(B+P_3)+y(\gamma E-C_3)-\beta M+C_3]\end{aligned} \tag{12}$$

To obtain the equilibrium solution of the three-party evolutionary game under the operation mechanism of the logistics industry, it is necessary to simultaneously replicate the dynamic equations shown in (13).

$$\begin{cases}F(x) = x(1-x)[yz(-p_1)+z(p_1-B)-C_1+p_1]=0\\ G(y) = y(1-y)[xz(-p_1)+z(\delta E+p_1+p_2)\\ \qquad +xp_1+R_1-R_2]=0\\ H(z) = z(1-z)[x(B+P_3)+y(\gamma E-C_3)\\ \qquad -\beta M+C_3]=0\end{cases} \tag{13}$$

Among them, (13) has 8 special equilibrium points $(0,0,0)$, $(0,0,1)$, $(0,1,0)$, $(0,0,1)$, $(0,1,0)$, $(1,0,0)$, $(1,1,0)$, $(1,0,1)$, $(0,1,1)$, $(1,1,1)$ in the equilibrium solution domain [22]$R=(x,y,z)|0\le x\le 1, 0\le y\le 1, 0\le z\le 1\}$. In addition, $E(x^*,y^*,z^*)$ is also in this domain, which can be solved by (14). Because the solution of $E(x^*,y^*,z^*)$ is complicated, numerical simulation can be carried out in combination with actual meaning and given conditions.

$$\begin{cases}y^*z^*(-p_1)+z^*(p_1-B)-C_1+p_1=0\\ x^*z^*(-p_1)+z^*(\delta E+p_1+p_2)+x^*p_1+R_1-R_2=0\\ x^*(B+P_3)+y^*(\gamma E-C_3)-\beta M+C_3=0\end{cases} \tag{14}$$

Derivation of the dynamic equation of each subject in the game obtains by:

$$F(x)' = \frac{dF(x)}{dx} = (1-2x)[yz(-p_1)+z(p_1-B)-C_1+p_1] \tag{15}$$

$$\begin{aligned}G'(y) = \frac{dG(y)}{dy} &= (1-2y)\,[xz\,(-p_1)\\ &\quad +\,z\,(\delta E+p_1+p_2)+xp_1+R_1-R_2]\end{aligned} \tag{16}$$

$$\begin{aligned}H'(z) = \frac{dH(z)}{dz} &= (1-2z)[x(B+P_3)\\ &\quad +y(\gamma E-C_3)-\beta M+C_3]\end{aligned} \tag{17}$$

According to evolutionary game theory, the equilibrium point is brought into (15) - (17). If $F(x)' < 0, G(y)' < 0, H(z)' < 0$, then the strategy represented by the equilibrium point is the three-party game evolutionary stable strategy (ESS) of the government, enterprises, and associations [33]. Based on this, the following sections analyze the gradual stability of each entity's evolution strategy.

B. ANALYSIS OF EVOLUTIONARY STABILITY STRATEGY BASED ON REPLICATION OF DYNAMIC EQUATIONS

From the perspective of the government, inferences can be made by replicating the dynamic equation:

1) When $z = \frac{C_1-P_1}{P_1(1-y)-B}$, $F(x) \equiv 0$, that is, all levels are in a stable state, the stability of x depends on the initial state.

2) When $z \neq \frac{C_1-P_1}{P_1(1-y)-B}$, $x = 0$ and $x = 1$ are the two solutions of $F(x) = 0$, which are the two equilibrium points of x. At this time, the equilibrium strategy for the government should be $\frac{dF(x)}{dx} < 0$, as shown in the following analysis.

Because $0 < y < 1$ and $0 < z < 1$, $z(1-y)P_1 > 0$, that is $yz(-p_1) + zp_1 > 0$.

a. When $P_1 > B + C_1$, $yz(-p_1)+z(p_1-B)-C_1+p_1 > 0$ can be got. Therefore, $F'(1) < 0$, and $x = 0$ is a stable strategy. It shows that when enterprises compete viciously, the fines by the government are greater than the government's supervision costs and incentive costs. This means the government's benefits exceed the costs, and then direct supervision is the government's evolutionary and stable strategy.

b. When $P_1 < B + C_1$, it is divided into the following two situations.

When $0 < z < \frac{C_1-P_1}{P_1(1-y)-B}$, $F'(0) < 0$, then $x = 0$ is a stable strategy. At this time, the government is more willing to choose indirect supervision.

When $1 > z > \frac{C_1-P_1}{P_1(1-y)-B}$, $F'(1) < 0$, then $x = 1$ is a stable state. At this time, the government tends to choose direct supervision.

Given that the other two groups remain unchanged, a schematic diagram of the dynamic evolution of government decision-making is shown in Figure 1.

From the perspective of the enterprise, inferences can be made by replicating the dynamic equation:

1) When $z = \frac{R_2-R_1-xP_1}{-P_1x+\delta E+P_1+P_2}$, $G(y) \equiv 0$, that is, all levels are in a stable state, the stability of y depends on the initial state.

2) When $z \neq \frac{R_2-R_1-xP_1}{-P_1x+\delta E+P_1+P_2}$, $y = 0$ and $y = 1$ are the two solutions of $G(y) = 0$, that is, there are two equilibrium points of y. At this time, the equilibrium strategy for obtaining the enterprise should be $\frac{dG(y)}{dy} < 0$, as shown in the following analysis.

Because $0 < x < 1$ and $0 < z < 1$, $xz(-p_1)+z(\delta E+p_1+p_2) > 0$ is always correct.

a. When $xP_1 > R_2 - R_1$, $G'(1) < 0$, then $y = 1$ is a stable strategy. This shows that when the net risk of the enterprise's implementation of vicious competition is less than the result of the multiplication of the probability of the government's direct supervision and the penalty cost, the enterprise is more willing to choose a healthy competition strategy.

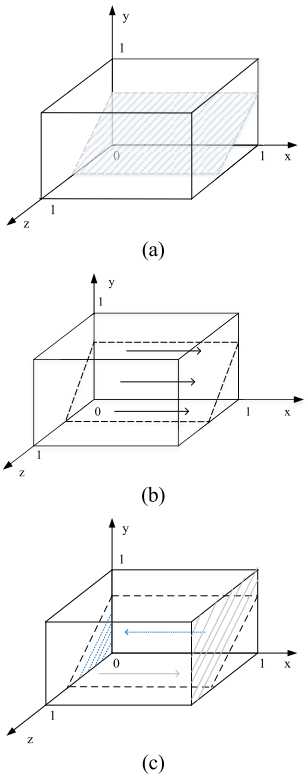

FIGURE 1. Schematic Diagram of the Dynamic Evolution of Government Decision-making. (a) $z = \frac{C_1-P_1}{P_1(1-y)-B}$. (b) $P_1 > B + C_1 x \to 1$. (c) $0 < z < \frac{C_1-P_1}{P_1(1-y)-B} x \to 0$, $1 > z > \frac{C_1-P_1}{P_1(1-y)-B} x \to 1$.

b. When $xP_1 < R_2 - R_1$, the following two situations may occur.

When $1 > z > \frac{R_2-R_1-xP_1}{-P_1x+\delta E+P_1+P_2}$, $G'(1) < 0$, then $y = 1$ is a stable strategy. At this time, the enterprise finally evolved into a healthy competition.

When $0 < z < \frac{R_2-R_1-xP_1}{-P_1x+\delta E+P_1+P_2}$, $G'(0) < 0$, then $y = 0$ is a stable strategy. At this time, the enterprise finally evolved into vicious competition.

A schematic diagram of the dynamic evolution of enterprise decision-making is shown in Figure 2.

From the perspective of the association, inferences can be made by replicating the dynamic equation:

1) When $y = \frac{\beta M-C_3-x(B+P_3)}{\gamma E-C_3}$, $H(z) \equiv 0$, that is, all levels are in a stable state, the stability of z depends on the initial state.

2) When $y \neq \frac{\beta M-C_3-x(B+P_3)}{\gamma E-C_3}$, $z = 0$ and $z = 1$ are the two solutions of $H(z) = 0$, which are the two equilibrium points of z. At this time, the equilibrium strategy should be $\frac{dH(z)}{dz} < 0$, as shown in the following analysis.

a. When $\gamma E > C_3$, and under the conditions of $0 < x < 1, 0 < y < 1$, $x(B + P_3) + y(\gamma E - C_3) - \beta M + C_3 > 0$. can be obtained. Therefore, when $H'(1) < 0, z = 1$ is a stable strategy. This shows that when the loss paid by the association for failing to implement complete independence for viciously competitive enterprises is, not only less than the benefits of

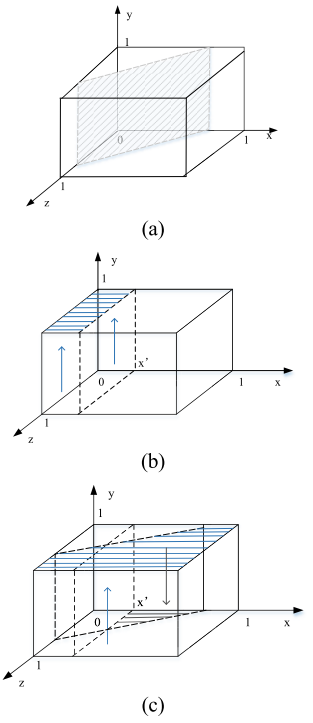

FIGURE 2. Schematic Diagram of the Dynamic Evolution of Enterprise Decision-making. (a) $z=\frac{R_2-R_1-xP_1}{-P_1x+\delta E+P_1+P_2}$. (b) $x>x'=\frac{R_2-R_1}{P_1}y\to 1$. (c) $0<z<\frac{R_2-R_1-xP_1}{-P_1x+\delta E+P_1+P_2}y\to 0$, $1>z>\frac{R_2-R_1-xP_1}{-P_1x+\delta E+P_1+P_2}y\to 1$.

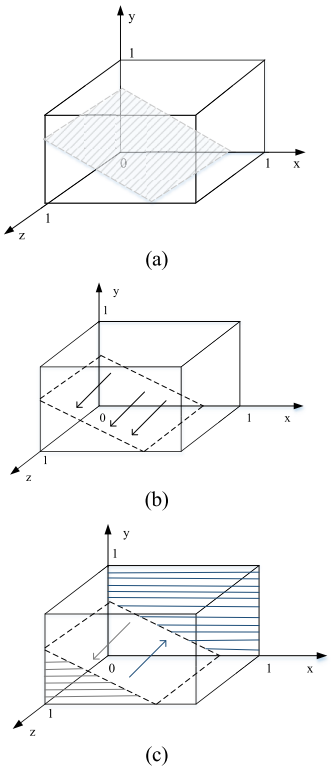

FIGURE 3. Schematic Diagram of the Dynamic Evolution of Association Decision-making. (a) $y=\frac{\beta M-C_3-x(B+P_3)}{\gamma E-C_3}$. (b) $\gamma E>C_3>\beta Mz\to 1$. (c) $0<y<\frac{\beta M-C_3-x(B+P_3)}{\gamma E-C_3}z\to 1$, $1>y>\frac{\beta M-C_3-x(B+P_3)}{\gamma E-C_3}z\to 0$.

its orderly operation of the logistics industry, but also greater than the cost of its performance of special duties, and the association can tend to implement complete independence.

b. When $\gamma E < C_3$, the following two cases may occur.

When $0 < y < \frac{\beta M-C_3-x(B+P_3)}{\gamma E-C_3}$, $H'(1) < 0$, then $z = 1$ is a stable strategy. At this time, the association can be more willing to choose a fully independent strategy.

When $1 > y > \frac{\beta M-C_3-x(B+P_3)}{\gamma E-C_3}$, $H'(0) < 0$, then $z = 0$ is a stable strategy. At this time, the association is more willing to implement an incomplete independent strategy.

A schematic diagram of the dynamic evolution of association decision-making is shown in Figure 3.

C. STABILITY ANALYSIS OF THE EQUILIBRIUM

By separately discussing the respective stable states of the government, enterprises, and associations, this paper can determine the method to make each subject inclined to the desired strategy. On this basis, this paper further analyzes the preconditions for the three parties to be in a stable state through the equilibrium point and the Jacobian matrix. According to the concept of evolutionary equilibrium proposed by Hirshleifer, if in a dynamic system, the trajectory starting in any adjacent domain of a certain equilibrium point eventually evolves toward the equilibrium point, then the equilibrium point is asymptotically stable, and this point is called the evolutionary stable strategy. At the same time, because the solution of asymptotic stability must be a strict Nash equilibrium solution, this paper only considers the asymptotic stability of the pure strategy equilibrium point (E1-E8). By solving the partial derivatives of x, y, and z by replicating the dynamic equations of the three game players, the Jacobian matrix shown in (18) can be obtained.

$$J = \begin{bmatrix} J_{11} & J_{12} & J_{13} \\ J_{21} & J_{22} & J_{23} \\ J_{31} & J_{32} & J_{33} \end{bmatrix} \tag{18}$$

The parameters in (18) are as follows:

$$\begin{aligned}
J_{11} &= (1-2x)[yz(-p_1)+z(p_1-B)-C_1+p_1] \\
J_{12} &= x\,(1-x)\,(-zP_1) \\
J_{13} &= x(1-x)(-yP_1+P_1-B) \\
J_{21} &= y(1-y)(-zP_1+P_1) \\
J_{22} &= (1-2y)[xz(-p_1)+z(\delta E+p_1+p_2) \\
&\quad +xp_1+R_1-R_2] \\
J_{23} &= y(1-y)(-xP_1+\delta E+P_1+P_2) \\
J_{31} &= z(1-z)(B+P3) \\
J_{32} &= z(1-z)(\gamma E-C_3) \\
J_{33} &= (1-2z)[x(B+P_3)+y(\gamma E-C_3)-\beta M+C_3]
\end{aligned}$$

By solving the Jacobian matrix, the eigenvalue corresponding to each balance point can be obtained, and then the asymptotic stability of each balance point can be analyzed,

TABLE 3. Equilibrium analysis of equilibrium points.

Equilibrium point	eigenvalues	stable state
$E_1(0,0,0)$	$\lambda_1 = -C_1 + P_1$ $\lambda_2 = R_1 - R_2$ $\lambda_3 = -\beta M + C_3$	Equilibrium point $E_1(0,0,0)$ is the saddle point because $-\beta M + C_3 > 0$
$E_2(1,0,0)$	$\lambda_1 = C_1 - P_1$ $\lambda_2 = P_1 + R_1 - R_2$ $\lambda_3 = B + P_3 - \beta M + C_3$	Equilibrium point $E_2(1,0,0)$ is the saddle point because $P_1 + R_1 - R_2 > 0$.
$E_3(0,1,0)$	$\lambda_1 = -C_1 + P_1$ $\lambda_2 = -R_1 + R_2$ $\lambda_3 = \gamma E - \beta M$	Equilibrium point $E_3(0,1,0)$ is the saddle point because $-R_1 + R_2 > 0$.
$E_4(0,0,1)$	$\lambda_1 = 2P_1 - B - C_1$ $\lambda_2 = \gamma E + P_1 + P_2 + R_1 - R_2$ $\lambda_3 = \beta M - C_3$	Equilibrium point $E_4(0,0,1)$ is the saddle point because$\gamma E + P_1 + P_2 + R_1 - R_2 > 0$.
$E_5(1,1,0)$	$\lambda_1 = C_1 - P_1$ $\lambda_2 = -P_1 - R_1 + R_2$ $\lambda_3 = B + p_3 + \gamma E - \beta M$	Equilibrium point $E_5(1,1,0)$ is the saddle point because $B + p_3 + \gamma E - \beta M > 0$.
$E_6(1,0,1)$	$\lambda_1 = -2P_1 + B + C_1$ $\lambda_2 = \delta E + P_2 + P_1 + R_1 - R_2$ $\lambda_3 = -B - p_3 - C_3 + \beta M$	Equilibrium point $E_6(1,0,1)$ is the saddle point because $\delta E + P_2 + P_1 + R_1 - R_2 > 0$.
$E_7(0,1,1)$	$\lambda_1 = -B - C_1 + P_1$ $\lambda_2 = -\delta E - P_2 - P_1 - R_1 + R_2$ $\lambda_3 = \beta M - \delta E$	If $P_1 < B + C_1$, Equilibrium point $E_7(0,1,1)$ is ESS. Otherwise, the point is a saddle point.
$E_8(1,1,1)$	$\lambda_1 = B + C_1 - P_1$ $\lambda_2 = -\delta E - P_2 - P_1 - R_1 + R_2$ $\lambda_3 = -B - p_3 - \gamma E + \beta M$	If $P_1 > B + C_1$, Equilibrium point $E_8(1,1,1)$is ESS. Otherwise, the point is a saddle point.

as shown in Table 3. From Table 3, it can be obtained that only $E_7(0, 1, 1)$ and $E_8(1, 1, 1)$ have the possibility of becoming ESS. The phase diagram of these two equilibrium points is shown in Figure 4. The remaining six balance points are saddle points.

The strategy represented by $E_8(1, 1, 1)$ is from direct government supervision, healthy competition of enterprises, and full independence of the association. The precondition for this three-party strategy to achieve long-term stability is $P_1 > B + C_1$; that is, the total cost from direct government supervision is less than the fines obtained from viciously competing companies. Although this precondition can stimulate the enthusiasm of the government to participate in supervision through additional benefits, it is not conducive to the full independence of the association, and this kind of stability is obviously not helpful to the sustainable development of the logistics industry.

The prerequisite for $E_7(0, 1, 1)$ to become ESS is $P_1 < B+C_1$, that is, the government cannot obtain positive income from direct supervision. This condition can prompt the government to implement indirect supervision and ultimately make the association evolve into complete independence and the enterprises' competition into a healthy one. This equilibrium point is the final stable state that this paper expects to achieve.

V. SIMULATION ANALYSIS OF THE OPERATION MACHANISM OF THE LOGISTICS INDUSTRY

A. SIMULATION ANALYSIS OF THE INITIAL STATE

To verify the constructed evolutionary game model of the logistics industry operation mechanism and its analysis results, the evolutionary behavior of governments, enterprises and associations can be numerically simulated. Based on the needs of simulation, the dynamic replication equations of

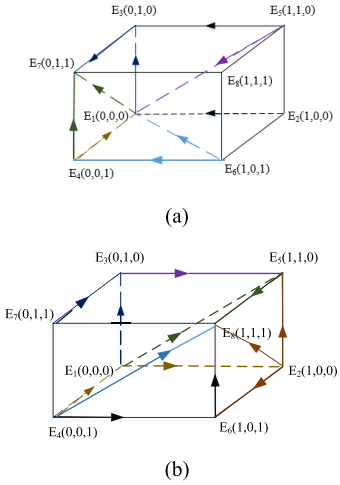

FIGURE 4. Phase diagram of the equilibrium point. (a)$E_7(0, 1, 1)$. (b) $E_8(1, 1, 1)$.

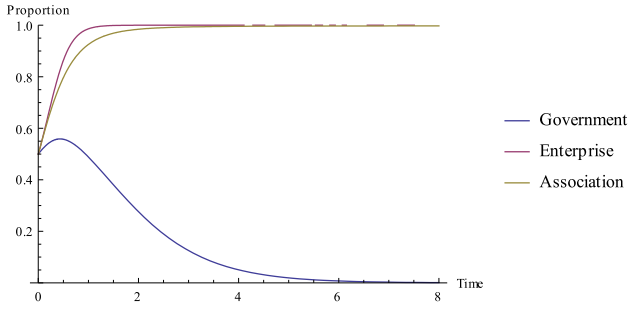

FIGURE 5. Evolution path of the three-party game of the initial logistics industry operation mechanism.

each subject are discretized to analyze the progressive and stable operation trajectory of the evolutionary game. Suppose the time step is Δt, and (19) –(21) can be obtained from the definition of the derivative.

$$\frac{dx(t)}{dt} \approx \frac{x(t+\Delta t)-x(t)}{\Delta t} \tag{19}$$

$$\frac{dy(t)}{dt} \approx \frac{y(t+\Delta t)-y(t)}{\Delta t} \tag{20}$$

$$\frac{dz(t)}{dt} \approx \frac{z(t+\Delta t)-z(t)}{\Delta t} \tag{21}$$

According to the above equations, this paper uses mathematical simulation to further study the actual influence of related variables on the evolutionary game. Among them, in order for the three-party entities to finally achieve the ideal state, the initial parameter settings must satisfy $R_1 < R_2$, $0 < \beta < 1$, $P_1 > R_2 - R_1$, $P_3 > \beta M$, $C_3 > \beta M$, $P_1 < B + C_1$. The initial parameter settings are as follows: $P_1 = 4$, $C_1 = 3.5$, $B = 2.5$, $E = 5$, $\gamma = 0.2$, $\delta = 0.4$, $P_2 = 1.5$, $P_3 = 2$, $R_1 = 6$, $R_2 = 8$, $C_3 = 2.5$, $M = 1.5$, $\beta = 0.6$

The initial evolution path is shown in Figure 5. The initial strategies of fixed government, enterprises and associations are all 0.5, so that the evolution path of the logistics industry

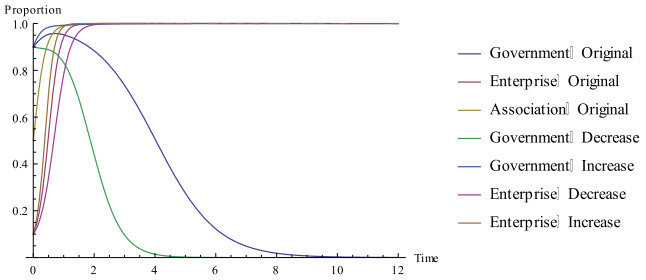

FIGURE 6. Impact on the evolutionary path of the three-party game in the logistics industry.

operation mechanism game can be objectively evaluated from an unbiased starting point.

B. SIMULATION ANALYSIS UNDER PARAMETER CHANGES

Among all the parameters, the three main factors, including the government's fines for enterprises that engage in vicious competition p_1, the government's reward B for implementing fully independent associations, and the positive social effect E obtained during the orderly operation of the logistics industry, are those determining the evolutionary path of this game. At the same time, these three parameters affect two parties in the game, so the following studies the influence of increasing or decreasing these parameters on the decision of the game entities. In addition, the following assumes that at the initial stage of the game, the proportion of the association choosing full independence is 0.5, which means the association is initially neutral. The ratio of enterprises choosing healthy competition is 0.1, which means enterprises initially prefer to violate regulations to obtain illegal income. The government's direct supervision ratio is 0.9, which means that the government initially prefers not to trust the competence of the independence of associations.

1)Adjusting the government's fines for enterprises engaging in vicious competition

Keeping the other parameters and the initial strategy of the three parties unchanged, increase the value of p_1 to 5.5 and decrease to 2.5. Because this parameter is not included in the replication dynamic equation of the association, its evolution path does not change. Therefore, the evolutionary path of the government and enterprises is highlighted, as shown in Figure 6.

As shown in Figure 6, the impact of government punishment of viciously competing enterprises on government behavior and corporate behavior is mainly examined. Enterprises adopt different strategies according to the regulatory policies of the government. The government's policy design and selection have an important guiding and demonstrative effect on corporate behavior [34]. When the government raises the fines for enterprises that engage in vicious competition, the government acts as the more stringent direct supervisor in a short period of time, and the strict state of direct supervision is maintained afterward. When enterprises are engaged in vicious competition and severely disrupt the

market ecology, the government often imposes high fines on enterprises and implements direct supervision. When enterprises face high fines and stricter supervision, they often carry out rectifications immediately, turning vicious competition into a healthy one sharply, because high fines would bring great economic pressure to the enterprise, which could be unbearable for the extended effect of penalties, including the blow to the enterprise's social reputation and product reputation. Therefore, enterprises turn to healthy competition to avoid fines, maintain reputation, and guarantee normal sales of the product. For example, in the field of intellectual property, the strategic choice of potential infringers is more sensitive to the government's punishment and compensation for infringement, and the increase in punishment and compensation can well restrain potential infringers [35]. Similarly, logistics enterprises are highly sensitive to government punishments, and increased punishments can effectively curb vicious competition among logistics companies.

On the other hand, direct supervision is a favorable means to curb the vicious competition behavior of enterprises. However, this does not mean that the greater the punishment is, the better the effect because there may be this marginal diminishing situation between the punishment and the inhibition efficiency [36]. Therefore, when the government lowers fines for enterprises that engage in vicious competition, it indicates that the government is gradually shifting from direct supervision to indirect supervision. Based on consideration of factors, such as high supervision costs and the release of market vitality, the government reduces fines, relaxes the deterrence effect and supervision is relieved. At the same time, although the number of fines imposed by the government on companies engaging in malicious competition has been reduced, enterprises still face fines and indirect supervision, and corporate behavior will also change from vicious competition to healthy behavior. However, this transition can be slower when higher fines are imposed. This is mainly due to the reduction in the amount of stimulus for enterprises after the fines have fallen. In addition, the emergence of policy effects often has a certain lag, and enterprises have a ''window period'' at the wait-and-see stage, which slows down their progress of the speed of the transition from vicious competition to healthy competition.

2) Adjusting the government's incentives for associations that implement full independence

Keeping the other parameters and the initial strategy of the three parties unchanged, increase the value of B to 4 and decrease it to 1. Because this parameter is not included in the replication dynamic equation of the enterprise, its evolution path does not change. The evolution path of the government and associations is highlighted as shown in Figure 7.

As Figure 7 shows, government rewards for implementing fully independent associations have an important impact on government behavior and the independence of associations. Associations are important suppliers of public goods in the industry, and they can provide public goods that benefit the entire industry by lobbying the government to issue favorable industrial policies and improve their own independence and

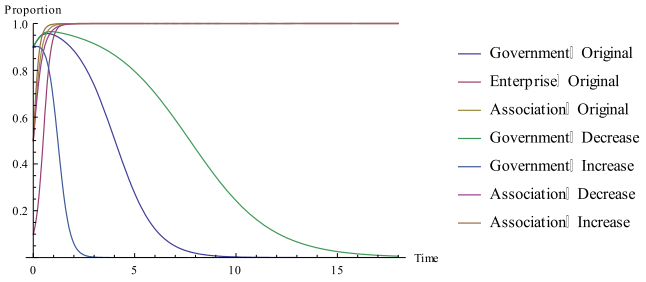

FIGURE 7. B's influence on the evolutionary path of the three-party game in the logistics industry.

competency [37]. When the government grants incentives for implementing fully independent associations, the government switches from direct supervision to indirect in a short period of time, including a series of measures, such as decentralizing management functions, improving policy support, providing political participation opportunities, and increasing financial support. This could enable associations to gain more sufficient independence and free development space, organizational socialization and maturity have been improved. The power structure of the relationship between the government and the association can be transformed from ''strong country-weak association'' to ''strong country-strong association'' [38], which helps reach a level of complete independence in a short time.

In addition, when the government's reward for implementing fully independent associations drops, the government increases supervision in a short period of time and then gradually reduces the intensity and switches to indirect supervision. This is mainly because the government's ability to supply public goods is limited, and direct supervision costs are high, so it chooses to reduce rewards and supervision costs. However, because it is uncertain whether the association can carry out effective self-government with reduced rewards, the government is more willing to provide direct supervision in the short term, strengthen supervisory behavior, and conduct a wait-and-see inspection of the association. However, due to the existence of rewards, the enthusiasm of associations for independence increases, and their role in industry self-discipline and independence could gradually become prominent. At the same time, whether it is to increase or decrease rewards, the government must bear the cost of supervision. When the cost of supervision accumulates to a certain extent and the level of independence of the association meets the government's requirements, the government gradually reduces supervision and switches to indirect supervision. Because associations have always been rewarded, their own capabilities also continue to improve. To undertake the functions of government repayment, the willingness of associations to supply public goods in the industry also gradually increases and develops from incomplete to complete independence [39], but the rate is slower when the reward is higher. The slower rate is due to the low government rewards to associations, and the incentives for them in the process of

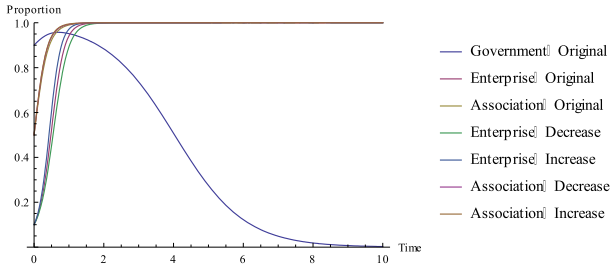

FIGURE 8. Impact of E on the evolutionary path of the three-party game in the logistics industry.

turning to full independence are not obvious, which leads to the lengthening of this process in the time dimension. At the same time, the decline in government rewards to associations also sends out an uncertain signal to enterprises, and an associations' doubts about the government's signals also led to a slower rate.

3) The positive social effects obtained when the logistics industry is adjusted in an orderly manner

Keeping the other parameters and the initial strategy of the three parties unchanged, increase the value of E to 7 and decrease it to 3. Because this parameter is not included in the government's replication dynamic equation, its evolution path does not change, so the evolution path of enterprises and associations is highlighted, as shown in Figure 8.

As Figure 8 reflects, positive social effects are obtained during the orderly operation of the logistics industry and the relationship between associations and enterprises. The acquisition of positive social effects requires the effective operation of associations, and the normal operation of associations requires a clear and quasi-public product industry standard and supervision mechanism [40]. Conversely, the positive social effect also promotes the healthy development of enterprises and associations. When the positive social effect obtained during the orderly operation of the logistics industry increases, the enterprises quickly turn from vicious competition to healthy competition. When the positive social effect decreases, enterprises also develop toward healthy competition, but it takes a longer time. The orderly operation of the logistics industry promotes the transformation of enterprises to healthy competition, but the reduction of positive social effects reduces the willingness of enterprises to engage in healthy competition because the pursuit of economic benefits is always the biggest goal of enterprises. When the positive social effects are reduced, enterprises prioritize the greatest gains. Although the trend toward healthy competition remains unchanged, the process is slower. In addition, the positive social effects obtained by the orderly operation of the logistics industry are of great benefit to the associations in enhancing their influence and authority and can also demonstrate the independence of the associations in their organization and operation. When the orderly operation of the logistics industry obtains a positive social effect, whether it is increasing or decreasing, the logistics association turns to full independence. The greater the positive social effect is, the faster the logistics association turns to full independence. The positive social effect encourages logistics associations to continuously standardize the behavior of practitioners in the industry, improve the industry's operating mechanism, and then continuously increase the degree of independence of the associations. Although the reduction of the positive social effect does not affect the association's transition to full independence, the positive effect declines. The positive stimulus received by associations can be weakened, and the transition to full independence can be slower.

C. DISCUSSION

Aiming at the existing problems of logistics industry governance, this paper takes the expected benefits of logistics industry participants as the research perspective and proposes corresponding solutions based on evolutionary game theory. There are three similarities between this paper and the existing research on the logistics industry. First, it emphasizes that an effective governance mechanism is of great significance for the sustainable development of the logistics industry. Second, it illustrates that the logistics association plays a key role in providing supervision and coordination for the government and enterprises. Third, it points out that the government, enterprises, and associations are the main participants in logistics industry management.

Compared with the existing research, the innovation of this paper is mainly reflected in the following three aspects:

First, this paper constructs an evolutionary game model of the whole process of logistics industry governance and discusses the expected benefits of logistics industry participants from the perspectives of the government, enterprises, and associations. From the perspective of the full life cycle, this paper solves the management problems in different development stages of the logistics industry and provides a new way to govern the logistics market. This paper makes up the gap in the research of logistics industry governance from the perspective of a multi-dimensional full life cycle.

Second, considering various uncertain factors faced by the logistics industry and the bounded rationality characteristics of relevant participants, this paper innovatively applies evolutionary game theory to the governance of the logistics industry. This paper analyzes the strategy evolution dynamics of the government, enterprises, and associations in the governance process and proposes strategic conditions for effective government supervision, reasonable autonomy of associations and benign competition of enterprises. Thus, solutions to problems such as market monopoly and incomplete systems are provided.

Third, based on evolutionary game theory, this paper reveals the governance mechanism involving the government, enterprises, and associations, gives a scheme to strengthen the autonomous function of logistics associations, and solves the dilemma of effective industry supervision and promoting market development. This paper provides a new method for the association to implement effective supervision on the

logistics market and enriches the relevant research on the cooperation between the government, industry self-governing organizations, and enterprises.

VI. CONCLUSION

The logistics association plays an important role in undertaking part of the government's functions, promoting the development of the logistics industry, and ensuring healthy competition among logistics enterprises. However, vicious competitive behavior of some logistics enterprises disrupts the normal operation of the entire industry, and the government intervenes in industry supervision, which indirectly decreases the independence of logistics associations. Associations are an important boost to help the government achieve the healthy development of the logistics industry. They act as a bridge between the government and enterprises. Therefore, if the independence degree of associations can be improved, the government's supervision costs can be reduced, and healthy competition among enterprises can be promoted to enable the logistics industry to develop in an orderly and healthy manner.

A. RESEARCH CONCLUSION

By constructing an evolutionary game model of the ''association-enterprise-government'' operating mechanism, this paper concludes that the independence degree of the logistics association and the healthy development of the logistics industry are largely affected by factors, such as the competition model of enterprise, the intensity of rewards and punishments from the government and the positive social effect produced by the effective operation of the logistics industry.

At the same time, to further study the evolution path in the steady state, this paper analyzes the influence of different parameters on the evolution behavior of the three game groups by numerically simulating the evolutionary stability strategy and ideal state of each subject. The following three conclusions are drawn.

First, the government's punishment and supervision of enterprises can promote the transformation of enterprises from vicious competition to healthy competition. However, confined by cost factors, the government cannot maintain the normalization of direct and strict supervision, nor can it truly increase the willingness of enterprises to compete in a healthy way, but the full realization of the independence of associations can play a positive role. There exists positive social effects brought by the orderly operation of the logistics industry to regulate corporate behavior and form a positive cycle of the healthy development of the logistics industry.

Second, the government's rewards to the logistics associations can prompt the associations to turn to full independence, and the willingness of the associations to provide public goods increases, which can better promote the orderly and healthy development of the industry. However, when the government's incentives are reduced, the support received by logistics associations is weakened, and the willingness to provide public goods decreases, which may lead to the emergence of vicious competition in the industry. Therefore, the logistics association needs to continuously improve the supervisory mechanism of the association, reduce dependence on government rewards, and achieve a high level of association independence.

Third, the positive social effects obtained during the orderly operation of the logistics industry promote logistics associations to increase their degree of independence and strengthen self-management. At the same time, they also encourage enterprises to standardize operations and maintain healthy competition. However, when the positive social effect declines, the willingness of logistics associations to move toward full independence also decreases, and the degree of self-regulation of enterprises driven by economic interests also declines.

B. SUGGESTIONS FOR IMPROVEMENT

As important participants in the logistics industry, associations should ensure the orderly and healthy development of the logistics industry, urge enterprises to obtain profits under healthy competition, and continuously improve the positive social effects of the logistics industry. Therefore, based on the research results, this paper proposes the following two suggestions.

On the one hand, the logistics association should strengthen its own construction, such as grasping the status quo of the industry in a timely manner, studying and judging the development trend of the industry, promoting the establishment of an enterprise information sharing mechanism, and improving the industry meeting mechanism. After extensively consulting opinions from the industry, associations should implement standardization of rewards and punishments and formulate and improve the industry evaluation system to make the mechanism construction of industry independence the main driving force to promote the continuous improvement of the degree of independence of the logistics industry.

On the other hand, the logistics association should establish a good interactive relationship with the government and enterprises and take the initiative to build a bridge between them. The logistics association must actively undertake the functions delegated by the government, assist the government in releasing the vitality of enterprises, and create a good market environment and social atmosphere. The association should also actively communicate with enterprises to ensure profitability and healthy competition among enterprises, identify problems in the process of enterprise development, and be fully mobilized to coordinate and solve problems with the internal and external resources of the association.

C. FUTURE RESEARCH DIRECTION

Although this paper has achieved the expected research purpose, there are still some limitations that need to be improved in future research. In this paper, parameters are used to describe relevant decision variables, such as regulatory costs, etc. However, parameters cannot dynamically describe

realistic problems. In the future, the parametric model can be transformed into a functional model to reveal the dynamic evolution law. At the same time, the impact of social variables on the development of the logistics industry needs to be further considered because the behavioral decisions of participants will change in the complex evolutionary process. The regulatory bodies set up in this paper only include the government and autonomous organizations. In the future, social organizations such as consumer associations will be combined to analyze the game strategies of the logistics industry and strive to improve the effectiveness of the governance mechanism.

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CHI ZHANG is currently an Associate Professor working on international relations with the Shanghai University of Political Science and Law (SHUPL), the Dean of the Department of International Politics, and the Executive Director of the Center for Political and Social Security Studies, SHUPL. His research interests include international relations and regional cooperation, and more than 20 articles published.

GUANGHUI YUAN received the B.S. degree in mathematics and applied mathematics from Three Gorges University, Yichang, Hubei, China, in 2012, and the M.S. degree in systems engineering from the University of Shanghai for Science and Technology, Shanghai, China, in 2015. He is currently pursuing the Ph.D. degree in management science and engineering with the Shanghai University of Finance and Economics, Shanghai. He is currently an Associate Professor with the management science, Shanghai University of Political Science and Law (SHUPL). His research interests include data mining, information systems engineering, and big data analysis.

SHUAIWU LI is currently pursuing the M.A. degree with the School of Advanced International and Area Studies, East China Normal University. His research interests include international politics and northeast Asian studies, and more than two articles published.

JUN HE is currently a Senior Research Fellow working on ideological and political education with the Shanghai University of Political Science and Law and also the Executive Director of Shanghai Research Center for Students' Safety Education. His research interests include education and geopolitics, and more than two articles published.