

## Article

# Research on Green Development Decision Making of Logistics Enterprises Based on Three-Party Game

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**Abstract:** The concept of green logistics entails minimizing the ecological impact of logistical resources, enhancing the environmental quality within the logistics sector, and optimizing resource utilization to foster sustainable development in social economic production and consumption. Promoting green transportation is not only a positive reflection of the concepts of environmental protection and green development, but also an effective means for traditional logistics enterprises to reduce operating costs, win competitive advantages, and achieve transformation and upgrading. This paper takes logistics enterprises facing green transformation and development decisions as the research object, and puts forward an evolutionary game model between logistics companies, government, and community. The evolution path of logistics enterprises' green transformation development strategy choice under different conditions is analyzed in detail. The results show that, under the conditions of the government's incentive and supervision and the public's choice of green consumption, logistics enterprises are more inclined to green transformation development. Different levels of public choice and different levels of government regulation also make different corporate strategy choices. Therefore, it is suggested that the government provide policy, technical channels, funds, and other support for logistics companies promoting green logistics, and actively publicize the concept of green consumption in the market.



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**Keywords:** three-party game; green logistics; decision

## 1. Introduction

Logistics is developing rapidly in today's world. The market of logistics enterprises expands with the increase in online consumption. However, the sharp increase in material flow has also increased the sharp increase in carbon dioxide emissions, which have a serious impact on the environment in each logistics link. The logistics industry is an industry with high carbon and high energy consumption, in which carbon emission is an important pollution source that needs to be treated. It is a difficult process to replace non-green logistics with green logistics for the government, logistics enterprises, and the market public, but it is also a general and necessary trend. However, green development is not only an effective measure to adapt to the development trend of the global logistics industry, but also core to the competitiveness of logistics companies. Green development is one way to reduce its operating costs in the future for logistics.

In recent years, the problem of the environment being affected by the development of logistics has become more acute and prominent. The green development of logistics companies can reduce the pollution caused by the flow of raw materials and resource consumption. According to the current science and technology, there is no way to completely eliminate the damage to the environment caused by logistics, that is to say, the impact on the environment is irreparable. Therefore, one of the management objectives of logistics enterprises is to limit or reduce the burden on the environment through a series of measures. Only in this way can the society achieve sustainable development.

The concept of green logistics first appeared in China around 2000. At that time, industry regulators also put forward higher requirements for green logistics management for the logistics industry, including the coordination and planning of storage, packaging, distribution, and other links, with saving logistics resources, protecting the environment and improving logistics efficiency as the basic goal. This was not only intended to achieve the enterprise's own goal of energy saving and efficiency, but it was also necessary to cooperate with the participation of the whole society to further build a green and low-carbon environment in the economy and society as a whole. In 2021, seven national agencies issued the "Program for promoting Green Ecological consumption", which aims to encourage the green development of logistics enterprises with an objective of achieving the goal of "green ecological distribution". In fact, in recent years, various ministries have issued a series of policy guidelines on "lighter" and "thinner" express delivery. In 2021, the "14th five-year Plan" for plastic pollution prevention and Control Action Plan was issued, which aims to achieve the environmental protection goal of express delivery of e-commerce and the express delivery industry by 2025, completely eliminating secondary packaging and increasing the use of recyclable express packaging to 10 million. In 2022, the "9917" project continued to make efforts to achieve the lessening, standardization, and sustainable development of express packaging so as to meet the needs of consumers and promote social and economic development. In the field of green logistics, including packaging, transport, storage, and distribution, manufacturers, suppliers, and the public need to take joint action and retrograde green logistics activities. Due to the promotion of the green development concept and green and low-carbon development policy, logistics enterprises are developing in the direction of modern logistics, which is in the pursuit of high efficiency and intends to pay more attention to reducing pollution, consumption, and emissions in China. All localities speed up the construction of intelligently designed green logistics parks, optimize system design, carry out cloud computing, and carry out appropriate recycling. Currently, the state's support for the logistics industry is increasing so as to help in the development of other industries in the country.

In recent years, the concept of green logistics continues to take root in the hearts of the people, and the green construction of logistics enterprises has gradually become the general trend of the development in industry. The implementation of green logistics measures of enterprises needs the promotion, support, and supervision of the government, and also needs to guide the market public to turn to the concept of green consumption.

Based on the previous studies, we know that the government and the public are two important influencing factors on whether logistics enterprises choose green development. However, scholars mostly discuss the relationship between the two from a unilateral perspective, and few study how the government and the public affect the choice of enterprises from the perspective of logistics enterprises. Therefore, this paper tries to put forward a game model between logistics enterprises, the government, and the market public as the main body and analyzes the strategic choice of each subject. It then puts forward some suggestions on the present situation of green logistics development for enterprises, government supervision policy, and green consumption behavior of the market public.

Our research makes three distinctive contributions within the existing field. Firstly, we consider several major aspects that affect logistics enterprises' choices of green development, which are the government's regulation and subsidy choices and public preference for green products and logistics enterprises' choices. Secondly, establishing the tripartite game relationship between the logistics enterprises, the government, and the public, this study examines the promotion process of dynamic equalization. Finally, according to the conclusion of our analysis, the paper gives some feasible suggestions for the green development of logistics enterprises.

The subsequent structure of this article is arranged as follows. Section 2 reviews the theories related to the subject of this study. The problems to be investigated and the modeling assumptions are detailed in Section 3. Section 4 shows the game process and equilibrium analysis of the parties. In Section 5, based on the results discussed above, the development

strategy of logistics enterprises is proposed. Section 6 is the conclusion part, which summarizes the main conclusions of this paper and the action suggestions of all parties.

## 2. Theoretical Development

At present, many studies have shown that the power of government to promote the green development of enterprises cannot be underestimated. Fu Hongying (2022) studied and analyzed the development from the perspective of game theory for green logistics and found that government financial subsidies and the effective supervision mechanism were important driving forces for logistics enterprises to carry out green innovation [1]. Yu Lijing et al. (2018) pointed out that green innovation is an effective way for logistics enterprises to maintain a competitive advantage, and government participation in supervision is a booster of green innovation diffusion in logistics enterprises [2]. Chen and Zhang (2024) pointed out that, in order to cope with environmental challenges, the Chinese government encouraged enterprises to abide by corporate social responsibility, which made many enterprises gradually adopt cleaner production practices [3]. Han and Yang (2022) analyzed the interest game behavior between two typical target companies and a government, and found that the role of the government is embodied in guiding and motivating, such as guiding the alliance team to standardize the internal system and encouraging the restraint mechanism. The government also plays a crucial role in oversight, as enterprises may engage in collusion to deceive allowance and reward from government. This necessitates the establishment of robust mechanisms for monitoring systems, revealing information, and protecting intellectual property by both the government and relevant coalitions [4]. Cao et al. (2024) studied the effect of policies on green innovation and emphasized the mediating role of digitization, community responsibility, and treatment performance [5].

Regarding how to develop green logistics, Zhang Xiaolin et al. (2020), based on the perspective of green environmental protection, constructed a distribution route optimization model and solved it using the ant colony algorithm (ACA) by introducing factors such as fuel consumption and pollutant emissions into logistics distribution. It was proven that the optimization model was feasible and effective, as well as able to achieve the goal of shortest path and lowest pollutant discharge [6]. Fei Yin et al. (2022) expounded the role of circular economy in green logistics and gave reasonable policy suggestions to help build circular a green logistics system by introducing the operation mode of circular economy in the development of green logistics [7]. Yan Xiaoxia (2020) studied the logistics companies in China and optimized all the strategies for the government and logistics companies to encourage enterprises to reduce carbon emissions. According to the analysis, it was found that the comprehensive benefit of enterprises was obviously improved, and the cost was reduced after bringing low carbon into effect. The inspection strategy and meticulous comprehensive measures after the implementation of low-carbon subsidies by the government created a good environment for low-carbon development of enterprises [8]. Wang et al. (2021) put forward a freight price optimization model integrating market competition and carbon emissions of freight systems [9].

Regarding the impact of consumer choice on green development, Gizem Shou et al. (2023) studied how technological innovation in greenness affects the marketing sharing of logistics firms, and concluded that there is a role of relevant subjects and public concern [10]. Yang et al. (2023) pointed out that the green cooperation between logistics enterprises and the demand side can promote the sustainable consumption behavior of consumers and increase the trust in enterprises [11]. Zhang, Fang, and Wang (2020) analyzed the influence of customers in cold chain logistics enterprises on cold chain logistics service pricing, the pricing strategies under different conditions were given [12].

Concerning the factors influencing the implementation of green development in logistics, Cheng (2019) concluded that externalities and unimpeded information were the root causes of insufficient motivation for corporations to engage in green development [13]. Dong Yu et al. (2022), in order to study how various factors affect the implementation of

green logistics in enterprises, analyzed the evolutionary stability strategies of all parties in different situations. This showed that the participation willingness of the government, logistics corporations, and users had different effects on the evolution of the system [14]. Yu et al. (2019) found that the green technology innovation of logistics enterprises was affected not only by the intensity of government supervision, but also by the cost of green technology innovation and consumer behavior; government environmental protection publicity; and innovation incentives and pollution to logistics enterprises. The concept of green consumption can promote the green technology innovation of logistics enterprises [15]. Liang et al. (2020) found that environmental legislation and technical renovation can impact green development in the logistics industry [16]. Wu (2022) proposed a sustainable development strategy of green reverse logistics based on blockchain, used the structure of a Merkel tree to design a license chain to store detailed commodity traceability information, and stored the Merkel tree root node of the license chain block in the public chain [17]. Cheng, Han, and Ren (2023) analyzed panel data of 30 provinces during 2001–2019 using a generalized estimating equations regression model, and concluded that under the full sample, technological innovation, trade openness, and logistics infrastructure positively affected the green logistics development level, while government regulation and energy intensity negatively influenced the green logistics development level [18]. Tian et al. (2018) proposed a hybrid multi-criteria decision-making method combining the analytic hierarchy process and grey correlation technology to promote green development [19].

With regard to green logistics management and its importance, Li Xiaochen (2021) briefly introduced the significance of green logistics management, analyzed the problems existing in China's green logistics management in detail, and deeply analyzed its coping strategies [20]. Fu Junping (2022) pointed out that we must pay attention to the application of management methods in green logistics [21]. Taking urban joint distribution as an example, Zhang Ran (2021) introduced its distribution model, analyzed its green concept, revealed the importance of urban logistics greening, and made an in-depth analysis of its influencing factors to put forward some innovative suggestions to develop urban green logistics [22]. He Junze et al. (2022) pointed out that, in the process of logistics management, green management should be actively introduced to improve the effect of modern logistics management [23]. Wu Xuejin (2021) analyzed the current development of logistics management in China and a series of problems in the process of development, and put forward feasible methods for problems caused by the social development caused by the logistics industry in the process of development so as to promote the development of green logistics management in the future [24]. Wu Xie Mei (2021) expounded the research background of green logistics management, analyzed the current situation through PEST analysis, and put forward the corresponding management strategies for our country [25]. Wang et al. (2018) studied how the development of green logistics affects international trade. Through data analysis, it was found that the benefits of the former can promote the development of the latter [26].

To sum up, relevant scholars have studied and discussed the path and the influencing factors of green development of logistics enterprises. Green development is a necessary measure for logistics enterprises to reduce costs. Logistics enterprises can reduce environmental pollution by introducing low-carbon logistics equipment. A series of related behaviors such as government tax policies, laws, and regulations are the key factors for the development of green logistics [27,28]. By combing the relevant literature, we found that most scholars can reach a consensus: The role of government actions and consumer choice in the development of green logistics should not be underestimated. While the Chinese government is committed to promoting the advancement of eco-friendly logistics, conflicts of interest frequently arise among the three key stakeholders involved—namely, the government itself, logistics enterprises, and the market public. These conflicting interests often pose challenges in terms of achieving desired objectives. In practice, each of these participants tends to prioritize their own interests rather than aligning with one another. When it comes to green logistics development, the government's focus lies in

enhancing overall societal well-being; however, logistics enterprises and the market public have displayed limited enthusiasm due to their concerns for personal gains. Therefore, it is also common for logistics enterprises to give up the development of green logistics in order to pursue short-term interests. Based on this, coordinating the conflicts of interest of all parties can help to promote the development of green logistics in logistics enterprises. Therefore, from the perspective of game, this paper puts forward a tripartite game model of logistics companies, the government, and the market public; analyzes the interaction and key influencing factors of the strategic choices of all parties; and lays a theoretical foundation for logistics enterprises for green development.

### 3. Model Hypothesis and Construction and Its Evolutionary Equilibrium Analysis

#### 3.1. Problem Description

Logistics enterprises choose green development according to their own needs. Profit maximization is the ultimate goal of every enterprise. As shown in Figure 1, the green development of logistics enterprises has certain economic externalities, and it is necessary to adopt vague measures to internalize the external benefits of green logistics development. The government uses some incentives and constraints to encourage enterprises to develop green logistics. These measures include tax breaks, subsidies, fines, and other policies. The development of logistics systems tends to become more and more sustainable. However, the distribution of interests is still a complex issue which involves multi-party participation. There will be a series of games. Therefore, the sustainable development of logistics depends not only on the power of the market, but also on the participation of the government. The Chinese government is taking a series of measures, including comprehensively implementing the green logistics policy, establishing a sound environmental protection system, increasing financial investments, encouraging and guiding enterprises to adopt advanced environmental protection technology, and implementing scientific environmental protection management. With the improvement of the public's concept of green consumption, green logistics has significantly improved the total utility of the public. Logistics corporations are committed to promoting green material flow, which is not only out of their own development needs, but also affected by the supervision of the government and the behavior choices of the public. The purpose of government supervision is to ensure the maximization of social benefits. Enterprises are concerned about whether they can obtain the maximum economic benefits, and the goal of the public is to pursue the overall interests of the individual.

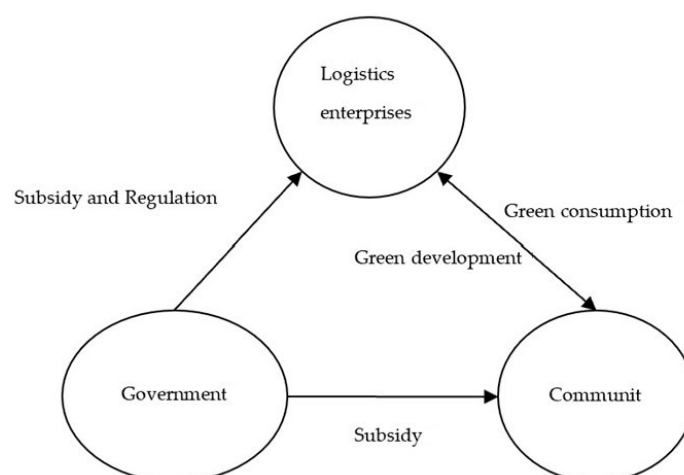


**Figure 1.** Relationships among the participants in green development decision making by logistics enterprises.

#### 3.2. Basic Assumptions

The main body of the model includes logistics enterprises, the government, and the public, which follow the basic hypothesis of a bounded rationality evolution game. The

three utilize trial and error and choose through the game, and then change their own strategies so as to choose the optimal strategy to achieve equilibrium in the game. It is known that the strategy of logistics enterprises is green development or non-green development; the government's strategy is regulation or non-regulation; and the public's strategy is green consumption or non-green consumption. The probability that logistics companies choose green development is  $x$ , the probability that the government chooses to monitor is  $y$ , and  $z$  is the probability of the public choosing green consumption.

**Hypothesis 1:** The net income of logistics companies to choose green development is  $R_1$ , and the cost of capital, technology, manpower, and other resources invested in green logistics is  $C_1$ . If government supervises and the public chooses green consumption, the public demand for green logistics enterprises will increase the market share of logistics enterprises, and the increase in extra income is  $R_{11}$ . Under the condition that the government does not regulate and the public chooses green consumption, the increase in the extra income of enterprises is  $R_{12}$ . At this time, if the public does not choose green consumption, the extra income is 0.

**Hypothesis 2:** The behavior of the government is analyzed from two angles of subsidy and regulation cost. The government subsidizes  $W_1$  to logistics enterprises that carry out green logistics development, and  $W_2$  (logistics enterprises choose green development) and  $W_3$  (logistics enterprises have no green development) to the public with a green consumption concept. Specific human and material resources require the government to invest in publicity and inspection, and the supervision cost is  $C_2$ . Green development increases social green benefits, and this is represented by an added value,  $R_2$ .

**Hypothesis 3:** There is a strong game relationship between the public green consumption concept and the green development of logistics companies. Therefore, it will guide the public to carry out green consumption for the process of green development for logistics companies. The utility of public non-green consumption is  $R_3$ , and public green consumption needs to pay costs  $C_3$  (logistics enterprises choose green development) and  $C_4$  (logistics enterprises choose non-green development). The public enjoys the logistics services brought by logistics companies, increasing the extra utility, and the utility increase is  $R_{31}$ .

### 3.3. Income Matrix of Tripartite Game

The return matrix for logistics enterprises, the government, and the public are presented in Table 1.

**Table 1.** Return matrix of tripartite game.

| Logistics Enterprises           | Government                          | Public                                                                              |                                                 |
|---------------------------------|-------------------------------------|-------------------------------------------------------------------------------------|-------------------------------------------------|
|                                 |                                     | Green Consumption ( $z$ )                                                           | Non-Green Consumption ( $1-z$ )                 |
| Green development ( $x$ )       | Subsidy and regulation ( $y$ )      | $R_1 + R_{11} - C_1 + W_1$<br>$R_2 - W_1 - W_2 - C_2$<br>$R_3 + R_{31} - C_3 + W_2$ | $R_1 + W_1 - C_1$<br>$R_2 - W_1 - C_2$<br>$R_3$ |
|                                 | No subsidy and regulation ( $1-y$ ) | $R_1 + R_{12} - C_1$<br>$R_2$<br>$R_3 + R_{31} - C_3$                               | $R_1 - C_1$<br>$R_2$<br>$R_3$                   |
| Non-green development ( $1-x$ ) | Subsidy and regulation ( $y$ )      | $R_1 - C_1$<br>$-C_2 - W_3$<br>$R_3 + W_3 - C_4$                                    | $R_1 - C_1$<br>$-C_2$<br>$R_3$                  |
|                                 | No subsidy and regulation ( $1-y$ ) | $R_1 - C_1$<br>$0$<br>$R_3 - C_4$                                                   | $R_1 - C_1$<br>$0$<br>$R_3$                     |

### 3.4. Construction of Replication Dynamic Equation

According to the income matrix, when a logistics enterprise chooses green development, the number equation of its expected return is:

$$E_{11} = yz(R_1 + R_{11} - C_1 + W_1) + y(R_1 - C_1 + W_1)(1 - z) + (1 - y)(R_1 + R_{12} - C_1)z + (1 - y)(R_1 - C_1)(1 - z) \quad (1)$$

When logistics enterprises choose non-green development, the expected return is:

$$E_{12} = yz(R_1 - C_1) + (1 - z)(R_1 - C_1)y + (1 - y)z(R_1 - C_1) + (1 - y)(R_1 - C_1)(1 - z) \quad (2)$$

The expected income of logistics enterprises is:

$$E_1 = E_{11}x + E_{12}(1 - x) \quad (3)$$

Thus, the replication dynamic equation for companies' green logistics development is:

$$\begin{aligned} F(x) &= \frac{dx}{dt} = x(E_{11} - E_1) \\ &= [R_{11}yz + W_1y + R_{12}(1 - y)z]x(1 - x) \end{aligned} \quad (4)$$

which can be known by the income matrix.

When the government implements a subsidy and regulation strategy, its expected return is:

$$E_{21} = xz(R_2 - W_1 - W_2 - C_2) + x(1 - z)(R_2 - W_1 - C_2) + (-C_2 - W_3)(1 - x)z + (-C_2)(1 - x)(1 - z) \quad (5)$$

When the government implements a non-subsidy and regulation strategy, its expected return is:

$$E_{22} = xzR_2 + R_2x(1 - z) \quad (6)$$

The expected income of the government is:

$$E_2 = E_{21}y + E_{22}(1 - y) \quad (7)$$

In the same way, the replication dynamic equation for a government with strict regulation is:

$$\begin{aligned} F(y) &= \frac{dy}{dt} = y(E_{21} - E_2) \\ &= [W_3xz - W_1x - W_3z - W_2xz - C_2]y(1 - y) \end{aligned} \quad (8)$$

In the same way, when the public is to carry out green consumption, its expected return is:

$$E_{31} = xy(R_3 + R_{31} + W_2 - C_3) + x(1 - y)(R_3 + R_{31} - C_3) + (1 - x)y(R_3 + W_3 - C_4) + (1 - x)(1 - y)(R_3 - C_4) \quad (9)$$

When the public chooses non-green consumption, its expected return is:

$$E_{32} = xyR_3 + xR_3(1 - y) + yR_3(1 - x) + (1 - y)R_3(1 - x) \quad (10)$$

The expected income of the enterprise is:

$$E_3 = E_{31}z + E_{32}(1 - z) \quad (11)$$

The dynamic equation of expectations for the public with green consumption is:

$$\begin{aligned} F(z) &= \frac{dz}{dt} = z(E_{31} - E_3) \\ &= [(W_2 - W_3)xy + (R_{31} - C_3 + C_4)x + W_3y - C_4]z(1 - z) \end{aligned} \quad (12)$$

Formulas (4), (8) and (12) constitute a dynamic replication system.

#### 4. Equilibrium of Evolutionary Game and Its Asymptotic Stability Analysis

##### 4.1. Asymptotic Stability Analysis

To solve the evolutionary game equation, let Equations (4), (8) and (12) be equal to zero. Eight special equilibrium points can be gained: there are  $P_1$  (0,0,0),  $P_2$  (1,0,0),  $P_3$  (0,1,0),  $P_4$  (0,0,1),  $P_5$  (1,1,0),  $P_6$  (1,0,1),  $P_7$  (0,1,1), and  $P_8$  (1,1,1). The stability of the above eight special equilibrium points is analyzed.

By calculating the partial derivatives of the independent variables of the Equations (4), (8) and (12), we can obtain the Jacobian matrix as follows:

$$J = \begin{bmatrix} \frac{dF(x)}{d(x)} & \frac{dF(x)}{d(y)} & \frac{dF(x)}{d(z)} \\ \frac{dF(y)}{d(x)} & \frac{dF(y)}{d(y)} & \frac{dF(y)}{d(z)} \\ \frac{dF(z)}{d(x)} & \frac{dF(z)}{d(y)} & \frac{dF(z)}{d(z)} \end{bmatrix} = \begin{bmatrix} J_{11} & J_{12} & J_{13} \\ J_{21} & J_{22} & J_{23} \\ J_{31} & J_{32} & J_{33} \end{bmatrix} \quad (13)$$

$$J_{11} = [(R_{11} - R_{12})yz + W_1y + R_{12}z](1 - 2x) \quad (14)$$

$$J_{12} = [(R_{11} - R_{12})z + W_1]x(1 - x) \quad (15)$$

$$J_{13} = [(R_{11} - R_{12})y + R_{12}]x(1 - x) \quad (16)$$

$$J_{21} = [W_3z - W_2z - W_1]y(1 - y) \quad (17)$$

$$J_{22} = [W_3xz - W_2xz - W_1x - W_3z - C_2](1 - 2y) \quad (18)$$

$$J_{23} = [W_3x - W_2x - W_3]y(1 - y) \quad (19)$$

$$J_{31} = [(W_2 - W_3)y + R_{31} - C_3 + C_4]z(1 - z) \quad (20)$$

$$J_{32} = [(W_2 - W_3)x + W_3]z(1 - z) \quad (21)$$

$$J_{33} = [(W_2 - W_3)xy + (R_{31} - C_3 + C_4)x + W_3y - C_4](1 - 2z) \quad (22)$$

Therefore, by substituting eight special points into Equation (13), the proper values of all special points can be calculated. Table 2 shows the proper values and stability conditions.

**Table 2.** Eigenvalues and stability conditions of equilibrium points.

| Equilibrium Points | Eigenvalues     |                      |                      | Signs of Eigenvalues | Stability            |
|--------------------|-----------------|----------------------|----------------------|----------------------|----------------------|
|                    | $\lambda_1$     | $\lambda_2$          | $\lambda_3$          |                      |                      |
| (0,0,0)            | 0               | $-C_2$               | $-C_4$               | 0; −; −              | Critical equilibrium |
| (1,0,0)            | 0               | $-W_1 - C_2$         | $R_{31} - C_3$       | 0; −; uncertain      | Conditional critical |
| (0,1,0)            | $C_2$           | $W_1$                | $W_3 - C_4$          | +; +; uncertain      | Unstable             |
| (0,0,1)            | $C_4$           | $R_{12}$             | $-C_2 - W_3$         | +; +; −              | Unstable             |
| (1,1,0)            | $-W_1$          | $C_2 + W_1$          | $R_{31} - C_3 + W_2$ | −; +; uncertain      | Unstable             |
| (1,0,1)            | $C_3 - R_{31}$  | $-R_{12}$            | $-C_2 - W_1 - W_3$   | uncertain; −; −      | Conditional stable   |
| (0,1,1)            | $R_{11} + W_1$  | $C_4 - W_3$          | $C_2 + W_3$          | +; uncertain; +      | Unstable             |
| (1,1,1)            | $-R_{11} - W_1$ | $C_3 - R_{31} - W_2$ | $C_2 + W_1 + W_2$    | −; uncertain; +      | Unstable             |

Table 2 uses ‘0’, ‘+’, and ‘−’ to represent eigenvalues, with the symbols 0, positive, negative, and ‘uncertain’ indicating that the symbol of the eigenvalue can be positive or negative under certain conditions. The stability of points is judged by the proper value symbol of the matrix. If the proper value of a particular equilibrium point is negative, the point is locally asymptotically stable, and if there is at least one positive point, the point is unstable. The conditional stable point occurs with uncertain eigenvalues, and the conditional critical point occurs with uncertain eigenvalues and “0” eigenvalues.

Points  $P_3$  (0,1,0),  $P_4$  (0,0,1),  $P_5$  (1,1,0),  $P_7$  (0,1,1), and  $P_8$  (1,1,1) all have at least one positive eigenvalue and are unstable points.

For point  $P_1$  (0,0,0), two eigenvalues are negative and one is “0”.  $P_1$  (0,0,0) is asymptotically critical stable.

For point  $P_2 (1,0,0)$ , the eigenvalues are negative or “0”, and  $P_2 (1,0,0)$  is a conditional critical equilibrium point if  $R_{31} < C_3$  is satisfied.

For the point  $P_6 (1,0,1)$ , the corresponding eigenvalues are all negative if it satisfies  $R_{31} < C_3$ , and then  $P_6 (1,0,1)$  is a conditional stable point.

#### 4.2. Stability Analysis of Enterprises

$F(x) = 0$  represents the dividing line of the steady state. According to Equation (4), when  $(R_{11} - R_{12})yz + W_1y + R_{12}z = 0$ , i.e.,  $y = y^* = -\frac{R_{11}z}{W_1 + R_{11}z - R_{12}z}$ , then  $F(x) = F'(x) = 0$ , and it can reach a steady state. That is to say, when the probability  $y$  of the government choosing regulation and subsidies and the probability  $z$  of the public choosing green logistics products meet the condition  $y = y^* = -\frac{R_{11}z}{W_1 + R_{11}z - R_{12}z}$ , the choice of logistics enterprises is stable. The proportion of logistics enterprises choosing whether to develop green logistics or not has no great impact on their income.

If  $y > y^* = -\frac{R_{11}z}{W_1 + R_{11}z - R_{12}z}$ , when  $F(x) = 0$ , and  $F'(x) < 0$ ,  $x^* = 1$  is a steady state for the system of tripartite relations. That is to say, when logistics enterprises choose to develop green logistics, the system can reach a stable state.

If  $y < y^* = -\frac{R_{11}z}{W_1 + R_{11}z - R_{12}z}$ , when  $F(x) = 0$ , and  $F'(x) > 0$ ,  $x^* = 0$  is a steady state for the system of tripartite relations. That is to say, when logistics enterprises do not choose to develop green logistics, the system can reach a stable state.

The dynamics trend of logistics enterprises is shown in Figure 2, where the overall feasible region is divided into two adjacent sections by the intersection space of  $y$  and  $z$ , which is marked in purple. The mixed strategy space of the logistics enterprises is produced as  $\{x|x \in [0, 1]\}$ , and the arrows show the trend of  $x$  between  $[0, 1]$ . That is,  $x$  converges to 0 when the feasible region is located in the lower plane region; then, it is optimal for logistics enterprises to develop non-green logistics. However,  $x$  converges to 1 when the feasible region is located in upper plane region; then, the optimal strategy is for logistics enterprises to develop green logistics.

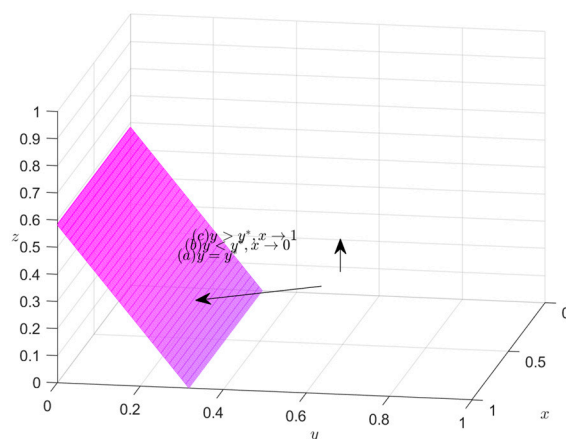


**Figure 2.** Dynamics trend schematic diagram of logistics enterprises.

#### 4.3. Stability Analysis of Government

$F(y) = 0$  represents the dividing line of the steady state. According to the Formula (8), When  $W_3xz - W_1x - W_3z - W_2xz - C_2 = 0$ , i.e.,  $z = z^* = -\frac{C_2 + W_1x}{W_3 + W_2x - W_3x}$ , then  $F(z) = F'(z) = 0$ , and it can reach a steady state. That is to say, the probability  $z$  of the public choosing green logistics products and the probability  $x$  of logistics enterprises to develop green logistics meet this condition:  $z = z^* = -\frac{C_2 + W_1x}{W_3 + W_2x - W_3x}$ . The proportion of the government to choose whether regulation and subsidies or not has no great impact on their income.

When  $W_3xz - W_1x - W_3z - W_2xz - C_2 \neq 0$ , if  $F(y) = 0$ , then  $y^* = 0$ ,  $y^* = 1$ , which are a pair of stable points, are obtained.

If  $z > -\frac{C_2+W_1x}{W_3+W_2x-W_3x}$ , when  $F(y) = 0$ , and  $F'(y) < 0$ ,  $y^* = 1$  is a steady state for the system of tripartite relations. That is to say, regulation and subsidies are better options for governments to develop green logistics.

If  $z < -\frac{C_2+W_1x}{W_3+W_2x-W_3x}$ , when  $F(y) = 0$ , and  $F'(y) > 0$ ,  $y^* = 0$  is a steady state for the system of tripartite relations. That is to say, a lack of regulation and subsidies is a better option for governments.

The dynamics trend of the government is described in Figure 3, where the overall feasible region is divided into two adjacent sections by the intersection space of  $x$  and  $z$ , which is marked in pink. The mixed strategy space of the governments is produced as  $\{y|y \in [0, 1]\}$ , and the arrows show the trend of  $y$  between  $[0, 1]$ . That is, if  $y$  converges to 0 when the feasible region is located in the sub-plane region, then it is optimal for government to adopt non-regulation and non-subsidies. However, if  $y$  converges to 1 when the feasible region is located in the upper plane region, then the optimal strategy is for the government to choose regulation and subsidies.

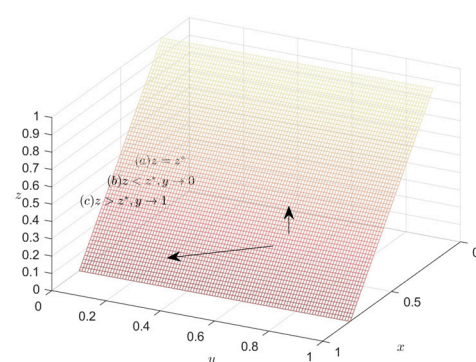


Figure 3. Dynamics trend schematic diagram of the government.

#### 4.4. Stability Strategy of the Public

According to Formula (12), if  $(W_2 - W_3)xy + (R_{31} - C_3 + C_4)x + W_3y - C_4 = 0$ , i.e.,  $x = x^* = \frac{C_4 - W_3y}{C_4 - C_3 + R_{31} + W_2y - W_3y}$ , then  $F(z) = F'(z) = 0$ , it can reach a steady state. That is to say, when the probability  $x$  of logistics enterprises to develop green logistics and the probability  $y$  of the government choosing regulation and subsidies meet this condition, then  $x = x^* = \frac{C_4 - W_3y}{C_4 - C_3 + R_{31} + W_2y - W_3y}$ . The proportion of the public choosing green logistics products or not has no great impact on their income.

When  $(W_2 - W_3)xy + (R_{31} - C_3 + C_4)x + W_3y - C_4 \neq 0$ , if  $F(z) = 0$ , then  $z^* = 0$ ,  $z^* = 1$ , which are a pair of stable points, are obtained.

If  $x > \frac{C_4 - W_3y}{C_4 - C_3 + R_{31} + W_2y - W_3y}$ , when  $F(z) = 0$ , and  $F'(z) < 0$ ,  $z^* = 1$  is a steady state for the system of tripartite relations. That is to say, choosing green logistics products is a better option for the public.

If  $x < \frac{C_4 - W_3y}{C_4 - C_3 + R_{31} + W_2y - W_3y}$ , when  $F(z) = 0$ , and  $F'(z) > 0$ ,  $z^* = 0$  is a steady state for the system of tripartite relations. That is to say, not choosing green products is a good decision for the public.

The dynamics trend of the public is described in Figure 4, where the overall feasible region is divided into two adjacent sections by the intersection space of  $x$  and  $y$ , which is marked in blue. The mixed strategy space of the public is produced as  $\{z|z \in [0, 1]\}$ , and the arrows show the trend of  $z$  between  $[0, 1]$ . That is, if  $z$  converges to 0 when the feasible region is located in the left plane region, then it is optimal for the public to adopt non-green consumption. However, if  $z$  converges to 1 when the feasible region is located in right plane region, then the optimal strategy for the public is to choose green consumption.

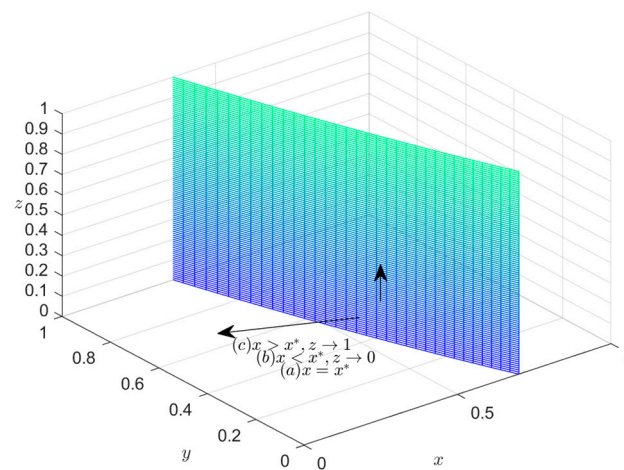


**Figure 4.** Dynamics trend schematic diagram of the public.

Through stability analysis, we found that there is a close relationship between the development status of logistics enterprises, the government's regulation and subsidies intensity  $y$ , and the public's green logistics preference intensity  $z$ ; different national policies also bring different green development levels  $x$  of logistics corporations and green consumption levels  $z$  of the public; meanwhile, the public's green consumption is also affected by the level of green logistics and the intensity of government regulations and subsidies. By adjusting various parameters, we can achieve the best balance of the tripartite behavior and thus achieve the best game result.

### 5. Development Strategy Based on Equilibrium Analysis

Through the basic theory and method of an evolutionary game model, this paper analyzes how logistics corporations choose green development in a tripartite relationship. The following results are obtained: (1) Whether logistics companies choose green development is affected by public behavior, state support, and supervision. The more the public has a concept of green consumption, the greater the government's supervision and support for green logistics enterprises, and the more it can encourage logistics companies to develop green logistics. In order to implement green logistics, enterprises should not only consider the market, but also rely on the support of the government. Only by effectively guiding enterprises to participate in green logistics can the government better provide incentives for green logistics. Consumers' concepts of green consumption can impulse the technological innovation of logistics companies in green development. (2) Government supervision is mainly affected by profits and supervision costs. When the total benefit exceeds the cost of government regulation, the government will intervene in logistics enterprises to regulate. National supervision is the "thruster" of logistics enterprises' green development. The government plays a crucial role in oversight. The green development of logistics enterprises is affected by the intensity of government supervision, environmental protection publicity, and innovation incentives of the government, as well as pollution fines and taxes on logistics enterprises. (3) The lower the cost of green development, the more logistics enterprises tend to pursue green development. Therefore, as there are more green subsidies to these enterprises, along with subsidies to the public and more government investment in the implementation of green logistics enterprises, the green development of enterprises and the formation of a public green consumption concept will be promoted. The more we promote the formation of green concept, the more we can promote the development of green logistics enterprises.

To sum up, logistics companies that want to achieve green development can:

- (1) Establish a green information disclosure system. In accordance with the requirements of environmental audit, they can regularly issue sustainable development reports and

corporate social responsibility reports and encourage enterprises to strengthen their environmental responsibility.

- (2) Strengthen the research, development, and application of green technology innovation. If we want to protect the environment more effectively, we need to take measures to make technology more environmentally friendly. First of all, we need to strengthen the management of renewable packaging, formulate relevant environmental protection policies, and promote environmentally friendly packaging. Secondly, we also need to take measures to save resources, such as using clean fuel, controlling energy consumption, and reducing environmental pollution. Finally, we also need to carry out scientific warehouse management in order to improve environmental protection. In a word, we need to take measures to promote environmental protection and social progress. The use of big data, IoT, artificial intelligence, and accurate orientation technology greatly enhance the efficiency of logistics, thus greatly promoting logistics corporations to a higher level of progress.
- (3) Encourage cooperation and exchanges and promote the transformation of the industry. Encourage industry, university, and research to jointly build an innovation platform, encourage mutual cooperation among enterprises, establish a green postal and express service alliance, promote the green development experience of the industry in multiple levels and multiple channels, and promote the promotion of the concept of green logistics.

Companies can improve resource deployment and reduce the burden of transportation. They can accomplish this by vigorously pushing forward the development of “end-to-end” and “door-to-door” logistics models; vigorously developing third-party suppliers; promoting the simplification of logistics distribution; promoting the utilization of renewable resources; reasonably configuring and planning transport routes and transport channels; reducing vehicle congestion; actively promoting the construction of logistics supply chain information platforms; and further strengthening the overall operation of logistics components.

## 6. Conclusions

From the findings of this paper, we can obtain some enlightenment regarding the green development of logistics enterprises: (1) Although logistics enterprises have carried out a series of green development initiatives, they still need the government to adopt different ways and methods to promote this modernization process. The government should support the green innovation of logistics companies, strengthen regulatory measures, and reduce regulatory expenditure so as to avoid wastes of resources caused by wasteful expenditure. (2) The impact of mass consumption on green logistics cannot be ignored. If the public does not have green consumption, the government should increase public subsidies and increase public demand for green consumption, which will further stimulate logistics companies to invest in green development. (3) Logistics companies need to be environmentally conscious so that they can invest more money in innovation research for green development, reduce pollution, and reduce resource consumption. The public must understand the concept of green consumption, which can consume green products and promote the demand for and development of logistics companies.

Green logistics will bring about the coordinated development of economic benefits, environmental benefits, and social benefits. Based on this characteristic, logistics enterprises should actively invest in cooperation with the government and gradually promote the improvement of the standardized service system of green logistics through the co-construction of government and enterprises, which can not only effectively enhance the entry threshold of the green logistics industry, but also help to eliminate backward production capacity and solve the restrictive impact of traditional logistics on the development of green. It reflects the advantages of the development of green logistics enterprises.

At present, with the in-depth application of green business models, not only will logistics enterprises achieve their own sustainable and high-quality development, but the green development of the industry will also be accelerated. To this end, logistics enterprises

should continue trying to achieve comprehensive coverage of green logistics. In order to realize the modern management and development of green logistics, we must strengthen the green logistics awareness of enterprises, managers, employees, and consumers, and establish a comprehensive management and supervision mechanism through publicity activities using various channels. In order to obtain the double return of economy and society, and to encourage all parties to participate in it, enterprises should make full use of their influence to provide positive examples for employees, customers, and suppliers to accelerate the greenization of logistic., This will create a win-win situation for the economy, society, and environment, and contribute to the sustainable development of the country.

Enterprises should actively promote the concept of green logistics so as to realize the long-term development of enterprises and society, and advocate for a team spirit of unity, cooperation, and environmental friendliness. Saving manpower, reducing waste, and preventing pollution are the long-term strategic goals of enterprise development. The government should issue policies and regulations to push forward green logistics, speed up the construction of green logistics infrastructure, and enhance the support of basic economic education facilities so as to push forward the sustainable development of green companies. The government should take some measures, such as encouraging the application of innovation and technology, strengthening the transformation of existing infrastructure, expanding its scale, optimizing its layout, realizing the integration of science and culture, improving the management efficiency of facilities, and maximizing its comprehensive economic benefits.

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