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RESEARCH ARTICLE

Profit distribution and stability analysis of joint distribution alliance based on tripartite evolutionary game theory under the background of green and low carbon

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Abstract

Joint distribution is an advanced logistics organization model for improving the quality and efficiency of express logistics industry and achieves high-quality development of logistics, but the distribution of common profit has always been a key obstacle to the effective development of joint distribution. Based on the background of green and low carbon, this paper explores a fairer and more reasonable profit distribution scheme. The profit game between the government and the two types of member enterprises is analyzed. By focusing on how the government plays a role in inducing the joint distribution alliance to bring the green and low-carbon requirements into the profit distribution, the strategy evolution process of the three parties, the factors affecting the profit distribution and the stability of alliance are discussed through the establishment of "government-member enterprise A-member enterprise B" tripartite evolutionary game model. Finally, the evolutionary game model is numerically simulated based on system dynamics. It is found that (1) it is necessary for the government to guide and motivate the alliance to create internal incentives and constraints. The effect of government subsidies and rewards to member enterprises is greater than the penalties for member enterprises. (2) The member enterprises are likely to conspire together to defraud government subsidies and rewards, carry out "free riding" and other speculative activities, which makes it necessary for the government and the alliance to establish supervision mechanism, information disclosure mechanism, and property rights protection system. (3) The willingness of member enterprise to positively cooperate will increase with the increase of the additional benefit coefficient, the proportion of profit distribution and the importance of environmental benefit factor; and will decrease with the increase of the cost of promoting green distribution operations.

Keywords Green and low carbon · Evolutionary game · Joint distribution · Profit distribution · Stability of alliance · Numerical simulation

Introduction

The express logistics industry is a leading industry in China that promotes the transformation of circulation and consumption upgrades, and terminal distribution is a vital part of the industry. In 2018, some scholars (Yang et al. 2018) selected 150 terminal express service outlets in Haidian District of Beijing by random sampling to conduct field research. They found problems such as vicious competition at low prices among outlets, large diffience in business volume between different express brands, loose management system of franchise outlets, difficult traffic, and high frequency of workplace replacement. In order to solve these "last mile" distribution problems, joint distribution can be a good way.

Joint distribution, a distribution activity jointly organized and implemented by multiple express logistics enterprises, plays an important role in reducing costs and improving efficiency for express logistics industry. Joint distribution cannot only reduce the distribution cost, improve the efficiency of resource allocation, meet the public's demand for small batch and various products under the background of the

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rapid development of e-commerce, but also save resources and reduce the negative externalities of distribution operation to the city and environment. In 2019, the “Opinions on Promoting the High-quality Development of Logistics and Promoting the Formation of a Strong Domestic Market” was issued by the National Development and Reform Commission to encourage and support the development of advanced logistics organization models including joint distribution, centralized distribution, night distribution, and time-sharing distribution. In February 2021, the “Guiding Opinions on Accelerating the Establishment and Improvement of a Green and Low-carbon Circular Development Economic System” was issued by the State Council to support the development of joint distribution and propose that new energy or clean energy vehicles should be used in areas such as urban logistics and postal express delivery. It can be seen that China hopes to enhance the endogenous power of high-quality development of logistics and improve the circulation system of green and low-carbon circular development through joint distribution.

Joint distribution is a way in which multiple express logistics enterprises jointly form an enterprise alliance to delivery. According to the close cooperation between member enterprises, the enterprise alliance can be divided into equity alliance and contractual alliance. The former one refers to the alliance that member enterprises establish in the form of holding shares, which requires enterprises to share risks and interests. The latter one refers to the alliance established by member enterprises in the form of signing contracts or agreements. Compared with equity alliance, the relationship between member enterprises is not very close in a contractual alliance, which reflects the instability of contractual alliance to some extent. However, the current joint distribution practice of China’s express logistics enterprises shows that contractual alliance is easier to achieve, either in the way of establishing virtual joint distribution center run by a neutral committee or in the way of jointly investing in a joint distribution center in the form of a company. Combined with the practice in China, the alliance in this paper refers to the contractual alliance, that is, member enterprises jointly invest in the establishment of a common distribution center, and each member contributes to it. However, there still remains some challenges in the process of alliance operation, such as unclear operation steps and inefficient terminal layout. Among these challenges, the lack of fair and reasonable distribution of common economic profit has always been a key challenge to the effective implementation of joint distribution, and even affects the stability and longevity of joint distribution alliance. Therefore, focusing on the problems of profit distribution and alliance stability caused by the former problem, the rest of this paper is organized as follows: conducts a literature review on the relevant documents, then analyzes the profit game of joint distribution participants, establishes a tripartite evolutionary game model, and carries out numerical simulation based on the model. Finally, conclusions and suggestions are discussed, so as to provide theoretical reference for solving the above problems, promoting the implementation of joint distribution, and promoting the sustainable development of express logistics industry.

Literature review

Nowadays, the research on the problem of profit distribution mainly focuses on introducing factors that affect it to improve the Shapley value and other methods with the purpose of optimizing the profit distribution scheme. Some scholars (Bin et al. 2016; Xu et al. 2018; Li et al. 2019) realized the importance of environmental sustainability, and introduced ecological and environmental factors to improve profit distribution methods and models. There are also scholars who combined a variety of game models, such as incomplete information dynamic game model, stackelberg model, to analyze the game behaviors and profit distribution relationships between member enterprises in an alliance (Du and Gong 2018), among which the evolutionary game model is widely used.

Evolutionary game theory is a theory that combines game theory analysis with dynamic evolution process analysis. It holds that humans improve their strategies by continuous learning and imitation, rather than taking the optimal strategies from the beginning. Compared with traditional game theory, evolutionary game theory assumes that humans are bounded rational. Owing to players with bounded rationality have multiple levels of rationality, their ways and speeds of learning and strategy adjustment are quite different, and it is almost impossible to obtain the optimal results in the fast-changing economic activities, so the perspective of evolutionary game are necessarily used to simulate the evolution of and the interactive relationship between the players’ strategies, which reflect the reality better. Scholars at home and abroad have used evolutionary game theory to study the strategic interaction between member enterprises in a logistics alliance, the stability of alliance, and the factors affecting the stability of alliance. Huang et al. (2010) focused on the investment efficiency of specific assets within the alliance and the trust mechanism associated with it. By establishing a two-party evolutionary game model between the demand side and the supply side of logistics services, they made it clear that the equivalence and soundness of the trust mechanism have a positive impact on the stability of logistics alliance and the specific asset investment efficiency. Xu et al. (2011) discussed the formation mechanism of logistics alliance, considered risk aversion conditions when establishing the alliance’s collaboration game model, and analyzed the factors that affect the investment of logistics enterprises. Li and Hu (2012) put forward a two-party evolutionary game model to describe the cooperation and coordination process within the alliance formed by logistics enterprises of the same nature in an asymmetric state, pointed out that factors such as cooperation cost, retained profit, alliance profit, and profit distribution rate have an impact on the stability of logistics alliance. Wu et al. (2014) believed that the stability of cooperation between regional logistics alliance member enterprises is related to time discount factors, enterprise profit, and alliance constraint mechanisms, and it is necessary for the government to take measures to reward and punish the member enterprises so that the benefits of betraying the alliance are always less than the benefits of cooperation. Sun et al. (2014) focused on the joint distribution of urban cold chain logistics, established a two-party evolutionary game model and found that the member enterprise's willingness to cooperate is affected by initial input costs, profit distribution, and degree of mutual dependence. Wang and Zhang (2015) conducted incomplete information dynamic game analysis on the leading logistics enterprises, other logistics enterprises and production enterprises in a logistics alliance, and discussed the equilibrium conditions for the formation of logistics alliance. Liu et al. (2015) explored the motivation and stability factors of the formation of logistics alliance by establishing a two-party evolutionary game model between third-party logistics enterprises and functional logistics enterprises, concluded that the higher the cooperation cost of member enterprises and the lower the fees paid by third-party logistics to functional logistics, the lower the probability that the alliance can be formed and maintained stable. Du et al. (2018) initially identified the operational risks of cross-border logistics alliance, and then established an evolutionary game model under the alliance's internal punishment mechanism, believed that it is necessary for the alliance to establish a scientific punishment mechanism to prevent speculative activities by member enterprises and avoid the operation risks of alliance. Zou et al. (2019) established a co-evolution game model for self-operated logistics packaging enterprises and logistics outsourcing third-party packaging enterprises, and pointed out that product market share, synergy cost, synergy effect, synergy cost sharing, revenue sharing ratio have an impact on the synergy between the two. Du et al. (2019a) put forward an evolutionary game model between domestic cross-border e-commerce enterprises and foreign logistics enterprises, and found that the willingness of both parties to cooperate depends on the initial state of cooperation, input costs, excess returns, and cloud technology platform. Based on the evolutionary game model of collaborative innovation between manufacturing enterprises and logistics enterprises, Yu et al. (2019) found that under the influence of market mechanism, only when the enterprise's collaborative innovation benefits are higher than the sum of the "free-riding" benefits and investment, can the alliance reach a stable state of collaborative innovation. ("Free-riding" means the act of obtaining benefits from others without paying any cost). The greater the intensity of government subsidies and penalties, the more conducive to the formation of the alliance. Besides, the profit distribution ratio, input costs, and knowledge transfer efficiency have an impact on the stability of alliance. Chen et al. (2019) divided alliance member enterprises into three categories according to input elements and market power, established a tripartite evolutionary game model and analyzed the factors that affect the strategic choices of the three parties, concluded that the intensity of punishment, transaction costs among member enterprises, and speculative gains have significant influence on the strategic choice of member enterprises and the stability of logistics alliance. The incentive and preferential policies among the member enterprises can promote more active cooperation of the member enterprises than the unilateral alliance punishment. After establishing a co-evolution game model of cross-border e-commerce and cross-border logistics, Mu et al. (2020) found that the co-evolution of the two features obvious path dependence, and the path and state of the evolutionary game between the two will change with the changes of the initial state and the return matrix. Fu et al. (2020) analyzed the strategy evolution path of cross-border logistics alliance member enterprises by establishing a two-party evolutionary game model between domestic logistics enterprises and foreign logistics enterprises, and believed that the stability of alliance is affected by the profit distribution mechanism, the scale of resource input and operational efficiency. Du et al. (2020) proposed a tripartite evolutionary game model of "cross-border e-commerce platform-logistics service provider-merchant" for the cross-border e-commerce logistics alliance based on 4PL. In addition, there are analyses highlighting the impact of information sharing and information collaboration on logistics alliance. For example, Zhang et al. (2017) believed that in the initial stage of the formation of logistics alliance, the proportion of information resource input affects the construction of logistics alliance. During the operation of the logistics alliance, the sharing degree of information resources between member enterprises, the benefits brought about by the reduction of shared information resources, overflow benefits, and the degree of loss affect the member enterprises' decision-making and the stability of alliance. Hu et al. (2018) believed that increasing the degree of information sharing will increase the willingness of enterprises to cooperate positively, and the total profit of the alliance and the proportion of profit distribution also increase accordingly, which is beneficial to the stability of alliance. Zhang et al. (2020a, b) believed that supply chain logistics information collaboration (SCLIC) is the basis and premise of supply chain logistics collaboration, analyzed the evolution game process of suppliers, manufacturers, and their combination by establishing a two-level supply chain evolution game model composed of suppliers and manufacturers.

What's more, other documents (Li et al. 2017; Ji and Shi 2018; Liang et al. 2017; Gu et al. 2017; Zhang and Hou 2019; He and Li 2021; Xing et al. 2020; Xu and Yang 2021; Zhu et al. 2021a, b; Wang et al. 2021) took into account the important role of government participation, regarded the government as a participant, conducted the evolution game analysis of cold chain logistics, reverse logistics, cross-border e-commerce and logistics, combined transport by road transport enterprises and railway transport enterprises, strategic interaction between manufacturing enterprises and logistics enterprises, etc. by introducing government rewards, government punishment, and regulatory mechanism. Especially, Zhang et al. (2019b) discussed the behavioral mechanism of joint distribution alliance under government supervision based on the background of sustainable development. They believed that in the early stage of implementing joint distribution, the government needs to subsidize and reward member enterprises, or increase the penalties for non-cooperation of member enterprises to promote the formation of a benign logistics environment and market mechanism. As long as the government's goals are achieved, the benefits of cooperation within the alliance are improved and costs are reduced, the government can then withdraw its supervision. Zhang et al. (2020a, b) also introduced government reward and punishment mechanism, used evolutionary game theory to explore the behavioral mechanism of joint distribution alliance member enterprises and the factors that affect the implementation of joint distribution.

Besides, owing to strong shocks to society and the economy from environmental problems, green and low-carbon development patterns have gradually attracted more attention from all over the world (Wu et al. 2017). Many scholars studied the strategic game relationships between the government and various market participants under the background of green and low carbon (Zhao et al. 2016; Fan et al. 2017; Wu et al. 2017; Zhang et al. 2019a; Sun and Feng 2021). At this time, the research field is no longer limited to logistics, but also covers electric vehicles (Hirte and Tscharaktschiew 2013; Liu et al. 2017; Zhou et al. 2019; Du et al. 2019b), green supply chain (Sheu and Chen 2012; Hafezalkotob et al. 2016; Madani and Rasti-Barzoki 2017; Zu et al. 2018; Mahmoudi and Rasti-Barzoki 2018; Yuan et al. 2018; Hafezalkotob 2018; Shi et al. 2020; Long et al. 2021), e-waste (Peng et al. 2019), and so on.

In summary, although scholars have recognized the impact of environmental sustainability on the behavioral decisions of express logistics enterprises, consider the environmental benefits when discussing profit distribution of joint distribution alliance, they pay so much attention to discuss the profit distribution methods that lack the research on the profit distribution mechanism, especially on how to incorporate the green and low-carbon requirements into the alliance's profit distribution scheme. It should be noted that there is no conscious motivation for joint distribution alliance to incorporate the green and low-carbon requirements into the profit distribution scheme so as to formulate a fairer and more reasonable profit distribution scheme. Whether it is necessary for the government to participate and what kind of policy means and tools should be used to promote the formation of this mechanism is worth thinking about. Besides, some scholars believe that profit distribution is closely related to the stability of alliance, the stability of logistics alliance, including joint distribution alliance, is not static. There are many studies on the stability of logistics alliance from the perspective of evolutionary game theory, but there is a lack of research on the impact of the alliance's internal profit distribution strategy on the stability of alliance, especially when the profit distribution takes into account the green and low-carbon requirements, will the alliance continue to remain stable? Therefore, based on previous research and from the perspective of evolutionary game, this paper initially divides the member enterprises into two types (A and B) according to the volume and green level of distribution and the joint distribution alliance can be simplified to include only the above two types of enterprises. In addition, the government is also an important participant, so the interaction between the alliance and the government can be embodied as the interaction among enterprise A, enterprise B, and the government. Then the "government-member enterprise A-member enterprise B" tripartite evolutionary game model is put forward to explore the government's important role in guiding and motivating alliance to incorporate green and low-carbon requirements into profit distribution scheme, the strategy evolution paths, the interaction between the tripartite participants involved in this process, and the factors that affect the stability of alliance. Finally, according to the system dynamics, the tripartite evolutionary game is numerically simulated to study the influence of the different decision-making behaviors of the three parties on their stable operation status, reveal the formation process of the alliance's profit distribution mechanism considering the green and low-carbon requirements under government participation. On this basis, this paper will enrich the related theoretical results, provide decision-making reference for the government to promote the reasonable distribution of common profit and green development of the logistics alliance.

Profit game analysis of the three parties

Promoting the green development of the express logistics industry is the general trend. Although joint distribution has the advantages of reducing the number of vehicles used for distribution, increasing the loading rate of vehicles, thereby reducing carbon emissions, pollution emissions, and increasing environmental benefits (Bi et al. 2020), it does not mean that joint distribution can completely eliminate the negative externalities brought by member enterprises to the cities and the environment, nor does it mean that member enterprises have endogenous motivation to promote green distribution operations. Promoting green distribution operations usually costs member enterprises a lot, if so, member enterprises are likely to recoup the cost of green distribution operations by sharply raising the price of delivery services. However, in reality, that is a price level the market cannot afford. Since joint distribution is an advanced logistics organization method vigorously advocated by the state, it is necessary for express logistics enterprises to reflect green and low-carbon requirements in the process of forming a joint distribution alliance and implementing joint distribution.

Based on the hypothesis that humans are rational, member enterprises pursue the maximization of their own profit. If the marginal transaction cost of joint distribution from the market is lower than the marginal organization cost of distribution organized by member enterprise itself, member enterprises will form and participate in the alliance; otherwise, they will withdraw and disband the alliance (Yang and Han 2021).

According to the reality, member enterprises can be divided into two types: one is large enterprises with a larger volume of delivery and a higher level of green distribution operations (denoted as member enterprise A), and the other is small and medium-sized enterprises with a smaller volume of delivery and a lower level of green distribution operations (denoted as member enterprise B). The reason why member enterprise A hopes to form an alliance with member enterprise B is that it can take advantage of large-scale distribution operations by cooperating with member enterprise B, reduce fixed cost per unit of delivery, and reach economies of scale. Meanwhile, member enterprise B hopes to cooperate with member enterprise A because it can get help from member enterprise A to promote green distribution operations, reduce its distribution costs, improve its distribution efficiency, as well as enhance its brand awareness in the process of cooperation. Considering the high costs, high risks, and long return period of greening distribution operations, neither of them has the motivation to implement the green and low-carbon requirements spontaneously. As for a single express logistics enterprise, it promotes green distribution operations under the dual effects of internal power and external pressure. However, if there is a conflict of profit with its stakeholders, coupled with a lack of endogenous power and external pressure, its process of green development will become difficult. For this reason, it is necessary for the government to motivate and supervise the enterprise (Li and Wang 2014). As for the alliance, the co-opetition relationship between member enterprises, the difference in strategic choices, and the difference in the ability to promote green distribution operations make the implementation of green and low-carbon requirements within the alliance quite different from the situation of a single enterprise. If the market mechanism cannot help member enterprises spontaneously implement green and low-carbon requirements, then governments committed to maximizing social and economic benefits, including environmental benefits, should participate and induce member enterprises to consciously incorporate green and low-carbon requirements into joint distribution. In other words, the government can guide the alliance to take environmental benefits as one of the important factors affecting profit distribution and put it into the alliance's profit distribution scheme through necessary policy means and tools, so as to overcome the defect of profit distribution merely based on marginal business contribution of member enterprises in the past. The member enterprise who implements the green and lo- carbon requirements better, has a higher level of green distribution operations, and creates greater environmental benefits can be allocated more profit. At this time, member enterprise A will be more motivated to promote green distribution operations, and though member enterprise B is not as good as member enterprise A in terms of distribution volume, it can seize this opportunity to improve its green level of distribution operations in order to obtain more profit. It is worth mentioning that government subsidies, rewards, and penalties to the alliance are important parts of the government's strategy. Government subsidies and rewards can narrow the gap between the common profit of the alliance in the process of promoting green distribution operations and the common profit of alliance without promoting green distribution operations, reduce the risks and costs of member enterprises in implementing green and low-carbon requirements, and thus improve the stability of alliance. What can be not ignored is that all member enterprises may have opportunistic behaviors, which is not only manifested as defrauding government subsidies and rewards, but also as "free riding" behavior, for which the government must punish.

It can be seen from the above that each player's strategy choice not only depends on its own profit expectation, but also depends on the strategy choice of other players. All players' strategies are not always the same, but will be adjusted as time goes on.

The construction of tripartite evolutionary game model

Model hypothesis

Hypothesis 1. The government is participant 1, member enterprise A is participant 2, and member enterprise B is participant 3. All of them have bounded rationality, not only pursuing the maximization of their own profits, but also often failing to find the optimal strategies at the very beginning. They constantly adjust their own strategy choices based on their experience, and finally reach a stable equilibrium.

Hypothesis 2. The game between the three parties belongs to the asymmetric game, and the game strategies adopted by the three parties influence each other. The profit of any party depends not only on its own strategy choice, but also on the strategy choices of the other two parties.

Hypothesis 3. The government's strategy space is (incentive, non-incentive), in which the "incentive" strategy refers to subsidies, rewards and punishments coming from the government in the process of implementing green and low-carbon requirements; the "non-incentive" strategy refers to not subsidizing, rewarding or punishing member enterprises, hoping that member enterprises will consciously implement green and low-carbon requirements. The strategy space of member enterprise A is (positive cooperation, negative cooperation), in which the "positive cooperation" strategy refers to positively responding to the government's call to implement green and low-carbon requirements; the "negative cooperation" strategy refers to not responding to the government's call and not implementing green low-carbon carbon requirements. The strategy space of member enterprise B is (positive cooperation, negative cooperation), in which the "positive cooperation" strategy refers to positively responding to the government's call to implement green and low-carbon requirements; the "negative cooperation" strategy refers to not responding to the government's call and not implementing green low-carbon requirements.

Model parameters

Although the government, member enterprise A, and member enterprise B are stakeholders, their objectives and strategies are different. The relevant parameters are assumed and shown in Table 1.

Model construction

Profit matrix between the three parties

Based on the above model hypotheses and parameters, the profit matrix between government, member enterprise A, and member enterprise B can be formed, as shown in Tables 2 and 3 below. The probability of government adopting incentive strategy is *x*, and the probability of government adopting non-incentive strategy is (1-*x*). The probability of member enterprise A adopting "positive cooperation" strategy is *y*, and the probability of member enterprise A adopting "negative cooperation" strategy is (1 -*y*). The probability of member enterprise B adopting "positive cooperation" strategy is *z*, and the probability of member enterprise B adopting "negative cooperation" strategy is (1-*z*). x, y, $z \in [0,1]$.

According to Friedman's hypothesis of rationality (Friedman 1998), the government and member enterprises can obtain corresponding profit by adopting different stategies and establish the replication dynamic equations.

Evolutionary stabilization strategy of government

Suppose that when government chooses "incentive" strategy, its expected profit is U_{g1}; when government chooses "non-incentive" strategy, its expected profit is U_{g2} . The average expected profit for government is U_g.

$$\begin{aligned}
Ug1 &= (Rg1 - Mg - \beta 1L1 - \beta 2L2 - \alpha I)yz \\
&+(\gamma 3P3 - Mg - Tg - \beta 1L1 - \beta 2L2 - \alpha I)(1-y)z \\
&+(\gamma 2P2 - Mg - Tg - \beta 1L1 - \beta 2L2 - \alpha I)y(1-z) \\
&+(2\gamma 1P1 - Mg - Tg - \beta 1L1 - \beta 2L2 - \alpha I)(1-y)(1-z) \\
&= yzRg1 + (1-y)z\gamma 3P3 + y(1-z)\gamma 2P2 \\
&+2(1-y-z+yz)\gamma 1P1 + (yz-1)Tg - Mg - \beta 1L1 - \beta 2L2 - \alpha I
\end{aligned} \tag{1}$$

$$\begin{aligned}
Ug2 &= (Rg2 - \alpha Iyz + (-Cg - Tg - \alpha I)(1-y)z + (-Cg - Tg - \alpha I)y(1-z) \\
&+(-Cg - Tg - \alpha I)(1-y)(1-z) = yz(Rg2 + Cg + Tg) - Cg - Tg - \alpha I
\end{aligned} \tag{2}$$

$$Ug = xUg1 + (1-x)Ug2 \tag{3}$$

The replication dynamic equation of probability of "incentive" strategy selected by the government is as follows:

$$\begin{aligned}
F(x) &= \frac{dx}{dt} = x(Ug1 - Ug) = x(1-x)\Big[(1-y)z\gamma 3P3 \\
&+y(1-z)\gamma 2P2 + 2(1-y-z+yz)\gamma 1P1 \\
&- Mg - \beta 1L1 - \beta 2L2 - (yz-1)Cg + yz(Rg1 - Rg2)\Big]
\end{aligned} \tag{4}$$

The partial derivative of the replication dynamic equation $F(x)$ can be obtained as follows:

$$F'(x) = (1-2x)\left[(1-y)z\gamma 3P3 + y(1-z)\gamma 2P2 + 2(1-y-z+yz)\gamma 1P1 - Mg - \beta 1L1 - \beta 2L2 - (yz-1)Cg + yz(Rg1 - Rg2)\right] \tag{5}$$

According to the stability theorem for differential equation, the probability that the government chooses "incentive" strategy in a stable state must satisfy: $F(x) = 0$ and $\frac{dF(x)}{dx} < 0$. According to formula (5),

Table 1 The parameters and their meanings.

Participants	Paremeters	Meanings
Government	R_{g_1}	The environmental benefits created by the alliance’s implementation of green and low-carbon requirements under government incentives
	R_{g_2}	The environmental benefits created by the alliance’s implementation of green and low-carbon requirements without the government incentives
	C_g	The governance costs that the government has to bear due to the alliance’s failure to implement green and low-carbon requirements without government incentives
	T_g	The administrative penalties that the government has to bear due to member enterprises defrauding government subsidies or the government’s failure to incentivize the alliance
	M_g	The cost of government incentives
	$\beta_1 L_1$	Subsidies and rewards given to member enterprise A under government incentives. $\beta_1$means the intensity of government subsidies and rewards for member enterprise A, $0<\beta_1<1$
	$\beta_2 L_2$	Subsidies and rewards given to member enterprise B under government incentives. $\beta_2$means the intensity of government subsidies and rewards for member enterprise B, $0<\beta_2<1$
	$\gamma_1 P_1$	Penalties for both member enterprises when they cooperate negatively under government incentives. $\gamma_1$means the intensity of government's punishment on both member enterprises, $0<\gamma_1<1$
	$\gamma_2 P_2$	Penalties for member enterprise B when member enterprise A cooperates positively and member enterprise B cooperates negatively under government incentives. $\gamma_2$means the intensity of government’s punishment on member enterprise B, $0<\gamma_2<1$
	$\gamma_3 P_3$	Penalties for member enterprise A when member enterprise B cooperates positively and member enterprise A cooperates negatively under government incentives. $\gamma_3$means the intensity of government’s punishment on member enterprise A, $0<\gamma_3<1$
	αI	The government's investment in the construction of joint distribution infrastructure. α means the investment intensity, $0<\alpha<1$
Member enterprise A	R_{A_1}	The profit obtained by member enterprise A when it positively cooperates
	C_{A_1}	The distribution costs that member enterprise A positively cooperates, $C_{A_1}=G_A+C_{A_2}$
	G_A	The cost that member enterprise A promotes green distribution operations
	θR	The profit of member enterprise A when it negatively cooperates. θ means member enterprise A’s proportion in the profit distribution
	C_{A_2}	The distribution costs that member enterprise A negatively cooperates
	$\lambda\theta R$	Member enterprise A’s additional benefits resulting from positive cooperation between both member enterprises (such as economies of scale, etc.). λ means the additional benefit coefficient of member enterprise A, $0<\lambda<1$
	R_{A_3}	Speculative gains when member enterprise A negatively cooperates (such as defraudation)
	C_{A_3}	The risk cost that member enterprise A negatively cooperates (such as defraudation)
	L_A	Member enterprise A’s additional losses caused by member enterprise B’s negative cooperation
Member enterprise B	R_{B_1}	The profit obtained by member enterprise B when it positively cooperates
	C_{B_1}	The distribution cost that member enterprise B positively cooperates, $C_{B_1}=G_B+C_{B_2}$
	G_B	The cost that member enterprise B promotes green distribution operations
	$(1-\theta)R$	The profit of member enterprise B when it negatively cooperates
	C_{B_2}	The distribution costs that member enterprise B negatively cooperates
	$\varphi(1-\theta)R$	Member enterprise B’s additional benefits resulting from positive cooperation between both member enterprises (such as brand awareness, etc.). φ means the additional benefit coefficient of member enterprise B, $0<\varphi<1$
	R_{B_3}	Speculative gains when member enterprise B negatively cooperates (such as "free-riding" behavior)
	C_{B_3}	The risk cost when member enterprise B negatively cooperates (such as "free-riding" behavior)
Member enterprise A and member enterprise B	R	The total profit of the joint distribution alliance without considering the green and low-carbon requirements (total profit that both types of enterprises cooperate negatively)
	τR	The Profit caused by environmental benefits factor when considering green and low-carbon requirements. τ means the proportion of the profit caused by environmental benefits factor, $0<\tau<1$
	$\xi\tau R$	Incremental profit obtained by member enterprises A after considering the green and low-carbon requirements to redistribute the total profit. ξ means the proportion of the profits allocated by member enterprise A to the profit caused by environmental benefit factor, $0<\xi<1$
	S	Transaction costs of the cooperation between both member enterprises. If both enterprises positively cooperate, the transaction costs will decrease; if one of them negatively cooperates, the transaction costs will increase

Table 2 The profit matrix of the government, member enterprise A

Enterprise B	Government: incentives (x)		Government: non-incentives ($1-x$)	
	Enterprise A: positive cooperation (y)	Enterprise A: negative cooperation ($1-y$)	Enterprise A: positive cooperation (y)	Enterprise A: negative cooperation ($1-y$)
Positive cooperation (z)	(a_1, b_1, c_1)	(a_2, b_2, c_2)	(a_3, b_3, c_3)	(a_4, b_4, c_4)
Negative cooperation ($1-z$)	(a_5, b_5, c_5)	(a_6, b_6, c_6)	(a_7, b_7, c_7)	(a_8, b_8, c_8)

$$\begin{aligned}&(1-y)z\gamma 3P3+y(1-z)\gamma 2P2+2(1-y-z+yz)\\&\gamma 1P1-Mg-\beta 1L1-\beta 2L2-(yz-1)Cg+yz(Rg1-Rg2)=0\end{aligned} \tag{6}$$

indicates the boundary of the stable state, then $y=\frac{-Cg+\beta 1L1+\beta 2L2+Mg-2\gamma 1P1-(\gamma 3P3-2\gamma 1P1)z}{\gamma 2P2-2\gamma 1P1-(\gamma 2P2+\gamma 3P3-2\gamma 1P1+Cg-Rg1+Rg2)z}$. This shows that all levels are in a stable state, and the proportion of strategy selection does not change with time.

If $y>\frac{-Cg+\beta 1L1+\beta 2L2+Mg-2\gamma 1P1-(\gamma 3P3-2\gamma 1P1)z}{\gamma 2P2-2\gamma 1P1-(\gamma 2P2+\gamma 3P3-2\gamma 1P1+Cg-Rg1+Rg2)z}$, that is:

$$\begin{aligned}&(1-y)z\gamma 3P3+y(1-z)\gamma 2P2\\&+2(1-y-z+yz)\\&\gamma 1P1-Mg-\beta 1L1-\beta 2L2-(yz-1)\\&Cg+yz(Rg1-Rg2)>0\end{aligned} \tag{7}$$

Now $F'(x=0)>0$, $F'(x=1)<0$, then $x^*=1$ indicates that the "incentive" is a stable state, while the "non-incentive" is an unstable state.

If $y<\frac{-Cg+\beta 1L1+\beta 2L2+Mg-2\gamma 1P1-(\gamma 3P3-2\gamma 1P1)z}{\gamma 2P2-2\gamma 1P1-(\gamma 2P2+\gamma 3P3-2\gamma 1P1+Cg-Rg1+Rg2)z}$, that is:

$$\begin{aligned}&(1-y)z\gamma 3P3+y(1-z)\gamma 2P2+2(1-y-z+yz)\\&\gamma 1P1-Mg-\beta 1L1-\beta 2L2\\&-(yz-1)Cg+yz(Rg1-Rg2)<0\end{aligned} \tag{8}$$

Now $F'(x=0)<0$, $F'(x=1)>0$, then $x^*=0$ indicates that the "non-incentive" is a stable state, while the "incentive" is an unstable state.

The evolutionary phase diagram of the strategy stability of the government depends on the shape of the quadratic curve: $(1-y)z\gamma 3P3+y(1-z)\gamma 2P2+2(1-y-z+yz)\gamma 1P1-Mg-\beta 1L1-\beta 2L2-(yz-1)Cg+yz(Rg1-Rg2)=0$

Evolutionary stabilization strategy of enterprise A

Suppose that when enterprise A chooses "positive cooperation" strategy, its expected profit is U_{A1}; when enterprise A chooses "negative cooperation" strategy, its expected profit is U_{A2}.The average expected profit for enterprise A is U_A.

$$\begin{aligned}U\mathrm{A}1=&(\theta(R-\tau R)+\xi\tau R-CA-GA+\lambda\theta R+\beta 1L1+S)xz\\&+(\theta(R-\tau R)+\xi\tau R-CA-GA+\lambda\theta R+S)(1-x)z\\&+(\theta R+\tau R-CA-GA+\beta 1L1-LA-S)x(1-z)\\&+(\theta R+\tau R-CA-GA-LA-S)(1-x)(1-z)=z((\xi-\theta-1)\tau R+\lambda\theta R)\\&+x\beta 1L1+\theta R+\tau R-CA-GA-LA+(2z-1)S\end{aligned} \tag{9}$$

$$\begin{aligned}U\mathrm{A}2=&(\theta R-\tau R-CA+RA3-CA3+\beta 1L1-\gamma 3P3-S)xz\\&+(\theta R-\tau R-CA+RA3-CA3-S)(1-x)z\\&+(\theta R-CA+RA3-CA3+\beta 1L1-\gamma 1P1)x(1-z)\\&+(\theta R-CA)(1-x)(1-z)=-xz\gamma 3P3+(x-z-xz)RA3\\&+(xz-x-z)CA3-zS+x\beta 1L1+x(z-1)\gamma 1P1+\theta R-CA-z\tau R\end{aligned} \tag{10}$$

$$U\mathrm{A}=\mathrm{y}U\mathrm{A}1+(1-\mathrm{y})U\mathrm{A}2 \tag{11}$$

The replication dynamic equation of probability of "positive cooperarion" strategy selected by member enterprise A is as follows:

Table 3 The profit matrix of the government, member enterprise B

	Government	Member enterprise A	Member enterprise B
(a_1, b_1, c_1)	$R_{g1}-M_g-\beta_1L_1-\beta_2L_2-aI$	$\theta(R-\tau R)+\xi\tau R-C_A-G_A+\lambda\theta R+\beta_1L_1+S$	$(1-\theta)(R-\tau R)+(1-\xi)\tau R-C_B-G_B+\varphi(1-\theta)R+\beta_2L_2+S$
(a_2, b_2, c_2)	$\gamma_3P_3-M_g-T_g-\beta_1L_1-\beta_2L_2-aI$	$\theta R-\tau R+C_A+R_{A3}-C_{A3}+\beta_1L_1-\gamma_3P_3-S$	$(1-\theta)R+\tau R-C_B-G_B+\beta_2L_2+S$
(a_3, b_3, c_3)	$R_{g1}-aI$	$\theta(R-\tau R)+\xi\tau R-C_A+G_A-\lambda\theta R+S$	$(1-\theta)(R-\tau R)+(1-\xi)\tau R-C_B-G_B+\varphi(1-\theta)R+S$
(a_4, b_4, c_4)	$-C_g-T_g-aI$	$\theta R-\tau R-C_A+R_{A3}-C_{A3}-S$	$(1-\theta)R-\tau R-C_B-G_B-S$
(a_5, b_5, c_5)	$\gamma_2P_2-M_g-T_g-\beta_1L_1-\beta_2L_2-aI$	$\theta R-\tau R-C_A-G_A-\beta_1L_1-L_A-S$	$(1-\theta)R-\tau R-C_B+R_{B3}-C_{B3}-\beta_2L_2-\gamma_2P_2-2$
(a_6, b_6, c_6)	$2\gamma_1P_1-M_g-T_g-\beta_1L_1-\beta_2L_2-aI$	$\theta R-C_A+R_{A3}-C_{A3}-\beta_1L_1-\gamma_1P_1$	$(1-\theta)R-C_B+R_{B3}-C_{B3}-\beta_2L_2-\gamma_1P_1$
(a_7, b_7, c_7)	$-C_g-T_g-aI$	$\theta R+\tau R-C_A-G_A-L_A-S$	$(1-\theta)R-\tau R-C_B+R_{B3}-C_{B3}-S$
(a_8, b_8, c_8)	$-C_g-T_g-aI$	$\theta R-C_A$	$(1-\theta)R-C_B$

$$F(y) = \frac{dy}{dt} = y(UA1 - UA) = y(1 - y)$$
$$\Big[z\xi\tau R - z\theta\tau R + z\lambda\theta R + 3zS + \tau R - GA - LA - S + xz\gamma 3P3$$
$$- (x - z - xz)(RA3 + CA3) - x(z - 1)\gamma 1P1\Big] \tag{12}$$

The partial derivative of the replication dynamic equation $F(y)$ can be obtained as follows:

$$F'(y) = (1 - 2y)[\boldsymbol{z\xi\tau R} - \boldsymbol{z\theta\tau R} + \boldsymbol{z\lambda\theta R} + 3zS + \tau R - GA - LA - S + xz\gamma 3P3 - (x - z - xz)(RA3 + CA3) - x(z - 1)\gamma 1P1] \tag{13}$$

According to the stability theorem for differential equation, the probability that member enterprise A chooses "positive cooperation" strategy in a stable state must satisfy: $F(y) = 0$ and $\frac{dF(y)}{dy} < 0$. According to formula (13),

$$\boldsymbol{z\xi\tau R} - \boldsymbol{z\theta\tau R} + \boldsymbol{z\lambda\theta R} + 3zS + \tau R - GA - LA - S + xz\gamma 3P3$$
$$-(x - z - xz)(RA3 + CA3) - x(z - 1)\gamma 1P1 = 0 \tag{14}$$

indicates the boundary of the stable state, then $z = \frac{S+LA+GA-\tau R-(\gamma 1P1-RA3+CA3)x}{(\xi-\theta)\tau R+\lambda\theta R+3S+RA3+CA3+(\gamma 3P3+RA3-CA3-\gamma 1P1)x}$.

If $z > \frac{S+LA+GA-\tau R-(\gamma 1P1-RA3+CA3)x}{(\xi-\theta)\tau R+\lambda\theta R+3S+RA3+CA3+(\gamma 3P3+RA3-CA3-\gamma 1P1)x}$, that is:

$$\boldsymbol{z\xi\tau R} - \boldsymbol{z\theta\tau R} + \boldsymbol{z\lambda\theta R} + 3zS$$
$$+ \tau R - GA - LA - S + xz\gamma 3P3 - (x - z - xz)(RA3 + CA3) - x(z - 1)\gamma 1P1 > 0 \tag{15}$$

Now $F'(y=0) > 0$, $F'(y=1) < 0$, then $y^* = 1$ indicates that the "positive cooperation" is a stable state, while the "negative cooperation" is an unstable state.

If $z < \frac{S+LA+GA-\tau R-(\gamma 1P1-RA3+CA3)x}{(\xi-\theta)\tau R+\lambda\theta R+3S+RA3+CA3+(\gamma 3P3+RA3-CA3-\gamma 1P1)x}$, that is:

$$\boldsymbol{z\xi\tau R} - \boldsymbol{z\theta\tau R} + \boldsymbol{z\lambda\theta R} + 3zS + \tau R - GA - LA - S$$
$$+xz\gamma 3P3 - (x - z - xz)(RA3 + CA3) - x(z - 1)\gamma 1P1 < 0 \tag{16}$$

Now $F'(y=0) < 0$, $F'(y=1) > 0$, then $y^* = 0$ indicates that the "negative cooperation" is a stable state, while the "positive cooperation" is an unstable state.

The evolution phase diagram of the strategic stability of member enterprise A depends on the shape of the quadratic curve:

$$z\xi\tau R - z\theta\tau R + z\lambda\theta R + 3zS + \tau R - GA - LA - S + xz\gamma 3P3$$
$$-(x - z - xz)(RA3 + CA3) - x(z - 1)\gamma 1P1 = 0$$

Evolutionary stabilization strategy of enterprise B

Suppose that when enterprise B chooses "positive cooperation" strategy, its expected profit isU_{B1}; when enterprise B chooses "negative cooperation" strategy, its expected profit isU_{B2}.The average expected profit for enterprise B isU_B.

$$UB1 = ((1 - \theta)(R - \tau R) + (1 - \xi)\tau R - CB - GB + \varphi(1 - \theta)R + \beta 2L2 + S)xy$$
$$+((1 - \theta)R + \tau R - CB - GB + \beta 2L2 - S)(1 - y)x$$
$$+((1 - \theta)(R - \tau R) + (1 - \xi)\tau R - CB - GB + \varphi(1 - \theta)R + S)y(1 - x)$$
$$+((1 - \theta)R + \tau R - CB - GB - S)(1 - x)(1 - y)$$
$$= x\beta 2L2 - y(1 - \theta)\tau R + y(1 - \xi)\tau R + y\varphi(1 - \theta)R - y\tau R$$
$$+(2y - 1)S + (1 - \theta)R + \tau R - CB - GB \tag{17}$$

$$UB2 = ((1 - \theta)R - \tau R - CB + RB3 - CB3 + \beta 2L2 - \gamma 2P2 - S)xy$$
$$+((1 - \theta)R - CB + RB3 - CB3 + \beta 2L2 - \gamma 1P1)(1 - y)x$$
$$+ ((1 - \theta)R - \tau R - CB + RB3 - CB3 - S)y(1 - x)$$
$$+((1 - \theta)R - CB)(1 - x)(1 - y)$$
$$= xy(\gamma 1P1 - \gamma 2P2 - RB3 + CB3) + x(RB3 - CB3 + \beta 2L2 - \gamma 1P1)$$
$$+y(RB3 - CB3 - S - \tau R) + (1 - \theta)R - CB \tag{18}$$

$$UB = zUB1 + (1 - z)UB2 \tag{19}$$

The replication dynamic equation of probability of "positive cooperarion" strategy selected by the enterprise B is as follows:

$$F(z) = \frac{dz}{dt} = z(UB1 - UB) = z(1 - z)$$
$$\Big[- y(1 - \theta)\tau R + y(1 - \xi)\tau R + y\varphi(1 - \theta)R + (3y - 1)S + \tau R$$
$$-GB - xy(\gamma 1P1 - \gamma 2P2 - RB3 + CB3) - x(RB3 - CB3 - \gamma 1P1) - y(RB3 - CB3)\Big] \tag{20}$$

The partial derivative of the replication dynamic equation $F(z)$ can be obtained as follows:

$$F'(z) = (1 - 2z)\Big[- y(1 - \theta)\tau R + y(1 - \xi)\tau R + y\varphi(1 - \theta)R + (3y - 1)S + \tau R$$
$$- GB - xy(\gamma 1P1 - \gamma 2P2 - RB3 + CB3) - x(RB3 - CB3 - \gamma 1P1) - y(RB3 - CB3)\Big] \tag{21}$$

According to the stability theorem for differential equation, the probability of member enterprise B choosing "positive cooperation" strategy in a stable state must satisfy: $F'(z) = 0$ and $\frac{dF(z)}{dz} < 0$. According to formula (21),

$$- y(1 - \theta)\tau R + y(1 - \xi)\tau R + y\varphi(1 - \theta)R + (3y - 1)S + \tau R - GB - xy$$
$$(\gamma 1P1 - \gamma 2P2 - RB3 + CB3) - x(RB3 - CB3 - \gamma 1P1) - y(RB3 - CB3) = 0 \tag{22}$$

indicates the boundary of the stable state, then $x = \frac{\tau R - S - GB + [(\theta - \xi)\tau R + \varphi(1-\theta)R + 3S - RA3 + CB3]y}{RB3 - CB3 - \gamma 1P1 + (\gamma 1P1 - \gamma 2P2 - RB3 + CB3)y}$.

If $x > \frac{\tau R - S - GB + [(\theta - \xi)\tau R + \varphi(1-\theta)R + 3S - RA3 + CB3]y}{RB3 - CB3 - \gamma 1P1 + (\gamma 1P1 - \gamma 2P2 - RB3 + CB3)y}$, that is:$-y(1-\theta)\tau R + y(1-\xi)\tau R + y\varphi(1-\theta)R + (3y-1)S + \tau R - GB - xy(\gamma 1P1 - \gamma 2P2 - RB3 + CB3) - x(RB3 - CB3 - \gamma 1P1) - y(RB3 - CB3) < 0$ (23)

Now $F'(z=0) < 0$, $F'(z=1) > 0$, then $z^* = 0$ indicates that "negative cooperation" is in a stable state, while the "positive cooperation" is in an unstable state.

If $x < \frac{\tau R - S - GB + [(\theta - \xi)\tau R + \varphi(1-\theta)R + 3S - RA3 + CB3]y}{RB3 - CB3 - \gamma 1P1 + (\gamma 1P1 - \gamma 2P2 - RB3 + CB3)y}$, that is:$-y(1-\theta)\tau R + y(1-\xi)\tau R + y\varphi(1-\theta)R + (3y-1)S + \tau R - GB - xy(\gamma 1P1 - \gamma 2P2 - RB3 + CB3) - x(RB3 - CB3 - \gamma 1P1) - y(RB3 - CB3) > 0$ (24)

Now $F'(z=0) > 0$, $F'(z=1) < 0$, then $z^* = 1$ indicates that "positive cooperation" is in a stable state, while the "negative cooperation" is in an unstable state.

The evolution phase diagram of the strategic stability of member enterprise B depends on the shape of the quadratic curve: $-y(1-\theta)\tau R + y(1-\xi)\tau R + y\varphi(1-\theta)R + (3y-1)S + \tau R - GB - xy(\gamma 1P1 - \gamma 2P2 - RB3 + CB3) - x(RB3 - CB3 - \gamma 1P1) - y(RB3 - CB3) = 0$

Stability analysis of the equilibrium points of the tripartite evolutionary game system

In order to find the equilibrium points of this evolutionary game, three equations are simultaneously established: $F(x)=0$, $F(y)=0$, $F(z)=0$, it can be found that there are eight three-species pure strategy equilibrium points:$E_1(0,0,0)$, $E_2(0,0,1)$, $E_3(0,1,0)$, $E_4(1,0,0)$, $E_5(1,1,0)$, $E_6(0,1,1)$, $E_7(1,0,1)$, $E_8(1,1,1)$. These equilibrium points are located at the boundary of the solution domain of the evolutionary game, and the enclosed area Ω is called the equilibrium solution domain of the tripartite game. Under normal circumstances, there may also be pure strategy equilibrium points adopted by a single species: $E_9(0,y_1,z_1)$, $E_{10}(1,y_2,z_2)$, $E_{11}(x_1,0,z_3)$, $E_{12}(x_2,1,z_4)$, $E_{13}(x_3,y_3,0)$, $E_{14}(x_4,y_4,1)$, and the equilibrium solution (x^*,y^*,z^*) that satisfies equations (6) (14) (22).

The stable equilibrium points of the game can be judged by Jacobian matrix (Friedman 1991). The Jacobian matrix is as follows:

$$J = \begin{bmatrix} \partial F^{(x)}/_{\partial x} & \partial F(x)/_{\partial y} & \partial F(x)/_{\partial z} \\ \partial F^{(y)}/_{\partial x} & \partial F(y)/_{\partial y} & \partial F(y)/_{\partial z} \\ \partial F^{(z)}/_{\partial x} & \partial F(z)/_{\partial y} & \partial F(z)/_{\partial z} \end{bmatrix},$$ in which

$$\partial F^{(x)}/_{\partial x} - (1-2x)\big[1-y)z\gamma_3P_3 + y(1-z)\gamma_2P_2 + 2(1-y-z+yz)\gamma_1P_1 - Mg - \beta_2L_2 - (yz-1)Cg + yz\big(R_{g1} - R_{g2}\big)\big]$$

$$\partial F^{(x)}/_{\partial y} = x(1-x)\big[-z\gamma_3P_3 + (1-z)\gamma_2P_2 + 2(z-1)\gamma_1P_1 - zCg + zR_{g1} - zR_{g2}\big)\big]$$

$$\partial F^{(x)}/_{\partial z} = x(1-x)\big[(1-y)\gamma_3P_3 - y\gamma_2P_2 + 2(y-1)\gamma_1P_1 - yCg + yR_{g1} - yR_{g2}\big]$$

$$\partial F^{(y)}/_{\partial x} = y(1-y)\big[y\gamma_3P_3 + (z-1)R_{A3} - C_{A3} - \gamma_1P_1\big)\big]$$

$$\partial F^{(y)}/_{\partial y} = (1-2y\big[z\xi\tau R - z\theta\tau R + z\lambda\theta R + 3zS + \tau R - G_A - L_A - S + xz\tau\gamma_3P_3 - (x-z-xz)\big(R_{A3} + C_{A3}\big) - x(z-1)\gamma_1P_1\big)$$

$$\partial F^{(y)}/_{\partial z} = y\Big(1 - y\big[\xi\tau R + \theta\tau R + 3S + R_{A3} + C_{A3} + x\big(R_{A3} - C_{A3} - \gamma_1P_1\big)\big]$$

$$\partial F^{(z)}/_{\partial x} = z\Big(1 - z\big[-y\big(\gamma_1P_1 - \gamma_2P_2 - R_{B3} + C_{B3}\big) - R_{B3} + C_{B3} + \gamma_1P_1\big]$$

$$\partial F^{(z)}/_{\partial y} = z$$

$$\big(1 - z[\theta - \xi)\tau R + \varphi(1 = \theta)R + 3S + x\big(\gamma_1P_1 - \gamma_2P_2 - R_{B3} + C_{B3}\big) - R_{B3} + C_{B3}\big]$$

$$\partial F^{(z)}/\partial z = (1-2z)\Big[-y\Big(1 - \theta\tau R + y(1-\xi)\tau R + y\varphi(1-\theta)R + (3y-1)S + \tau R - G_B - xy\big(\gamma_1P_1 - \gamma_2P_2 - R_{B3} + C_{B3}\big) - x\big(R_{B3} - C_{B3} - \gamma_1P_1\big) - y\big(R_{B3} - C_{B3}\big)\Big]$$

According to Lyapunov's first rule: if all eigenvalues of the Jacobian matrix have negative real parts, then the equilibrium point is an asymptotically stable point. If all eigenvalues of the Jacobian matrix have positive real parts, then the equilibrium point is an unstable point. If the eigenvalues of the Jacobian matrix have both positive real parts and negative real parts, then the equilibrium point is also an unstable point. If the eigenvalues of the Jacobian matrix have both zero real parts and negative real parts, the equilibrium point is in a critical state, and the stability cannot be determined by the symbol of the eigenvalue.

The stability of the tripartite evolutionary game system can be studied only by discussing the stability of the eight three-species pure strategy equilibrium points, and the rest are in non-asymptotically stable states. Eight three-species pure strategy equilibrium points were substituted into the Jacobian matrix to analyze the stability of each equilibrium point. The results are shown in Table 4 below.

When$(\xi - \theta)\tau R + \lambda\theta R + 2S + \tau R - G_A - L_A + \gamma_3P_3 + R_{A3} + C_{A3} > 0$, $(\theta\xi)\tau R + \varphi(1-\theta)R + 2S + \tau R - G_B + \gamma_2P_2 + R_{B3} + C_{B3} > 0$ and $\tau R - G_A - L_A - S - R_{A3} + C_{A3} + \gamma_1P_1 < 0$,$\tau R - S - G_B R_{A3} + C_{B3} + \gamma_1P_1 < 0$, there are two stable points in the replication dynamic system: $\boldsymbol{E_4}(1,0,0)$ and $\boldsymbol{E_8}(1,1,1)$, obviously $\boldsymbol{E_8}$ is a more ideal stable point than $\boldsymbol{E_4}$.

When $(\xi-\theta)\tau R+\lambda\theta R+2S+\tau R-G_A-L_A+\gamma_3P_3+R_{A3}+C_{A3}>0$, $(\theta\xi)\tau R+\varphi(1-\theta)R+2S+\tau R-G_B+\gamma_2P_2+R_{B3}+C_{B3}>0$and $\tau R-(R_{A3}-C_{A3})+\gamma_1P_1>G_A+L_A+S>0$, $\tau R-(R_{B3}-C_{B3})+\gamma_1P_1>G_B+S>0$, there is only one stable point for the replication of dynamic systems: $\boldsymbol{E}_{\mathbf{8}}(1,1,1)$.

Simulation analysis of the tripartite evolutionary game

Assign values to the parameters according to the actual situations, use MATLAB R2020b software to perform numerical simulation on the ideal strategy set {incentive, positive cooperation, positive cooperation} to verify the asymptotic stability of the evolutionary game and analyze the influence of β_1, β_2, γ_1, γ_2, γ_3, L_A, G_A, G_B, λ, φ, R_{A_3}, R_{B_3}, τ, θ, ξ on the evolutionary game process and results (Zhu et al. 2021a, b). Set the initial probability of the three parties' different behaviors as 0.2, the values of each parameter are shown in Tables 5 and 6 below.

(1) The influence of β_1 on the strategy evolution of the tripartite participants

Assign values of 0.2, 0.5, 0.8 to β_1, respectively, representing the low, medium, and high intensity of government subsidies and rewards for member enterprise A. The simulation results are shown in Fig. 1. Figure 1 shows that during the process of system evolution to a stable point, the increase in government subsidies and rewards to member enterprise A can increase the rate of member enterprise A's evolution in the direction of positive cooperation. As β_1 increases, the probability that member enterprise A adopts "positive cooperation" strategy increases and eventually stabilizes at 1, while the probability that the government converges to "incentives" decreases. This is because the greater the subsidies and rewards that the government gives to member enterprise A, the more cost that member enterprise A promotes the green distribution operations will be compensated, and the faster it will evolve in the direction of positive cooperation. However, the government has to bear significant incentive cost.

(2) The influence of β_2 on the strategy evolution of the tripartite participants

Assign values of 0.2, 0.5, 0.8 to β_2, respectively, representing the low, medium, and high intensity of government subsidies and rewards for member enterprise B. The simulation results are shown in Fig. 2. Figure 2 shows that in the process of system evolution to a stable point, the increase in government subsidies and rewards to member enterprise B can increase the rate of member enterprise B evolving in the direction of positive cooperation, especially when β_2=0.8, member enterprise B tends to cooperate positively at a very fast rate. As β_2 increases, the probability that member enterprise B adopts "positive cooperation" strategy increases and eventually stabilizes at 1, while the probability that the government converges to "incentives" decreases, or even decreases to zero. This is because the subsidies and rewards the government gives to member enterprise B are far greater than those given to member enterprise A. Although member enterprise B's cost of promoting green distribution operations can be more compensated, thus making it more inclined to cooperate actively, the incentive cost borne by the government is much significant.

(3) The influence of γ_1 on the strategy evolution of the tripartite participants

Assign values of 0.3, 0.5, 0.7 to γ_1, respectively, representing the low, medium, and high intensity of government's punishment on member enterprise B. The simulation results are shown in Fig. 3. Figure 3 shows that in the process of system evolution to a stable point, the increase in the government's punishment on member enterprise A/member enterprise B can reduce the rate of member enterprise A/member enterprise B evolving in the direction of positive cooperation. As γ_1 increases, the probability that member enterprise A/member enterprise B adopts "positive cooperation" strategy increases and eventually stabilizes at 1, and the probability that the government converges to "incentives" also increases. The reason why the government punishes both member enterprises is that they still cooperate negatively when they are motivated by the government, and the motive of negative cooperation is that both sides conspire to defraud the government subsidies and rewards. Once their speculative activities are discovered, the punishment given by the government will exceed the sum of the subsidies and rewards they have cheated, forcing them to cooperate actively. This is also the reason why when the intensity of punishment increases, the rate at which member enterprise B tends to cooperate positively decreases, but the probability will eventually stabilize at 1.

(4) The influence of γ_2 on the strategy evolution of the tripartite participants

Assign values of 0.3, 0.5, 0.7 to γ_2, respectively, representing the low, medium, and high intensity of the government's punishment of member enterprise B. The simulation results are shown in Fig. 4. Figure 4 shows that in the process of system evolution to a stable point, the increase of the government's punishment on member enterprise B can reduce the rate of member enterprise B evolving in the direction of positive cooperation. As γ_2 increases, the

Table 4 Stability analysis of each equilibrium point

Equilibrium points	The eigenvalues of the Jacobian matrix				Asymptotic stability and conditions
	λ_1	λ_2	λ_3	The symbol of the real part	
$\boldsymbol{E_1(0,0,0)}$	$2\gamma 1P1-Mg-\beta 1L1-\beta 2L2+Cg$	$\tau R-GA-LA-S$	$\tau R-GB-S$	(+, -, -)	Unstable point
$\boldsymbol{E_2(0,0,1)}$	$\gamma 3P3-Mg-\beta 1L1-\beta 2L2+Cg$	$(\xi-\theta)\tau R+\lambda\theta R+3S+\tau R-GA-LA-S+RA3+CA3$	$-[\tau R-GB-S]$	(x, +, x)	Unstable point
$\boldsymbol{E_3(0,1,0)}$	$\gamma 2P2-Mg-\beta 1L1-\beta 2L2+Cg$	$-[\tau R-GA-LA-S]$	$(\theta-\xi)\tau R+\varphi(1-\theta)R+2S+\tau R-GB-RB3+CB3$	(x, +, x)	Unstable point
$\boldsymbol{E_4(1,0,0)}$	$-\left[2\gamma 1P1-Mg-\beta 1L1-\beta 2L2+Cg\right]$	$\tau R-GA-LA-S-RA3+CA3+\gamma 1P1$	$\tau R-S-GB-RB3+CB3+\gamma 1P1$	(-, -, -)	Stable point(ESS) Conditions: ①
$\boldsymbol{E_5(1,1,0)}$	$-\left[\gamma 2P2-Mg-\beta 1L1-\beta 2L2+Cg\right]$	$-\left[\tau R-GA-LA-S+\gamma 1P1+\gamma 3P3-RA3+CA3\right]$	$(\theta-\xi)\tau R+\varphi(1-\theta)R+2S+\tau R-GB+\gamma 2P2-RB3+CB3$	(-, -, -)	Stable point(ESS) Conditions: ②
$\boldsymbol{E_6(0,1,1)}$	$-Mg-\beta 1L1-\beta 2L2+Rg1-Rg2$	$-\left[\xi\tau R-\theta\tau R+\lambda\theta R+2S+\tau R-GA-LA+RA3+CA3\right]$	$-\left[(\theta-\xi)\tau R+\varphi(1-\theta)R+2S+\tau R-GB-RB3+CB3\right]$	(+, x,, x)	Unstable point
$\boldsymbol{E_7(1,0,1)}$	$-\left[\gamma 3P3-Mg-\beta 1L1-\beta 2L2+Cg\right]$	$(\xi-\theta)\tau R+\lambda\theta R+2S+\tau R-GA-LA+\gamma 3P3+RA3+CA3$	$-[\tau R-S-GB-RB3+CB3+\gamma 1P1]$	(-, -, -)	Stable point(ESS) Conditions: ③
$\boldsymbol{E_8(1,1,1)}$	$-\left[-Mg-\beta 1L1-\beta 2L2+Rg1-Rg2\right]$	$-\left[(\xi-\theta)\tau R+\lambda\theta R+2S+\tau R-GA-LA+\gamma 3P3+RA3+CA3\right]$	$-\left[(\theta-\xi)\tau R+\varphi(1-\theta)R+2S+\tau R-GB+\gamma 2P2-RB3+CB3\right]$	(-, -, -)	Stable point(ESS) Conditions: ④
$\boldsymbol{E_9}$-$\boldsymbol{E_{14}}$	The eigenvalues of E_9-E_{14} are different and will not be described in detail				

①$\tau R-GA-LA-S-RA3+CA3+\gamma 1P1<0,\ \tau R-S-GB-RB3+CB3+\gamma 1P1<0$

②$-[\tau R-GA-LA-S+\gamma 1P1+\gamma 3P3-RA3+CA3]<0,\ (\theta-\xi)\tau R+\varphi(1-\theta)R+2S+\tau R-GB+\gamma 2P2-RB3+CB3<0$

③$(\xi-\theta)\tau R+\lambda\theta R+2S+\tau R-GA-LA+\gamma 3P3+RA3+CA3<0,\ -[\tau R-S-GB-RB3+CB3+\gamma 1P1]<0$

④$-[(\xi-\theta)\tau R+\lambda\theta R+2S+\tau R-GA-LA+\gamma 3P3+RA3+CA3]<0,\ -[(\theta-\xi)\tau R+\varphi(1-\theta)R+2S+\tau R-GB+\gamma 2P2-RB3+CB3]<0$

⑤"x"means the symbol of the real part is uncertain

Table 5 The values of each parameter

R_{g_1}	R_{g_2}	C_g	T_g	M_g	β_1	L_1	β_2	L_2	γ_1	P_1	γ_2	P_2	γ_3	P_3	α	I
150	25	120	125	40	0.5	60	0.5	70	0.5	85	0.5	75	0.5	80	0.5	70

Table 6 The values of each parameter

R_{A_1}	G_A	θ	R	C_{A_2}	λ	R_{A_3}	C_{A_3}	L_A	R_{B_1}	G_B	C_{B_2}	φ	R_{B_3}	C_{B_3}	S	τ	ξ
130	30	0.5	190	30	0.5	50	45	20	90	30	30	0.5	20	15	20	0.5	0.5

probability that member enterprise B adopts "positive cooperation" strategy increases and eventually stabilizes at 1, and the probability that the government converges to incentives also increases. The reason why the government punishes member enterprise B is that member enterprise B conducts the "free-riding" behavior on member enterprise A. Once the speculative behavior is discovered, the government will punish the member enterprise B more than the speculative gains it has obtained, forcing it to cooperate positively. This is also the reason why when the intensity of punishment increases, the rate at which member enterprise B tends to cooperate positively decreases, but the probability will eventually stabilize at 1.

(5) The influence of γ_3 on the strategy evolution of the tripartite participants

Assign values of 0.3, 0.5, 0.7 to γ_3, respectively, representing the low, medium, and high intensity of the government's punishment of member enterprise A. The simulation

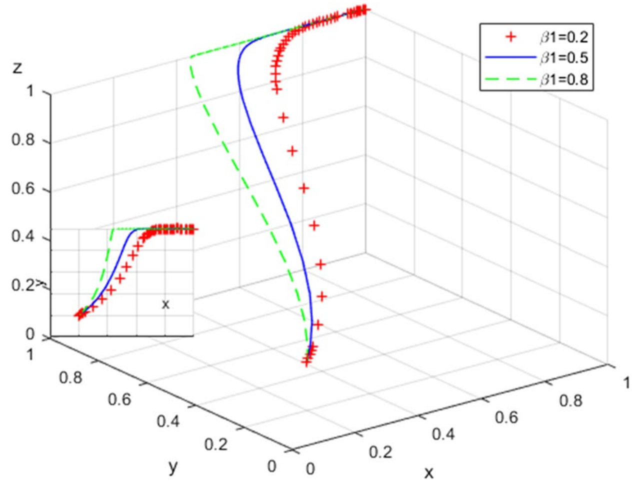

Fig. 1 The effect of β_1 on the strategy evolution

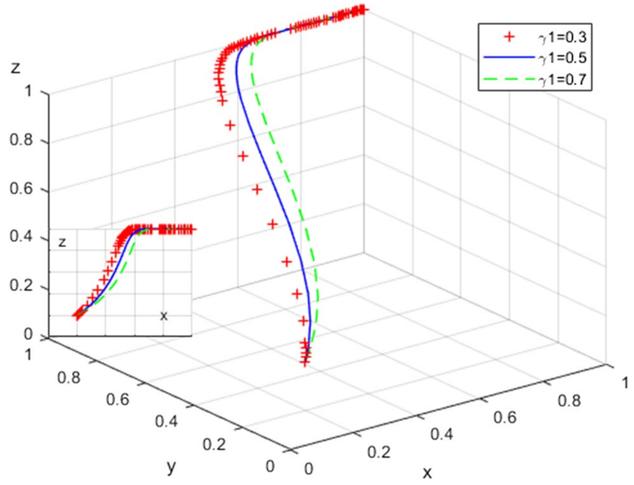

Fig. 3 The effect of γ_1 on the strategy evolution

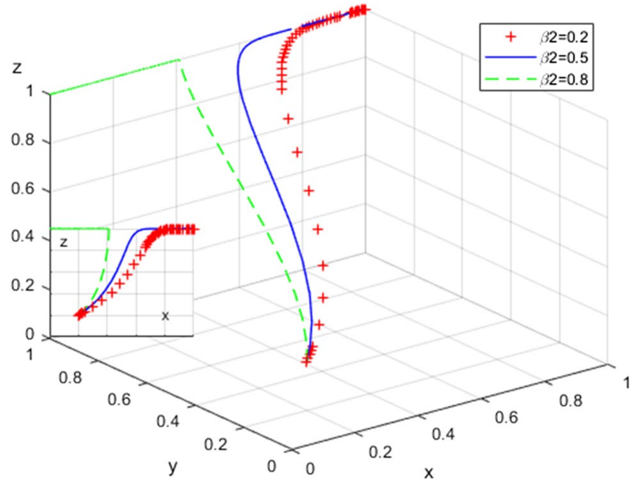

Fig. 2 The effect of β_2 on the strategy evolution

results are shown in Fig. 5. Figure 5 shows that in the process of system evolution to a stable point, the increase in the government's punishment on member enterprise A can reduce the rate of member enterprise A's evolution in the direction of positive cooperation. As $\gamma_3$increases, the probability that member enterprise A adopts "positive cooperation" strategy increases and eventually stabilizes at 1, and the probability of government convergence to "incentives" does not change significantly. The reason why the government punishes the member enterprise A is that member enterprise A takes advantage of information asymmetry to defraud the government subsidies and rewards. Once the speculative behavior is discovered, the punishment imposed by the government will exceed the speculative gains it has obtained, forcing it to cooperate positively. This is also the reason why when the intensity of punishment increases, the rate at which member enterprise A tends to cooperate positively decreases, but the probability will eventually stabilize at 1.

(6) The influence of L_A on the strategy evolution of the tripartite participants

Assign values of 0, 20, 40 to L_A, and the simulation results are shown in Fig. 6. Figure 6 shows that in the process of system evolution to a stable point, the increase in the additional losses suffered by member enterprise A can reduce the rate of its evolution toward positive cooperation, and the rate of member enterprise B's evolution toward positive cooperation increases. As $L_A$increases, the probability that member enterprise A adopts "positive cooperation" strategy increases and eventually stabilizes at 1, and the probability that member enterprise B adopts "positive cooperation" also increases. The change in L_A has not changed the trend of member enterprise A choosing to positively cooperate, because the government is also converging to "incentives." The "incentive" strategy adopted by the government includes punishment on member enterprise B, and the penalties obtained from member enterprise B can be transferred to member enterprise A to compensate its losses. In addition, due to the fact that member enterprise B has gradually lost the trust from others and is even at the risk of being removed from the alliance, it has to actively participate in promoting green distribution operations to improve its current poor image from the perspective of long-term benefits, thus its probability of positive cooperation also increases.

(7) The influence of G_A on the strategy evolution of the tripartite participants

Assign values of 5, 30, 55 to G_A respectively, and the simulation results are shown in Fig. 7. Figure 7 shows that in

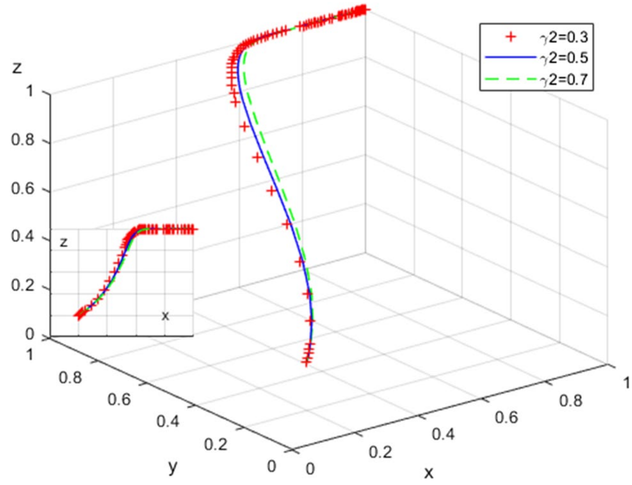

Fig. 4 The effect of γ_2 on the strategy evolution

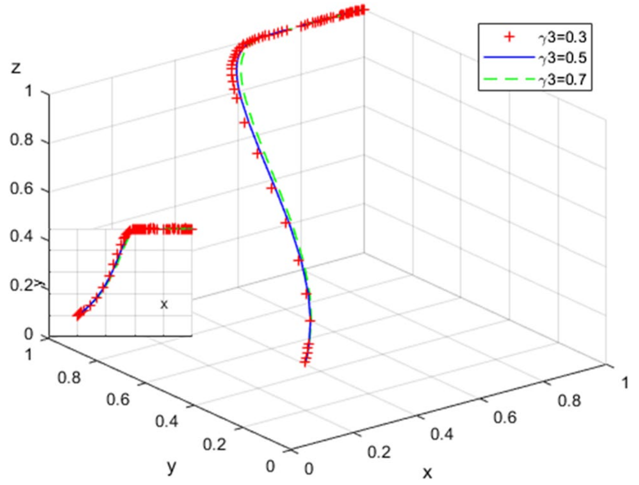

Fig. 5 The effect of γ_3 on the strategy evolution

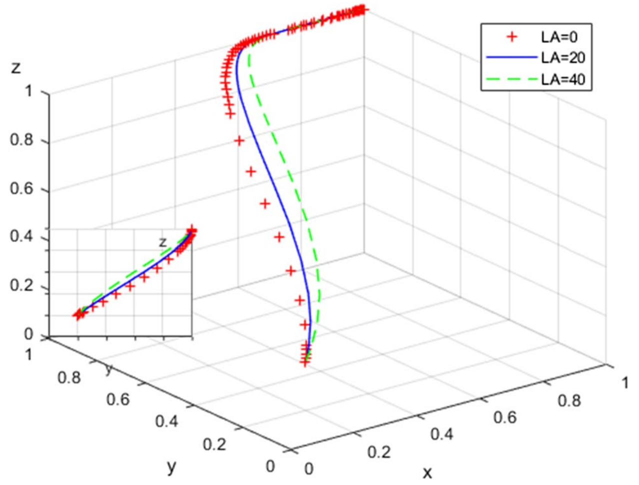

Fig. 6 The effect of L_A on the strategy evolution

the process of system evolution to a stable point, the increase in the cost of member enterprise A promoting green distribution operations can reduce the rate at which member enterprise A evolves in the direction of positive cooperation, while the rate at which the government converges to "incentive" strategy increases. As G_A increases, the probability of the government adopting "incentive" strategy increases, and the probability of member enterprise A adopting "positive cooperation" strategy will also increase as the probability of the government adopting "incentive" strategy increases, and eventually stabilizes at 1.

(8) The influence of G_B on the strategy evolution of the tripartite participants

Assign values of 10, 30, and 50 to the parameters respectively, and the simulation results are shown in Fig. 8. Figure 8 shows that in the process of system evolution to a stable point, the increase in the cost of member enterprise B promoting green distribution operations can reduce the rate of member enterprise B's evolution toward positive cooperation, while the rate at which the government converges to "incentive" strategy increases. As G_B increases, the probability that the government adopts "incentive" strategy increases, and the probability that member enterprise B adopts "positive cooperation" strategy will also increase as the probability of the government adopting "incentive" strategy increases, and eventually stabilizes at 1.

(9) The influence of λ on the strategy evolution of the tripartite participants

Assign values of 0.3, 0.5, 0.7 to λ respectively, and the simulation results are shown in Fig. 9. Figure 9 shows that in the process of system evolution to a stable point, the increase in member enterprise A's additional benefit coefficient can increase the rate of member enterprise A's evolution in the direction of positive cooperation, while the rate at which the government converges to "incentive" strategy does not change significantly. As λ increases, the probability that member enterprise A adopts "positive cooperation" strategy increases and eventually stabilizes at 1. The probability of the government converging to "incentives" does not change significantly. The size of the additional benefit coefficient does not have a significant impact on whether member enterprise A ultimately chooses to positively cooperate, because the additional benefits is non-monetary (such as the advantages brought by large-scale operations and a good business environment). Therefore, the government needs to play its role in reducing administrative burdens and creating a good market environment for member enterprises, thereby increasing their

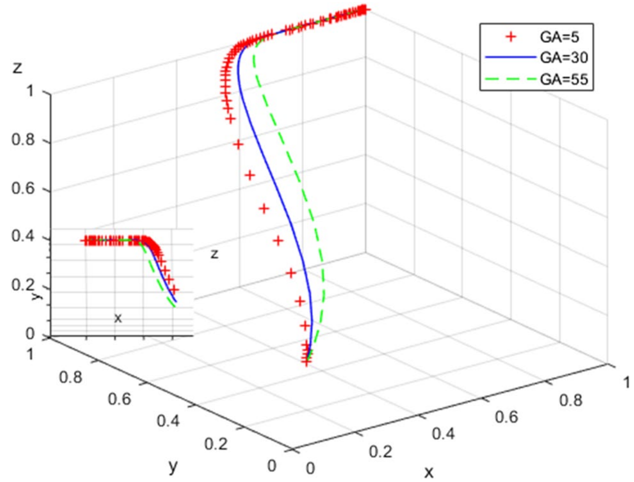

Fig. 7 The effect of G_A on the strategy evolution.

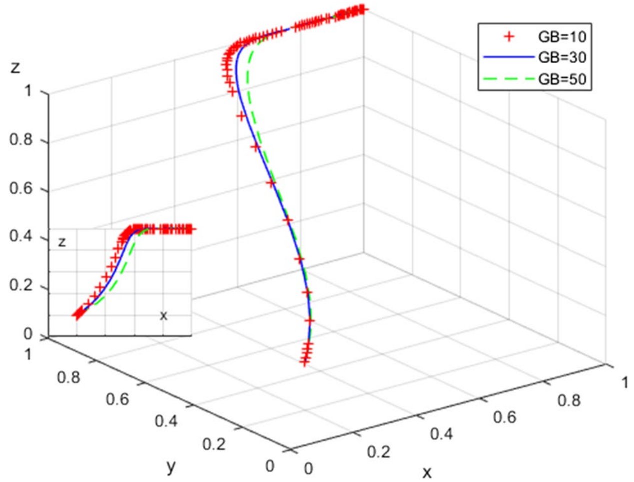

Fig. 8 The effect of G_B on the strategy evolution

additional benefits and enhancing their willingness to promote green distribution operations.

(10) The influence of φ on the strategy evolution of the tripartite participants

Assign values of 0.3, 0.5, 0.8 to φ respectively, and the simulation results are shown in Fig. 10. Figure 10 shows that in the process of system evolution to a stable point, the increase in member enterprise B's additional benefit coefficient can increase the rate of member enterprise B's evolution in the direction of positive cooperation, while the rate at which the government converges to "incentive" strategy does not change significantly. As φ increases, the probability of member enterprise B adopting "positive cooperation" strategy increases and eventually stabilizes at 1, while the probability of government adopting "incentive" strategy does not change significantly. The size of the additional benefit coefficient does not have a significant impact on whether member enterprise B ultimately chooses to positively cooperate, and the reason is the same as that of member enterprise A in (9).

(11) The influence of R_{A_3} on the strategy evolution of the tripartite participants

Assign values of 30, 50, 70 to R_{A_3}, and the simulation results are shown in Fig. 11. Figure 11 shows that in the process of system evolution to a stable point, the change of member enterprise A's speculative gains does not have a significant impact on both the rates at which member enterprise A tends to positively cooperate and the government tends to incentivize. As R_{A_3} increases, the probability of member enterprise A adopting "positive cooperation" strategy and the probability of government adopting "incentive" strategy are not significantly changed. This is because the government and the alliance trust member enterprise A so that its speculative activities are difficult to be detected. In addition, the speculative gains of it will increase linearly with the increase of the government subsidies and rewards, which reveals the bad situation caused by the absence of the necessary supervision mechanism.

(12) The influence of R_{B_3} on the strategy evolution of the tripartite participants

Assign values of 0, 20, 40 to R_{B_3}, and the simulation results are shown in Fig. 12. Figure 12 shows that during the process of system evolution to a stable point, the increase in member enterprise B's speculative gains can reduce the rate of member enterprise B's evolution toward positive cooperation, while the rate at which the government converges to "incentive" strategy increases. As R_{B_3} increases, the probability that member enterprise B adopts "positive cooperation" strategy increases and eventually stabilizes at 1, and the probability that the government converges to "incentives" also increases. The change of R_{B_3} does not change the trend of member enterprise B to choose "positive cooperation," and the reason is the same as that of the government's punishment on member enterprise B in (4).

(13) The influence of τ on the strategy evolution of the tripartite participants

Assign values of 0.1, 0.3, 0.5 to τ respectively, and the simulation results are shown in Fig. 13. Figure 13 shows that in the process of system evolution to a stable point, the increase in the proportion of the profit caused by environmental benefit factor to the total profit of the alliance can increase the rate at which member enterprises A and B evolve in the direction of positive cooperation. The rate at which the government converges to "incentives" also increases. As τ increases, the probabilities of member

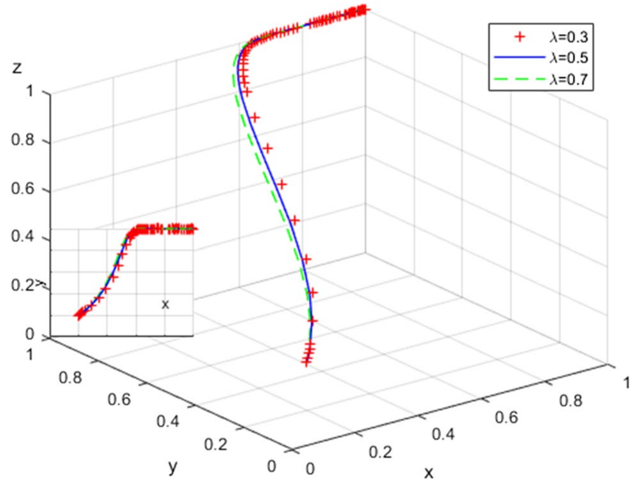

Fig. 9 The effect of λ on the strategy evolution

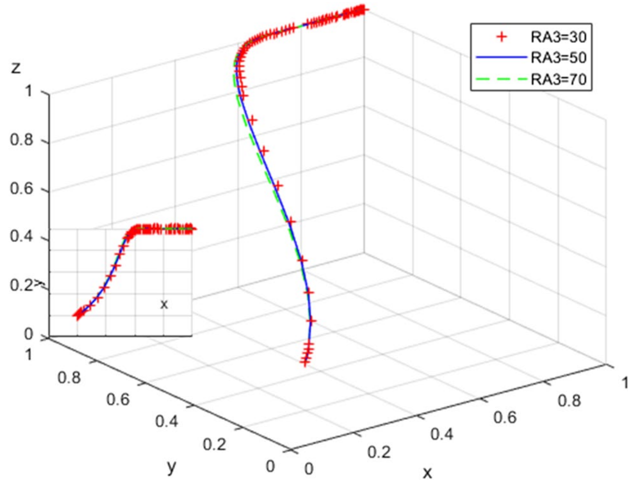

Fig. 11 The effect of R_{A_3} on the strategy evolution

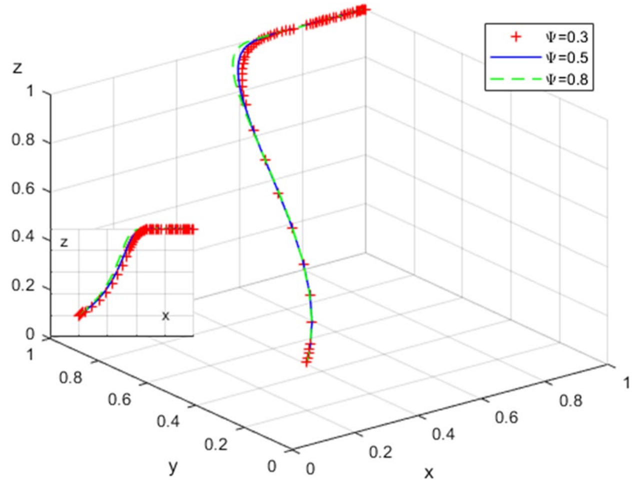

Fig. 10 The effect of φ on the strategy evolution

enterprises A and B adopting "positive cooperation" strategy increase and eventually stabilize at 1, and the probability that the government converges to "incentives" also increases. This is because if the environmental benefit factor has a larger weight in the factors affecting the profit distribution, it will encourage member enterprises to participate more actively in the green process of distribution operations and strive for more profit. Meanwhile, the government also needs to introduce preferential policies in time to incentivize them and reduce their risks and costs of green distribution operations.

(14) The influence of θ on the strategy evolution of the tripartite participants

Assign values of 0.1, 0.5, 0.9 to θ respectively, and the simulation results are shown in Fig. 14. Figure 14 shows that in the process of system evolution to a stable point, the increase in the proportion of member enterprise A's profit to the total profit ($\theta > 0.5$) can increase the rate of member enterprise A's evolution toward positive cooperation, while the rate at which member enterprise B converges to "positive cooperation" decreases. As θ increases, the probabilities of the two types of member enterprises adopting "positive cooperation" increase and eventually stabilize at 1. When $\theta > 0.5$, member enterprise A will be more motivated to promote green distribution operations and allocate more profit from within the alliance. Although member enterprise B has a smaller share of the total profit, and its willingness to evolve in the direction of positive cooperation is reduced, it can view the current situation as an opportunity to promote the green transformation of distribution operations and improve the green level of distribution operations in order to occupy a more favorable position in the following profit distribution. Hence they will eventually tend to positively cooperate. It is worth mentioning that the situation of $\theta \leq 0.5$ does not confrom to the characteristic description of member enterprises in the paper.

(15) The influence of ξ on the strategy evolution of the tripartite participants

Assign values of 0.3, 0.5, 0.7 to ξ respectively, and the simulation results are shown in Fig. 15. Figure 15 shows that in the process of system evolution to a stable point, the increase in the proportion of member enterprise A's profit to the profit caused by environmental benefit factor can increase the rate of member enterprise A's evolution towards positive cooperation. The increase in the proportion of member enterprise B's profit to the profit caused by environmental benefit factor can increase the rate of member enterprise B's evolution towards positive cooperation. The change of ξ will not change the trend of the two types of

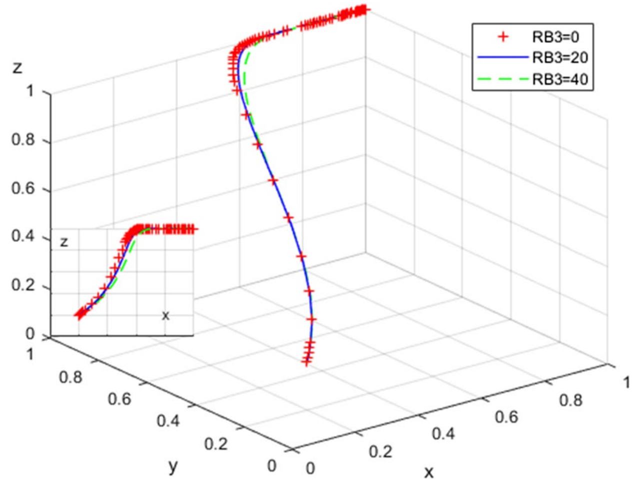

Fig. 12 The effect of R_{B_3} on the strategy evolution

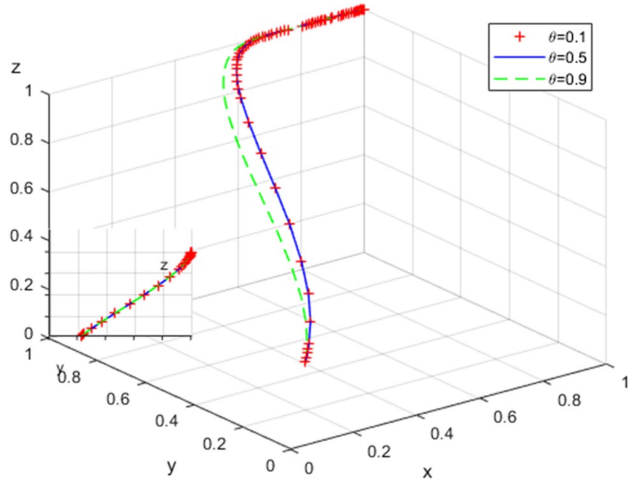

Fig. 14 The effect of θ on the strategy evolution

enterprises evolving towards positive cooperation, but it will affect the enthusiasm of the two to promote green distribution operations. The more profit caused by environmental benefits factor that a certain member enterprise is allocated, the fewer the other one is allocated. Therefore, the government can guide the latter one to form a benign competition and cooperation relationship with the former one, encourage it to exert the effect of "learning by doing" in the process of cooperation, so as to learn more from the former one in promoting green distribution operations.

Conclusions and suggestions

Under the background of green and low carbon, in order to come up with a fairer and more reasonable profit distribution scheme of joint distribution, the paper discusses the government's role in inducing green and low-carbon requirements into the alliance's profit distribution through the establishment of the tripartite evolutionary game model, then verifies the effectiveness of the stability analysis of the evolutionary game and analyses the factors affecting the stability of alliance through numerical simulation. The following conclusions are drawn and appropriate suggestions are given:

(1) It is inseparable from the government's guidance and incentives to incorporate the green and low-carbon requirements into the profit distribution of the alliance. The stability of alliance is affected by government subsidies and rewards, government's punishment, the cost of promoting green distribution operations, the additional benefit coefficient of member enterprise, the speculative gains of member enterprise, the proportion

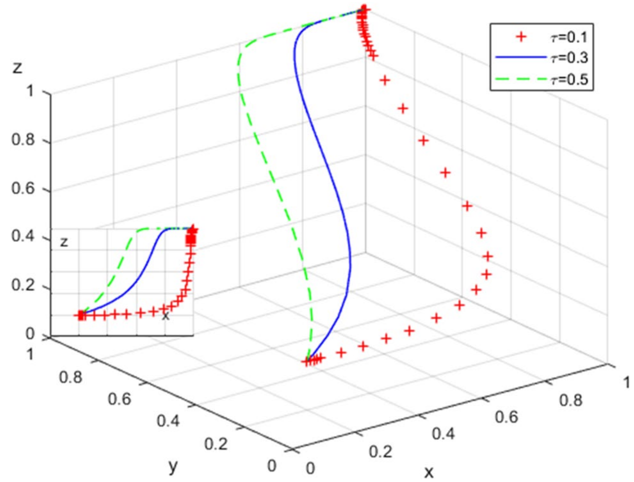

Fig. 13 The effect of τ on the strategy evolution

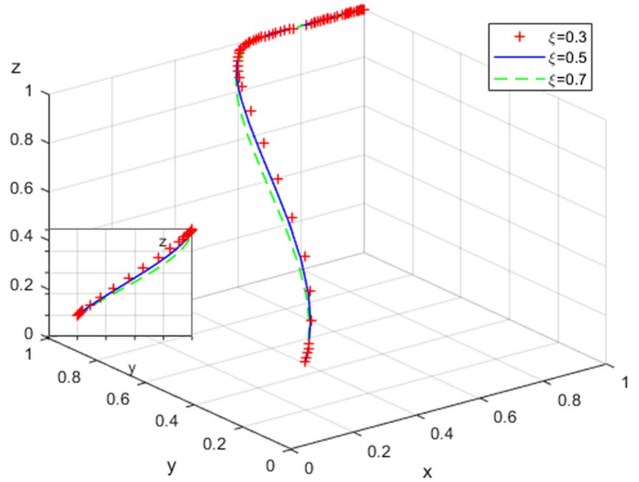

Fig. 15 The effect of ξ on the strategy evolution

of profit distribution, the importance of environmental benefit factor in profit distribution, and member enterprise's green level of distribution operations.

(2) The intensity of government subsidies and rewards is positively related to the willingness of member enterprise to positively cooperate. The government subsidies and rewards to member enterprise B are much greater than those to member enterprise A. Compared with penalties, subsidies and rewards play a greater role in promoting member enterprise. It should be noted that the intensity of subsidies and rewards must be within the scope allowed by the finances; otherwise, it will increase the government's financial burden.

(3) The cost of promoting green distribution operations is negatively related to the willingness of member enterprise to implement green and low-carbon requirements. Hence, the government needs to grant subsidies and rewards in a timely manner to stabilize member enterprises' profit expectations for implementing green and low-carbon requirements, and strengthen their confidence in green distribution operations.

(4) Based on the hypothesis of bounded rationality, member enterprises are likely to take advantage of information asymmetry to defraud government subsidies and rewards, or to conduct "free-riding" behavior on member enterprises with higher levels of green distribution operations. The abovementioned speculative activities have a negative impact on the profit distribution and the stability of alliance. For this reason, an effective supervision mechanism and an information disclosure mechanism should be established by the government to restrain their speculative activities and require them to disclose the use of subsidies and rewards on time. In addition, the property rights of the joint distribution alliance, which is based on the private property rights of member enterprises, belongs to collective property rights, which has the shortcoming of unclear property right. Just as the "free-riding" behavior shows, it ostensibly means that member enterprise B can use the resources of member enterprise A for the green distribution operations at almost no cost, but it essentially exposes the absence of the property rights protection system in the alliance, resulting in member enterprise B obtaining profit that is not its own. Therefore, the alliance should establish and improve the property rights protection system to solve the profit distribution problems from the perspective of property rights protection. At the same time, it should also focus on the long run, accelerating the implementation of the long-term mechanism of property rights protection, the assistance mechanism of property rights protection, and the diversified resolution mechanism in the property rights disputes.

(5) The size of the additional benefit coefficient of member enterprise is positively related to the willingness of member enterprise to implement green and low-carbon requirements. Although the additional benefit coefficient has no significant relationship with whether the government adopts "incentives" strategy, the government needs to take the responsibility of reducing the institutional transaction costs, creating a good business environment for enterprises, protecting their legitimate rights under government regulations.

(6) The proportion of profit distribution has a direct impact on the member enterprise's participation in the greening process of distribution operations. Member enterprises with larger profit will be more active in promoting green distribution operations. The difference in the proportion of profit distribution depends on the differences in the member enterprises' resource endowments and corporate capabilities. The article does not find that the difference in the proportion of profit distribution is negatively related to the stability of alliance under government participation.

(7) The greater the weight of environmental benefit factor in the influencing factors of profit distribution, the more important the environmental benefit factor is, and the stronger the willingness of member enterprise to positively cooperate. The more profit caused by environmental benefit factor that the member enterprise A is allocated, the stronger its willingness to promote green distribution operations. Although member enterprise B's enthusiasm to promote green distribution operations will weaken, it does not change its willingness to positively cooperate, which indicates that the government is successful in creating internal incentives for the alliance. At this time, the government also needs to guide the formation of a benign competition and cooperation relationship within the alliance, encourage member enterprise A to help member enterprise B improve the green level of distribution operations under the premise of clear property rights, motivate both of them to share green distribution resources, increase environmental benefits, and eventually achieve "win-win."

Author contribution Conceptualization, Renbin Han and Mengke Yang; methodology, Renbin Han and Mengke Yang; software, Renbin Han; validation, Renbin Han; formal analysis, Renbin Han and Mengke Yang; investigation, Renbin Han; resources, Mengke Yang; data curation, Renbin Han; writing—original draft preparation, Renbin Han; writing—review and editing, Renbin Han; visualization, Renbin Han; supervision, Mengke Yang; project administration, Mengke Yang; funding acquisition, Mengke Yang. All authors have read and agreed to the published version of the manuscript.

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Declarations

Competing interests The authors declare no competing interests.

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