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Evolutionary Game Analysis of Green Supply Chain Management Diffusion under Environmental Regulation

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Abstract: The continuous deterioration of the ecological environment and the increasing scarcity of resources have posed a serious challenge to the survival and development of human beings, and the implementation of green supply chain management (GSCM) in this context is an effective means to ensure the sustainable development of society and the economy. In order to seek the optimal strategy of evolutionary game in the implementation of green supply chain management and explore the influence of environmental regulation intensity and public preference degree on the evolution process of green supply chain management diffusion development, this paper takes the study of green supply chain management diffusion as the core innovation point, and under the premise of environmental regulation, selects the government, the core enterprise, and the public as the participating bodies of green supply chain management diffusion, and uses the theory of evolutionary game to construct a diffusion model of green supply chain management. Using evolutionary game theory to construct a diffusion model, and with the help of MATLAB and other mathematical tools for numerical simulation analysis, we discuss the diffusion of the green supply chain and derive the optimal combination strategy. The results of the study show that: (1) there are four evolutionary stable states in the process of green supply chain management diffusion: preliminary diffusion, extinction, semi-diffusion, and full diffusion; (2) it will be beneficial for the government to promote the evolutionary diffusion of green supply chain management by implementing a higher intensity of pollution tax policy while implementing green supply chain incentive strategies; (3) the government, while implementing environmental regulation policies, should also pay attention to the guidance of the public's awareness of environmental friendliness and greenness, and focus on the role of the comprehensive strategy selection of the three parties of the game in reaching the optimal state. The conclusions of the study provide theoretical guidance and decision support for the implementation and diffusion of green supply chain management under environmental regulation.

Keywords: environmental regulation; green supply chain; diffusion; evolutionary game theory

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1. Introduction

The traditional supply chain, with high energy consumption, has brought about increasingly serious problems of environmental pollution and resource wastage, which not only restrict the sustainable development of society and the economy but also causes great harm to the natural environment and human health all over the world. In the face of a continuously deteriorating ecological environment and increasingly severe resource challenges, the implementation and proliferation of green supply chain management has become a focal point of concern for governments, enterprises, the public, and scholars (Feng, Y., 2022) [1]. Under today's pressing environmental pressures, solutions of a socially or economically innovative nature are constantly being sought, and the practice of business is increasingly emphasizing a sustainable development orientation (Chomać-Pierzecka, E., 2023) [2]. For enterprises, the key to practicing green manufacturing to achieve green and sustainable development lies in green technological innovation, and through significantly

reducing environmental pollution, enterprises need to respond to society's goal of green and sustainable development to win sustainable goodwill and thus gain a competitive advantage (Zhang, C., 2022) [3]. Therefore, some enterprises have begun to take the initiative to seek transformation and actively develop green supply chain management, which provides a prerequisite for the promotion and proliferation of green supply chains.

In order to promote the reduction of greenhouse gas emissions in France, to achieve green and sustainable development, and to implement global actions such as the Paris Agreement and the United Nations 2030 Agenda for Sustainable Development, France has published an action plan for the 2030 greenhouse gas emissions reduction target in 2023, which focuses on the transportation sector, the construction sector, and the industrial and agricultural sectors, in order to strengthen actions and investments in the ecological transition. This program focuses on the transportation, construction, and agriculture and industry sectors to strengthen actions and investments in ecological transition. In China, the 14th Five-Year Plan for industrial green development explicitly states the need for China to reach a major national strategic decision to achieve carbon peak by 2030 and carbon neutrality by 2060. With the theme of promoting high-quality development, China has been implementing green manufacturing with supply-side structural reform as the main line and improving resource utilization efficiency and supply chain greening through green supply chain management, to support the achievement of the target of carbon peaking and carbon neutrality as scheduled. Therefore, the last five years will be a critical period for China to cope with climate change and achieve the goal of carbon peak, and the popularization of green supply chain management in enterprises is an important foundation for achieving this goal, so it is necessary to research how to help green supply chain management gain advantages in the game with traditional supply chain management and help green supply chain management to realize the proliferation.

In the face of the promotion of green supply chain management, the Chinese government has issued a series of relevant guidelines to support the development and management of green supply chains at the policy level (Sheng, X., 2023) [4]. For example, the China Green Manufacturing Technology Standardization Technical Committee released four national standards for green supply chain management in 2020, including Green Manufacturing, Green Supply Chain Management Evaluation Specification for Manufacturing Enterprises (GB/T 39257-2020) [5]. Made in China 2025 supports enterprises to develop green products, create green supply chains, accelerate the establishment of resource-saving, environmentally friendly-oriented procurement, production, marketing, recycling, and logistics systems, and support the implementation of green strategies, green standards, green management, and green production, as well as highlighting the need to improve energy-saving and environmentally friendly regulations and standards systems, and to strengthen green regulation. The Chinese government has formulated corresponding policies in various aspects to provide different degrees of environmental regulation for enterprises to implement green supply chain management. Environmental regulation refers to the government's efforts to guide enterprises to protect the environment through the formulation of specific environmental protection-related policies or through certain means, specifically including public environmental protection publicity, green supply chain incentives, and pollution taxes and other environmental regulation means of different strengths (Zhai, W., 2023) [6]; the government therefore faces a wide range of choices in the actual implementation of promoting green supply chain management.

Although the implementation of a green supply chain is a necessary development condition for realizing China's high-quality development and is the main goal of China's supply chain management development in the future, enterprises are still facing a relatively low level of implementation of green supply chain management and its popularity among enterprises due to the high implementation cost and complex implementation process (Xu, F., 2020) [7]. At present, although most of the public, enterprises, and the government recognize the necessity of green supply chain implementation, in the actual implementation process, the traditional supply chain competes with the green supply chain due to the

low price point of the products it produces (Qu, Y., 2023) [8]. According to the "Citizen's Ecological and Environmental Behavior Survey Report (2022)" released by the Center for Environmental and Economic Policy Research of the Ministry of Ecology and Environment of China in July 2023, the Chinese public generally has a strong willingness to engage in environmental behaviors, but there are differences in the actual behavioral performance in different areas. For example, in the areas of "concern for the ecological environment" and "reducing pollution generation", the behavioral performance is good, but in the areas of "practicing green consumption" and "participating in supervision and reporting", the behavioral performance is average. In terms of practicing green consumption, the proportion of people who could often buy green products was 30% to 40% in 2020, and the proportion of people who could buy green products was more than 60% in 2022, and the public's preference for green products is growing year by year; green products are gradually being supported by consumers, and they can compete with traditional products on the market, but there is still room for improvement in comparison with other fields. Green products produced under green supply chain management consider minimizing the consumption of natural resources and the generation of environmentally hazardous substances based on product manufacturing, and therefore incur additional green manufacturing costs in terms of production costs (Chen, K., 2023) [9]. There are individual differences in the level to which the public is influenced by consumption concepts and their degree of environmental awareness; whether the public will choose to participate in the green supply chain management of core enterprises with the temptation of practical economic aspects such as the price of the product, and whether the public's supervision and support for the development of green supply chain management, as well as their consumption preference of products and services, have an impact on the promotion of the spread of green supply chain management are questions that are worthy of investigation. In previous studies, research has focused more on the implementation of green supply chain management, and there is a gap for research on the further diffusion of green supply chain management, and research is needed on the diffusion of green supply chain management.

Therefore, in order to realize that the green supply chain still obtains strong and lasting vitality under environmental regulation, the positive-sum game between the government and enterprises is not the only problem to be solved, but also the need to carry out an in-depth study on the problem of green supply chain management diffusion based on the win-win game between the government, the core enterprises, and the public in the green supply chain. In view of this, this paper takes the study of green supply chain management diffusion as the core innovation point, under the premise of environmental regulation, uses the idea of evolutionary game to construct a game model between the government, core enterprises, and the public in the process of green supply chain diffusion, and explores the diffusion of green supply chains and optimal decision-making of all parties under different levels of environmental regulation and public preference, so as to provide a scientific insight into the diffusion of green supply chain management. Therefore, the purpose of this paper is to address the following questions: (1) What is the optimal strategy of the evolutionary game between the government, core enterprises, and the public in the implementation of green supply chain management? (2) What are the stable states in the evolution of green supply chain management diffusion development? Is there an optimal environmental regulatory intensity for the diffusion of green supply chain management? (3) How does the public's preference for different supply chain management developments affect the diffusion of green supply chain management? (4) How does the intensity of government environmental regulation affect the game between traditional and green supply chain management? What strategies should the government choose to effectively promote the diffusion of green supply chain management?

The main contributions of this study are as follows: (1) The core of this paper focuses on the diffusion of green supply chain management, focuses on the diffusion of the implementation scope of green supply chain management, considers the degree of public recognition and participation in green supply chain management, and constructs

a tripartite evolutionary game model between the core enterprises, the public, and the government from the perspective of macro-groups, so as to expand the influence of green supply chain management to achieve the sustainable development of green supply chains. (2) It explores the competitive blocking or symbiotic relationship between green supply chains and traditional supply chains in terms of market share, which helps to analyze the stable state of green supply chain management diffusion. (3) It differentiates the intensity of governmental environmental regulation means and explores the evolution trajectory of green supply chain management diffusion in terms of public environmental protection publicity, green supply chain incentive policy, and pollution tax, and selects the best combination strategy through game simulation to promote the popularization of green supply chains more effectively.

The rest of this study is structured as follows. Section 2 summarizes the literature review of existing studies and elaborates on the gaps in the existing studies, emphasizing the innovation and necessity of this study. Section 3 describes the research methodology by constructing an evolutionary game model for the survival of the government, core enterprises, and the public in the process of green supply chain diffusion, deriving the payoff matrices of core enterprises and the public under the constraints of whether or not there are environmental regulations, analyzing the stability of the model, exploring the local equilibrium point of green supply chain management diffusion of the core enterprises under the environmental regulations, and analyzing the four evolutionary stable states. Section 4 utilizes tools to numerically simulate the above model and discusses the optimal combination strategies for different scenarios by differentiating the intensity of regulation and the degree of demand preference. Section 5 provides an in-depth discussion of the results of the issues explored above and discusses them in conjunction with existing research results. Section 6 draws conclusions from the study, discusses the value of the study for theory and practice considering the purpose of the study and its innovations, and proposes the limitations of the study and future research directions to provide scientific management insights for the proliferation of green supply chain management.

2. Literature Review

Environmental degradation and energy overconsumption have become global economic development issues, and overconsumption of resources and damage to the environment threaten the very existence of human beings, which means the goal of supply chain management has gradually changed to achieve sustainable development that integrates the economy and the environment. The initial research focus of supply chain management was mainly on maximizing the economic benefits of each member of the chain, but there were also examinations of the economic benefits of resources and the ecological environment (Fahim Nia, B., 2015) [10]. In the process of development, the loss and destruction of the ecological environment is a cost, and this cost is more expensive than expected because of the irreversible nature of some of the resource loss, so focusing on the pursuit of explicit business economic benefits and ignoring the implicit benefits of good and sustainable development of the green ecological environment is one-sided. Research scholars have successively focused on the green development of supply chain management, advocating the use of green supply chain management by enterprises to minimize the impact on the environment and maximize the efficiency of resource use for the purpose of supply chain management, to jointly consider the economic benefits and environmental benefits, and to improve the efficiency of resource use (Sarkis, J., 2011) [11]. With the gradual deepening of the research, scholars took the development of green supply chain management as the core and carried out research into the optimization and improvement of green supply chain management, decision-making coordination, and other aspects of green supply chain management, aiming to enhance the practicality of green supply chain management.

The Implementation of green supply chain management is a multi-party interactive negotiation, common cooperation, and multi-governance situation, so to achieve the ideal effect of equilibrium of all parties, game theory is now more widely used in the study

of green supply chain management. Most of the studies related to green supply chain management utilizing the game method have been conducted by manufacturers, suppliers, retailers, and other enterprises (Zaefarian, T., 2023) (Sarkar, B., 2023) (Hu, H., 2022) [12–14]. Within them, the core of the research mainly centers on the optimal pricing of green products, which focuses on how to determine the optimal consumer price and the optimal level of investment in pollution reduction or green operations (Agi, M.A.N., 2021) [15]. For different scenarios, different participants, and different game sequences, scholars at this stage usually discuss single or multiple chains, cooperative or non-cooperative states (Peng, Y., 2022) [16]. The game relationship in the secondary green supply chain is currently a popular research topic in many studies. For example, Y.C. Chang (2023) conducted a study on dual-channel supply chains of retailers and suppliers and established a quantum game based on the classical game to study the optimal pricing problem of green products [17]. M.B. Jamali, et al. (2018), on the other hand, studied the pricing of green and non-green products in the green supply chain and conventional dual-channel supply chain, respectively, from the considerations of both the environment and the economy, and used the methodology of the Stackelberg game to study the pricing of green and non-green products in the green supply chain and conventional dual-channel supply chain [18]. M. Li (2022) proposed a dual-channel green supply chain model by combining online and offline marketing based on the more popular online direct marketing situation in enterprises at the current stage and studied the dual-channel green supply chain pricing strategy, considering service cooperation and free-riding [19]. D. Wang (2022) incorporated consumers' green preferences into supply chain evolutions by exploring green product pricing decisions under horizontal and vertical equity through a game relationship constructed for two competing manufacturers [20]. As the research progressed, studies on three-tier supply chains gradually began to emerge. R. Gupta (2023) considered demand uncertainty and investment in green technology to establish a three-tier supply chain with manufacturers, suppliers, and retailers, which was used to explore profitability and pricing decisions [21]. A. Paul (2022), to determine the optimal pricing and taxation, included the government as the environmental impact reduction of the top-tier members, to study government intervention in a three-tier supply chain consisting of government, manufacturer, and retailer [22].

However, in the process of green supply chain management, the government also plays an important and indispensable role. As the administrative subject of social governance, the government not only needs to carry out economic and policy support behavior for the development of green supply chains, but also plays a good role in the constraint and regulation of enterprises, while government departments also need to promote the concept of green energy saving and emission reduction, to make the green supply chain maintain sustainable development. Carrying out research on the impact of such regulatory bodies as the government on the results of green supply chain deployment is also a research direction explored by scholars (de Oliveira, U.R., 2018) [23]. It is the diverse roles of the government in the overall green supply chain management that allow scholars to think about the role played by the government in the development of green supply chains from different perspectives when studying green-supply-chain-related research. Therefore, in game research on green supply chains, the government is involved in the research either as the main body in the game, or as the influencing factor in the intervention game. In the studies on green supply chains game from the government perspective, the two-party game is the most researched at this stage, but with the deepening of the research, the three-party game has gradually become a research hotspot. Among the studies on two-party games, some of them take the government as the main body of the game. For example, Z. Zhou (2022) carried out a study on environmental regulation, reorganized and classified the types of environmental regulation, and added them to the study of the game between the government and enterprises to explore the impact of the types of environmental regulation on the choice of enterprises and regulatory policies [24]. B. Wu (2017) constructed a model of low-carbon strategies in the context of the government and enterprise game to explore

the impact of government incentives on the diffusion of low-carbon strategies [25]. And some of the studies have considered the effect of the government's relevant behavior on the outcome during the game process. A. Hafezalkotob (2018) considered the effect of direct tariffs and tradable licenses, with and without baseline, on green and non-green supply chain competition based on different modes of government intervention [26]. H. Jolai (2021) considered the effect of the government's moderating role in green decision-making on the game of two competing supply chains composed of retailers and manufacturers [27]. Z. Liu (2022) considered the "free riding" behavior of enterprises in the process of green supply chain development, and investigated the effect of government subsidy coefficients, performance incentive bases, and other factors on the evolutionary game outcome of a two-level green supply chain composed of green suppliers and green manufacturers. By exploring the influence of government subsidy coefficients, performance incentive bases, and other factors on the evolution of the two-level green supply chain composed of green suppliers and green manufacturers, their aim to eliminate free-riding behaviors as much as possible, so that enterprises upstream and downstream of the green supply chain can reduce emissions more quickly [28]. F. Zand (2022), considering that there is a government intention to improve the level of green management through the cooperation of manufacturers, adds government factors into the research of the two-level green supply chain model constructed by the manufacturer and retailer to explore government factors. The government factor is added to this study to explore the cooperation between the government and enterprises [29]. W. Cheng (2022) discussed the effects of government interventions, such as government subsidies and tax policies, on the competition between green supply chains and non-green supply chains [30]. H. Sun (2019) took green investment and government subsidies as the core of their research to explore the green investment strategy of the two-level supply chain game [31].

At this stage, most of the studies on three-party games are based on the two-party game for further optimization. W. Chen (2020) investigated the three-party game model of government, manufacturer, and public in relation to carbon tax and carbon subsidy in order to examine the green and low-carbon decision-making of enterprises in the context of complementary coordination between the government and the public [32]. Q. Long (2021) proposed a three-party evolutionary game model of the government, enterprises, and consumers based on green sensitivity [33]. K. Halat (2023) considered the competition problem among green supply chains and proposed to construct a game study between a government agency and two competing green supply chains [34]. C. Mondal (2022) [35] proposed a study of a two-level green closed-loop supply chain composed of two competing manufacturers and a common retailer with government intervention, which is used to discuss the optimal firm decision of the manufacturer [33].

Similarly, government-based green supply chain management research has also been conducted on the effectiveness of government environmental regulation, as well as government intervention in decision-making strategies. A. Hafezalkotob (2018), after exploring the impacts of six government regulatory policies on green supply chain competition, found that all intervention policies were favorable [36]. H. Khosroshahi (2021) considered the role of government subsidies and CSR behaviors in supply chain decision-making and analytically modeled different government subsidy strategies in the supply chain of production and distribution of green products in order to increase the transparency level of manufacturers and thus increase social welfare [37]. X. Yuan (2020) [38] conducted a study to address the effect of different government subsidy strategies on the price of green products, manufacturer's profit, retailer's profit, and other factors. I.E. Nielsen (2019) focused on government policy incentives and explored government decision-making and social welfare by comparing the game of green supply chain under two different incentive policies [39]. K. Liu (2022) constructed three green supply chain subsidy models based on behavioral pricing, using a game approach to study the optimal green supply chain government subsidy model [40].

To summarize, the relevant research carried out by scholars on green supply chain management is systematic and comprehensive, and the research on green supply chain management has been carried out from different research perspectives such as sales channels, green investment, green sensitivity, and other influencing factors, which provides important reference significance to the development of green supply chains. However, most of the existing research centers around the enterprise's revenue, pricing, and other supply, production, and marketing questions as the main body of the research, in which the government acts as a means of intervention from different perspectives into the game research; and for green supply chain management, the game research is discussed from the two sides of the game to find a win-win strategy. In the previous research on the game relationship between enterprises and the government, and enterprises and the public, if the government is only playing the role of policy subsidizer as an external constraint, that means that the optimal solution derived in the game analysis process is biased and weakened. Moreover, at this stage, the research mainly centers on the implementation of green supply chain management, focusing on the game strategy between the supply chain links to ensure the efficient and smooth implementation of green supply chain management, but there is still some research space for the promotion of green supply chain management in the overall perspective. By combining the public preference and environmental regulation factors mentioned in previous studies, it is of value to explore their influence on the promotion of green supply chain management, so that it can occupy the market and develop effectively in the game competition with the traditional supply chain. Therefore, under the premise of environmental regulation, this study utilizes the idea of the evolutionary game to construct a game model between the government, core enterprises, and the public in the process of green supply chain diffusion, to explore the diffusion of green supply chains under different strengths of environmental regulation and public preference, and to provide an optimal combination of strategies for the government to implement effective diffusion and promotion.

3. Research Methodology

The evolutionary game approach is inspired by evolutionary theory and was built on the basis of classical game theory. The evolutionary game is based on the two core concepts of evolutionary stable strategy and replication dynamics and pays more attention to the dynamic change of the strategy than classical game theory, putting the game between the subjects into the context of evolution in order to carry out research (Du, L., 2020) [41]. In the process of evolution, the interactive game will produce different benefits for different subjects, and the benefits determine the subsequent decisions of the subjects in the evolutionary environment. In social science research, taking into account that human beings have finite rationality, there is information asymmetry and finite rationality in the practical application of evolutionary game theory, and strategy choices are made on this basis, i.e., the subjects involved in the game are incompletely rational. As a decision analysis tool, evolutionary games are widely used in management, economics, sociology, and other fields.

For the research of this paper, whether the core enterprise is willing to adopt green supply chain management, whether the public is willing to participate in the management of the core enterprise's green supply chain, and whether the government implements effective environmental regulation policies, in the case of incomplete information and limited rationality, it is difficult for the main body of the tripartite game to make the choice of maximizing their interests, and in the process of the dynamic game, the main body will gradually achieve an evolutionary stabilization strategy through continuous imitation and learning. In the dynamic game process, the subjects will gradually realize an evolutionary stable strategy through continuous imitation and learning. Therefore, this paper selects the government, core enterprises, and the public as the participating subjects of green supply chain management diffusion, and at the same time, the three-party game subjects all have finite rationality and maximize their own interests to make a choice of game strategy. We construct the green supply chain management diffusion survival evolutionary game model

under the condition of environmental regulation, explore the local equilibrium point of the green supply chain management diffusion of core enterprises under environmental regulation, and finally arrive at the optimal decision-making for all parties involved in the game by analyzing various evolutionary stable states.

3.1. Research Hypotheses and Variables

According to stakeholder theory, in the proliferation of green supply chain management—the game process between the three parties—which here involves the government, core enterprises, and the public (the three-party game subjects), any party's game behavior will affect the decision-making of the other two game subjects; in essence, this is to ensure that their own interests are maximized on the basis of the other party's behavioral and strategic choices as the basis for a comprehensive consideration of their own decision-making process in the game. According to the above analysis, the game strategies of the three parties in this study are as follows: the government—environmental regulation, no environmental regulation, the core enterprise—green supply chain management, traditional supply chain management, and the public—participation, non-participation. In the evolutionary game model, the government, core enterprises, and the public make strategic choices according to their own interests, based on which the following research hypotheses are proposed.

Hypothesis 1. *Assume that x is the probability that the government regulates the environment, and $1-x$ is the probability that the government does not regulate the environment. The government pays a cost for adopting different levels of environmental regulation, but it also reaps the social effects of protecting environmental resources; however, it pays a cost for subsequent environmental governance if it does not implement the tools to allow the environment to become polluted. The government works through public environmental protection publicity, green supply chain incentives, and pollution tax—three types of environmental regulation tools to promote the core enterprises to adopt green supply chain management and encourage public participation in the core enterprises' green supply chain management. Referring to the research of previous scholars, the environmental regulation coefficients are refined on the basis of previous research, assuming that these three types of environmental regulation intensity coefficients are α_1, α_2, α_3, and the costs to be borne are $k_1\alpha_1$, $k_2\alpha_2$, and $k_3\alpha_3$, respectively (Liu, Z., 2022) [28]. V stands for the potential social benefits and economic benefits for the government after the core enterprise adopts green supply chain management, while ΔV is the added value of benefits after the government implements environmental regulation policies. G is the environmental management cost that the government needs to pay when the core enterprise adopts the environmental pollution caused by the traditional supply chain production method (Zhou, Z., 2022) [24].*

Hypothesis 2. *Suppose y is the probability that the core firm adopts green supply chain management, then $1-y$ is the probability that the core firm adopts traditional supply chain management. Let M be the product revenue of the core enterprise adopting a traditional supply chain management strategy. ΔM is the value of the increase in product revenue of the core enterprise adopting a green supply chain management strategy after the improvement of green technology innovation; then ΔM_1 is the value of the increase in product revenue of the core enterprise when the government adopts environmental regulation and the public adopts participation strategy; ΔM_2 is the value of the increase in product revenue of the core enterprise when the government does not carry out environmental regulation and the public adopts participation strategy; ΔM_3 is the value of the increase in product revenue of the core enterprise when the government adopts environmental regulation and the public adopts a non-participation strategy. When the government does not implement environmental regulations and the public adopts a non-participation strategy, the added value of core enterprise product revenue is 0 (Cheng, W., 2022) [30]. C_1 is the cost of traditional supply chain management, while ΔC_1 is the additional cost assumed by core enterprises adopting green supply chain management for green technology innovation (Zhou, Z., 2022) [24].*

Hypothesis 3. *Suppose z is the probability that the public chooses to participate in the strategy, and* $1 - z$ *is the probability that the public chooses not to participate in the strategy. When the core enterprise adopts green supply chain management, the public's environmental quality of life will be improved compared to the adoption of the traditional supply chain, while continuing to adopt the traditional supply chain will result in the loss of the public's living environment. The public will pay a participation cost if they assist in the development of green supply chain management, but they will also receive additional benefits such as praise. Let W be the green environmental benefits obtained by the public after the core enterprise adopts green supply chain management. Let S be the loss caused to the public by the core enterprise continuing to adopt the traditional supply chain management approach, such as environmental pollution, reduced quality of life, and so on. Let K be the benefits gained by the public when they choose the participation strategy, such as the government's commendation, the utility of green products, and the enhancement of environmental responsibility; and let* C_2 *be the cost of public participation (Chen, W., 2020) [32].*

Hypothesis 4. *The ranges of values of x, y, and z are* $0 \leq x \leq 1$, $0 \leq y \leq 1$, *and* $0 \leq z \leq 1$, *respectively.*

3.2. Research Modeling

According to the above settings of profit and loss variables, the gain matrix between the government, core enterprises, and public game subjects can be obtained, as shown in Table 1.

Table 1. Benefit matrix of the government, core companies, and the public.

Game Participants				The Public	
				Participation (z)	**Non-Participation (1−z)**
Government	Environmental Regulation (x)	Core Companies	Green Supply Chain (y)	$V + \Delta V - k_1\alpha_1 - k_2\alpha_2$ $M + \Delta M_1 + k_2\alpha_2 - C_1 - \Delta C_1$ $W + K - C_2$	$V + \Delta V - k_1\alpha_1 - k_2\alpha_2$ $M + \Delta M_3 + k_2\alpha_2 - C_1 - \Delta C_1$ $W - S$
			Traditional Supply Chain Management ($1 - y$)	$k_3\alpha_3 - k_1\alpha_1 - G$ $M - k_3\alpha_3 - C_1$ $K - S - C_2$	$k_3\alpha_3 - k_1\alpha_1 - G$ $M - k_3\alpha_3 - C_1$ $-S$
	No environmental regulations ($1 - x$)	Core Companies	Green Supply Chain (y)	V $M + \Delta M_2 - C_1 - \Delta C_1$ $W + K - C_2$	V $M - C_1 - \Delta C_1$ $W - S$
			Traditional Supply Chain Management ($1 - y$)	$-G$ $M - C_1$ $K - S - C_2$	$-G$ $M - C_1$ $-S$

According to the benefit matrix in Table 1, the expected benefits for the government, the core businesses, and the public—the tripartite game subjects—as well as their behavioral strategies in the replication of dynamic equations can be obtained as follows:

Assuming that the government's expected return from choosing the "environmental regulation" strategy is U_1, the expected return from choosing the "no environmental regulation" strategy is U_2, and the government's average expected return is $\overline{U}$, then there are:

$$U_1 = yz(V + \Delta V - k_1\alpha_1 - k_2\alpha_2) + y(1 - z)(V + \Delta V - k_1\alpha_1 - k_2\alpha_2) + z(1 - y)(k_3\alpha_3 - k_1\alpha_1 - G) + (1 - y)(1 - z)(k_3\alpha_3 - k_1\alpha_1 - G) \quad (1)$$

$$U_2 = yzV + y(1 - z)V + z(1 - y)(-G) + (1 - y)(1 - z)(-G) \quad (2)$$

$$\overline{U} = xU_1 + (1 - x)U_2 \quad (3)$$

Joining (1) and (3), one can find the equation for the replication dynamics of the government's behavioral strategy as follows:

$$F(x) = \frac{dx}{dt} = x(U_1 - \overline{U}) = x(1 - x)[y(\Delta V - K_2\alpha_2 - K_3\alpha_3) + K_3\alpha_3 - K_1\alpha_1] \quad (4)$$

Assuming that the expected return of the core enterprise choosing to adopt the "green supply chain management" strategy is P_1, and the expected return of continuing to choose the "traditional supply chain management" strategy is P_2, and the average expected return of the core enterprise is $\overline{P}$, then there are:

$$\begin{array}{l} P_1 = xz(M + \Delta M_1 + k_2\alpha_2 - C_1 - \Delta C_1) + x(1-z)(M + \Delta M_3 + k_2\alpha_2 - C_1 - \Delta C_1) + \\ z(1-x)(M + \Delta M_2 - C_1 - \Delta C_1) + (1-x)(1-z)(M - C_1 - \Delta C_1) \end{array} \tag{5}$$

$$\begin{array}{l} P_2 = xz(M - k_3\alpha_3 - C_1) + x(1-z)(M - k_3\alpha_3 - C_1) + \\ z(1-x)(M - C_1) + (1-x)(1-z)(M - C_1) \end{array} \tag{6}$$

$$\overline{P} = yP_1 + (1-y)P_2 \tag{7}$$

Joining (5) and (7), one can derive the equation for the replication dynamics of the core firm's behavioral strategy as follows:

$$\begin{array}{l} F(y) = \frac{dy}{dt} = y(P_1 - \overline{P}) = y(1-y)[xz(\Delta M_1 - \Delta M_3 - \Delta M_2) + \\ x(\Delta M_3 + K_2\alpha_2 + K_3\alpha_3) + z\Delta M_2 - \Delta C_1] \end{array} \tag{8}$$

Assuming that the public's expected return from choosing the "participation" strategy is Q_1, the expected return from choosing the "non-participation" strategy is Q_2, and the public's average expected return is $\overline{Q}$, then we have the following:

$$Q_1 = xy(W + K - C_2) + x(1-y)(K - S - C_2) + y(1-x)(W + K - C_2) + (1-x)(1-y)(K - S - C_2) \tag{9}$$

$$Q_2 = xy(W - S) + x(1-y)(-S) + y(1-x)(W - S) + (1-x)(1-y)(-S) \tag{10}$$

$$\overline{Q} = zQ_1 + (1-z)Q_2 \tag{11}$$

Joining (9) and (11), one can find the equation for the replication dynamics of the public behavior strategy as follows:

$$F(z) = \frac{dz}{dt} = z(Q_1 - \overline{Q}) = z(1-z)(yS + K - C_2) \tag{12}$$

Furthermore, the joint Equations (4), (8) and (12) are used to construct a three-dimensional power evolution system for the government, core business, and the public:

$$\begin{cases} F(x) = \frac{dx}{dt} = x(1-x)[y(\Delta V - K_2\alpha_2 - K_3\alpha_3) + K_3\alpha_3 - K_1\alpha_1] \\ F(y) = \frac{dy}{dt} = y(1-y)[xz(\Delta M_1 - \Delta M_3 - \Delta M_2) + x(\Delta M_3 + K_2\alpha_2 + K_3\alpha_3) + z\Delta M_2 - \Delta C_1] \\ F(z) = \frac{dz}{dt} = z(1-z)(yS + K - C_2) \end{cases} \tag{13}$$

If some core enterprises take the lead in adopting green supply chain management, there will be two supply chain management approaches on the market: adopting the green supply chain management approach x_1 and adopting the traditional supply chain management approach x_2. According to the survival evolution model (Jiang, Q.-Y., 2011) [42], the survival evolution model of green supply chain management and traditional supply chain management over time t is further constructed, as shown in Equation (1).

$$\begin{cases} \frac{dx_1(t)}{dt} = r_1x_1(1 - \frac{x_1}{N_1} - \sigma_1\frac{x_2}{N_2}) \\ \frac{dx_2(t)}{dt} = r_2x_2(1 - \sigma_2\frac{x_1}{N_1} - \frac{x_2}{N_2}) \end{cases} \tag{14}$$

Among them, x_1 is the number of core enterprises adopting green supply chain management in the market; x_2 is the number of core enterprises adopting traditional supply chain management in the market. The coefficients of r_1 and r_2 represent the government's efforts to promote green supply chain management and regulate the adoption of traditional supply chain management, respectively. σ_1 represents the blocking coefficient of traditional

supply chain management to green supply chain management in core enterprises, i.e., the strength of public supervision and the basic demand for ordinary products and services consumption; σ_2 represents the substitution coefficient of green supply chain management to traditional supply chain management in core enterprises, i.e., the strength of public supervision and the preference for green products and services consumption. N_1 is the coefficient of substitution of green supply chain management for traditional supply chain management in core enterprises, i.e., public supervision and consumption preference of green products and services is represented by N_2.

3.3. Stability Analysis of Green Supply Chain Management Diffusion

With the core enterprises successively adopting the green supply chain management approach, there will be two symbiotic evolution phenomena on the market: the blockage of traditional supply chain management against green supply chain management and the substitution of green supply chain management with traditional supply chain management, which also indicates that the green supply chain management approach will continue to evolve forward over time until it reaches a localized stable state. Meanwhile, under the conditions of limited rationality and incomplete information, the government (environmental regulation, no environmental regulation), core enterprises (green supply chain management, traditional supply chain management), and the public (participation, non-participation), the tripartite game groups, will continue to learn and imitate according to their own interests, and select the strategy that is favorable to them. The evolutionary game process is composed of two basic elements: "evolutionary stability" and "replication dynamics", in which the replication dynamics analysis is to study the degree of adaptation of a certain behavioral strategy in the whole population based on the establishment of a dynamic system of ordinary differential equations.

The replicated dynamic equation in the above three-dimensional dynamic system describes the dynamic evolution process of choosing environmental regulation, green supply chain management, and participation strategy between the three parties of the game, namely the government, the core enterprise, and the public, under the conditions of limited rationality and information asymmetry. In order to obtain the local equilibrium point of green supply chain management of core enterprises under government environmental regulation, allow the following:

$$\begin{cases} F(x) = 0 \\ F(y) = 0 \\ F(z) = 0 \end{cases} \tag{15}$$

From Equation (15), it can be seen that there are eight special equilibrium points of the three-dimensional dynamical system, i.e., (0, 0, 0), (0, 0, 1), (0, 1, 0), (1, 1, 0), (1, 0, 1), (0, 1, 1), and (1, 1, 1). According to the stability of the differential equation, it is known that when $F(m) = 0$, $\frac{\partial F(m)}{\partial m} < 0$, m^*, this is an evolutionary stable strategy, i.e., ESS, where:

$$\begin{cases} \frac{\partial F(x)}{\partial x} = (1-2x)[y(\Delta V - K_2\alpha_2 - K_3\alpha_3) + K_3\alpha_3 - K_1\alpha_1] \\ \frac{\partial F(y)}{\partial y} = (1-2y)[xz(\Delta M_1 - \Delta M_3 - \Delta M_2) + x(\Delta M_3 + K_2\alpha_2 + K_3\alpha_3) + z\Delta M_2 - \Delta C_1] \\ \frac{\partial F(z)}{\partial z} = (1-2z)(yS + K - C_2) \end{cases} \tag{16}$$

From Equation (16), it can be seen that the phase diagram of the government subject that tends to be evolutionarily stable is related to the straight line $y(\Delta V - K_2\alpha_2 - K_3\alpha_3) + K_3\alpha_3 - K_1\alpha_1 = 0$; similarly, the phase diagram of the core enterprise subject that tends to be evolutionarily stable is related to the quadratic curve $xz(\Delta M_1 - \Delta M_3 - \Delta M_2) + x(\Delta M_3 + K_2\alpha_2 + K_3\alpha_3) + z\Delta M_2 - \Delta C_1 = 0$; the phase diagram of the public subject that tends to be evolutionarily stable is related to the straight line $yS + K - C_2 = 0$.

To further analyze the steady state of green supply chain management diffusion in the evolutionary game model, we can make $\frac{dx_1(t)}{dt} = 0$ and $\frac{dx_2(t)}{dt} = 0$; then, we have the following:

$$\begin{cases} \frac{dx_1(t)}{dt} = r_1 x_1 (1 - \frac{x_1}{N_1} - \sigma_1 \frac{x_2}{N_2}) = 0 \\ \frac{dx_2(t)}{dt} = r_2 x_2 (1 - \sigma_2 \frac{x_1}{N_1} - \frac{x_2}{N_2}) = 0 \end{cases} \tag{17}$$

Solve Equation (17) to obtain four equilibrium points: $A_1(N_1, 0)$, $A_2(0, N_2)$, $A_3(\frac{N_1(1-\sigma_1)}{1-\sigma_1\sigma_2}, \frac{N_2(1-\sigma_2)}{1-\sigma_1\sigma_2})$, $A_3(0, 0)$. In the core enterprise green supply chain management, due to the public's green consumption concept and environmental protection awareness of the differences, green supply chain management cannot be in a dominant position and will be affected by the impact of traditional supply chain management on the green supply chain management of the blockage; with the evolution of time, the green supply chain management approach will gradually spread and reach a localized stable state, and compared with the ordinary products, the public will be more willing to accept the green products, and at the same time, more willing to participate in the core enterprises' green supply chain management, until the market becomes saturated with green products. At this time, it is also necessary to supplement the above local stability with phase track line analysis, assuming the existence of a straight line φ and a straight line μ; then, there are the following:

$$\begin{cases} \varphi(x_1, x_2) = 1 - \frac{x_1}{N_1} - \sigma_1 \frac{x_2}{N_2} \\ \mu(x_1, x_2) = 1 - \sigma_2 \frac{x_1}{N_1} - \frac{x_2}{N_2} \end{cases} \tag{18}$$

For the different ranges of values of σ_1 and σ_2, the relative positions of the straight line φ and the straight line μ in the phase plane are different; Figure 1 depicts four cases of these two lines in the phase plane.

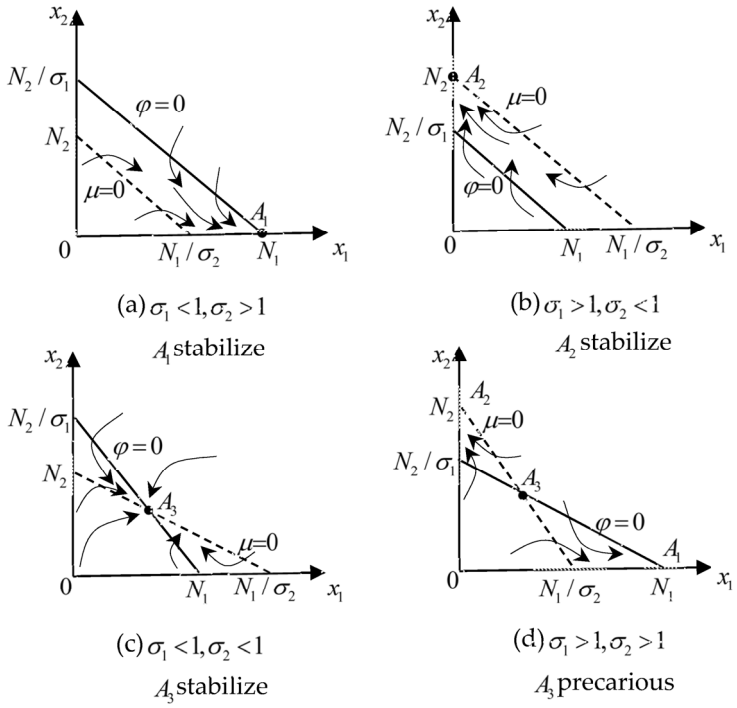


Figure 1. Phase plane analysis of equilibrium point stability.

Each of these four scenarios is analyzed below:

(1) $\sigma_1 < 1, \sigma_2 > 1$: when the government is willing to implement effective environmental regulation policies, and the public is also involved in monitoring the core enterprises to build green supply chain management, and is willing to buy green products, at this

time there will be a green supply chain management diffusion phenomenon as shown in Figure 1a. This shows that the number of core enterprises adopting traditional supply chain management in the market has tended reach saturation and the maximum capacity of the market, while the number of core enterprises adopting green supply chain management will still continue to proliferate in the market; with the evolution of time, the core enterprises adopting green supply chain management eventually occupy the whole market and tend to be in a stable state of evolution.

(2) $\sigma_1 > 1$, $\sigma_2 < 1$: when the government is not willing to consume manpower and funds to implement environmental regulation policies, and the public green awareness is weak and they are unwilling to participate in the core enterprises' adoption of green supply chain management, at this time there will be a green supply chain management diffusion phenomenon as shown in Figure 1b. This shows that the number of core enterprises adopting green supply chain management in the market will not grow and will stop spreading, while the number of core enterprises adopting traditional supply chain management will still grow and will gradually spread across the market; with the evolution of time, the core enterprises adopting traditional supply chain management will eventually occupy the whole market and tend to evolve to a stable state, while the green supply chain management approach will die in the middle of the diffusion.

(3) $\sigma_1 < 1$, $\sigma_2 < 1$: when the strength of the government's implementation of environmental regulatory policies is weak, and the public is also polarized, part of the public is willing to participate in the management of the core enterprises' green supply chain, and the other part of the public is not willing to participate in it, at this time, there will be a diffusion of green supply chain management phenomenon as shown in Figure 1c. This shows that the number of core enterprises adopting traditional supply chain management and the number of core enterprises adopting green supply chain management will grow simultaneously in the market, and the two types of management will proliferate simultaneously; with the evolution of time, core enterprises adopting traditional supply chain management and core enterprises adopting green supply chain management will coexist in the market and tend to be in a stable state of evolution.

(4) When $\sigma_1 > 1$, $\sigma_2 > 1 \frac{r_1 r_2 (1-\sigma_1)(1-\sigma_2)}{1-\sigma_1 \sigma_2} < 0$, so A_3 is not stable (saddle point), theoretically, the rail line tends to A_1, or tends to A_2; then there is the initial position of the rail line to decide, as shown in Figure 1d, and in this case A_1 and A_2 can only be a local stabilization rather than a global stabilization. In the actual green supply chain management diffusion, it is not possible to have the core enterprise adopting traditional supply chain management to reach the maximum capacity of the market, while at the same time adopting green supply chain management to reach the maximum capacity of the market; therefore, in this case, in order to prompt A_1 to tend towards global stability, it is necessary to add $\sigma_1 < 1$, or in order to prompt A_2 to tend towards global stability, it is necessary to add $\sigma_2 < 1$, and the fulfillment of any condition will prompt the system to evolve to the stabilized state.

To summarize, in the early stage of the proliferation of green supply chain management, due to the differing support and participation of the government and the public, coupled with the fact that both traditional supply chain management and green supply chain management have their own advantages, these two supply chain management approaches will block each other's development and growth in the process of proliferation, and force each other to withdraw from the market and stop proliferation through fierce market competition. In the middle stage of the diffusion of green supply chain management, due to the weak strength of the government's environmental regulation policy and the polarization of the public, part of the public will be willing to participate in the management of the green supply chain of the core enterprise, while the other part of the public will not be willing to participate; at this time, the traditional supply chain management approach and green supply chain management approach will coexist in the market. In the late stage of green supply chain management diffusion, as the government increases the intensity of environmental regulation, and the public is more willing to participate in supervising

the core enterprises to build green supply chain management, while the preference for purchasing green products is also gradually strengthened—at this time, the green supply chain management approach will diffuse to the whole market. Therefore, there are four stable evolutionary states of green supply chain management diffusion: initial diffusion, extinction, semi-diffusion (coexistence with traditional green supply chain management), and full diffusion (complete market capture).

4. Numerical Simulation Analysis

In order to analyze more intuitively the different intensities of government environmental regulation, this paper starts from the three-party game subjects of government, core enterprises, and the public, makes reasonable assumptions about the initial values of the parameters in the payment matrix, and simulates the asymptotically stable evolution trajectory of the three-party game subjects using MATLAB. Set the initial evolution time as 0 and the evolution end time as 5; the initial proportion of evolution is set as (0.5, 0.5, 0.5), the government's environmental protection propaganda to the public, the green supply chain incentive policy, and the pollution tax of the three types of environmental regulation intensity coefficients α_1, α_2, α_3 are 0.1, 0.5, 0.9, respectively, and the two-dimensional and three-dimensional trajectory of the evolution are shown in Figure 2.

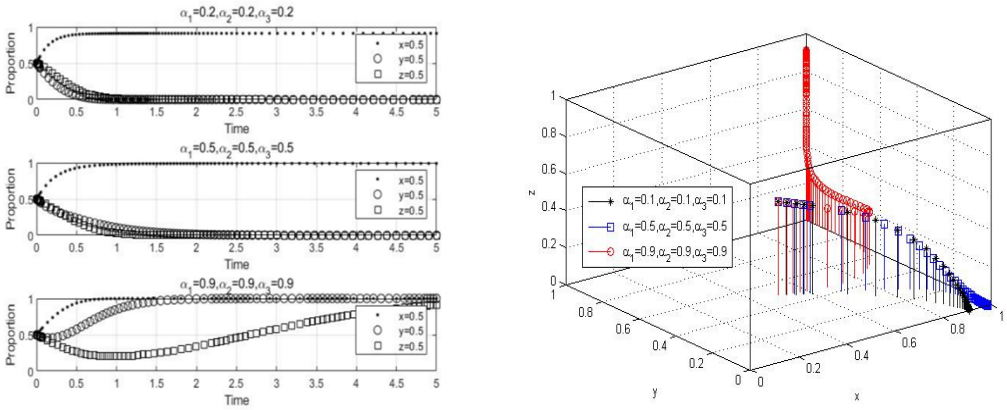


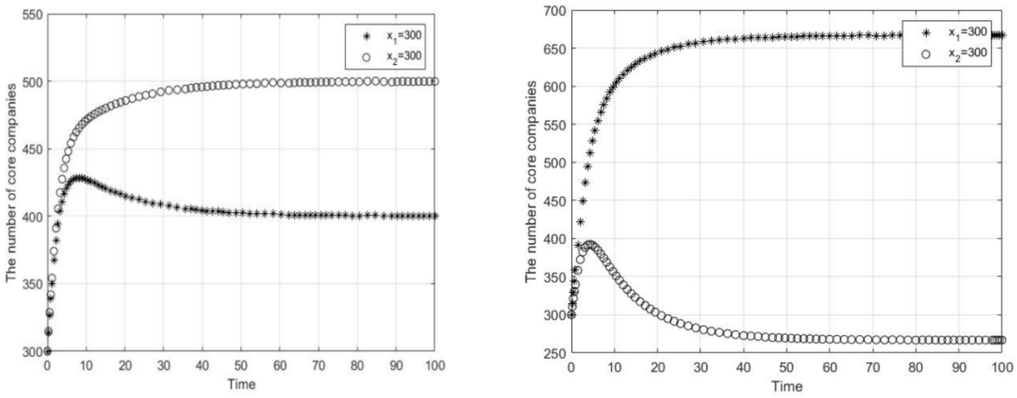
Figure 2. System evolutionary trajectories under different environmental regulation intensities.

As can be seen from Figure 2, with the government's environmental protection publicity to the public strengthened, and increased incentives for core enterprises to adopt green supply chain management as well as an increased pollution tax rate, the government, core enterprises, and the public are all evolving in the direction of the environmental regulation strategy, the strategy of adopting green supply chain management, and the participation strategy. This shows that the government's environmental protection publicity to the public is conducive to establishing public environmental awareness and green consumption concepts, and constantly prompts the public to participate in the core enterprise green supply chain management, while the public's participation also constantly stimulates the core enterprise to carry out the behavior of green supply chain management. Moreover, no matter how the core enterprises and public behavioral strategies are chosen, the government is bound to choose the environmental regulation strategy, and the intensity of environmental regulation directly affects the evolution of the core enterprises and public behavioral strategies. However, the core enterprise is profit-oriented, and the public's green key cultivation cannot be achieved overnight, so all kinds of environmental regulation intensity must be more than 0.5, and it is best for all kinds of environmental regulation intensity to reach 0.8 or 0.9 in order to make the system evolve to a stable state. However, even if the intensity of all kinds of environmental regulation reaches 0.9, the speed of the evolution of the public body to a stable state is still slow, and there may be a risk of evolution to a non-stable state in the early stages. Therefore, in the diffusion of green supply chain management, the government should favor the public group in the formulation of

environmental regulation policies and continue to cultivate green consumers who care about the ecological environment and prefer green products and services.

Based on the above study, it is explored whether different intensities of environmental regulation will have different impacts on the diffusion of green supply chain management in the whole market based on the choice of green supply chain management approaches by core enterprises. Therefore, the evolutionary trajectory of the diffusion of green supply chain management by core firms under environmental regulation is further analyzed.

Assume that the market capacity $N = 600$, in which the core enterprises adopting green supply chain management and the core enterprises adopting ordinary supply chain management share the market equally is 300 each; and set the intensity of environmental regulation for the government to promote the green supply chain and to promote the traditional supply chain, i.e., $r_1 = r_2$. As a result, the evolution process of green supply chain management diffusion can be obtained, as shown in Figure 3.



(**a**) $\sigma_1 = 0.8, \sigma_2 = 0.75$ (**b**) $\sigma_1 = 0.5, \sigma_2 = 0.8$

Figure 3. Coefficients σ. Simulation of the evolution of diffusion affecting green supply chain management.

From Figure 3, it can be seen that when $\sigma_1 = 0.8$, i.e., the public's demand and preference for common products are high, the green supply chain management approach and the traditional supply chain management approach will realize coexistence in the market. However, as the government strengthens the intensity of green supply chain management promotion and the public's green consumption concept improves, the number of core enterprises choosing the green supply chain management approach in the market is far more than the number of core enterprises choosing the traditional supply chain management approach; and with the evolution of time, the traditional supply chain management approach will disappear from the market, and the green supply chain management approach will be completely diffused. In addition, from Figure 3a, it can be seen that the diffusion of the green supply chain management approach in the market reaches the highest point due to the obvious blocking effect of traditional supply chain management on green supply chain management, which makes the rate of diffusion of the green supply chain management approach decline, and then there is a diffusion inflection point. On the contrary, it can also be seen from Figure 3b that after the diffusion of the ordinary supply chain management approach reaches the highest point in the market, its diffusion rate decreases, and a diffusion inflection point occurs. This suggests that the final evolutionary stable state of green supply chain management diffusion is related to the strength of public supervision and the consumption preference for green products and services (σ coefficient), and the higher the degree of public participation, the more complete the diffusion of green supply chain management.

In the above model, in addition to the different behavioral strategies of the public affecting the evolutionary trajectory of green supply chain management diffusion, the strength of governmental environmental regulation policies (r_1, r_2) also affects the evolu-

tionary trajectory of green supply chain management diffusion. From the above analysis, it can be seen that the higher the degree of public participation, the more complete the green supply chain management diffusion; set $\sigma_1 = 0.5, \sigma_2 = 0.6$, and set the proportion of r_1 and r_2 in turn, and other parameters remain unchanged. As a result, the evolution process of green supply chain management diffusion can be obtained, as shown in Figure 4.

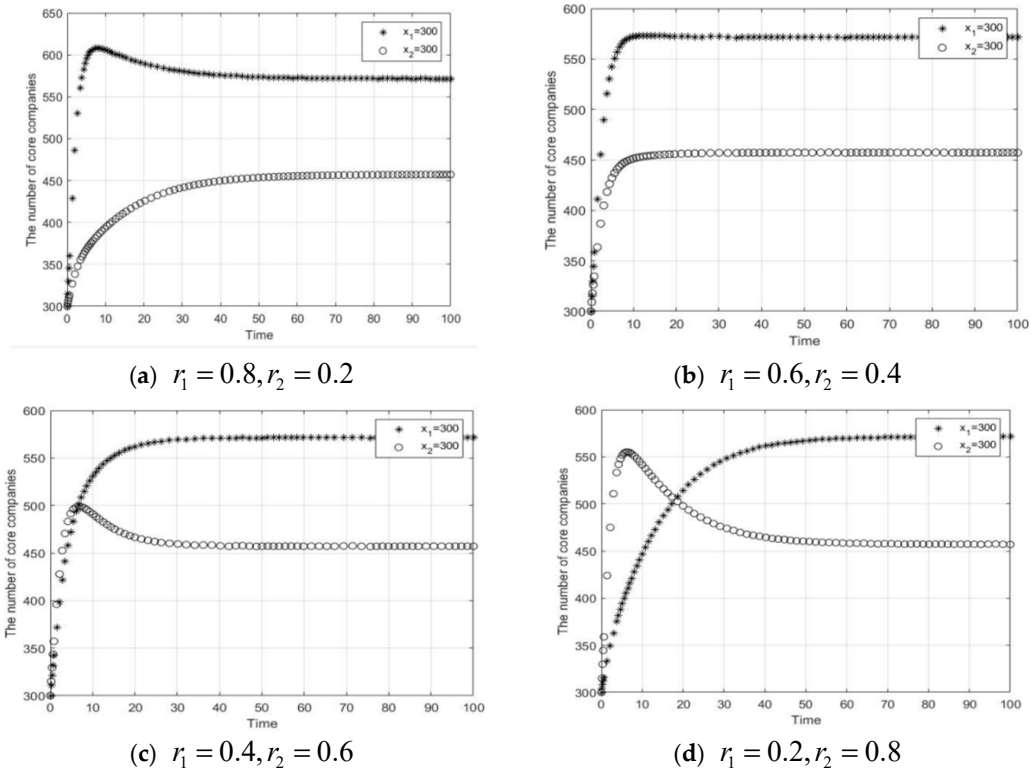


Figure 4. Simulation of the impact of different government regulatory instruments on the evolution of green supply chain management diffusion.

From Figure 4, it can be seen that the government keeps increasing the incentives for the implementation of green supply chain management, i.e., when r_1 is higher, it will cause the diffusion of the green supply chain management approach in the market to reach the highest point after its diffusion rate decreases and the diffusion inflection point occurs, but part of the traditional supply chain management approach still exists, as shown in Figure 4a. On the contrary, the government imposes higher pollution tax on the implementation of traditional supply chain management, i.e., r_2 is higher when the diffusion of the traditional supply chain management approach in the market reaches the highest point, after which its diffusion rate decreases rapidly, but the green supply chain management approach will continue to diffuse until the steady state, as shown in Figure 4d. From Figure 4b,c, it can be seen that when the coefficients of r_1 and r_2 are close to each other, i.e., the smaller $|r_1 - r_2|$ is, the green supply chain management approach and traditional supply chain management approach will appear symbiotically in the market, but the diffusion rate of the green supply chain management approach is higher than that of the traditional supply chain management approach. Comprehensive comparative analysis of Figure 4a–d shows that green supply chain incentives and pollution tax are two types of environmental regulatory tools that affect the diffusion of green supply chain management in the market; the larger $|r_1 - r_2|$, the more intense the competition between green products and ordinary products in the market, in which the two types of supply chain management diffusion will appear to reach the highest point by the rapid decline in the trend of the $|r_1 - r_2|$; the smaller it is, although the green supply chain management and traditional supply chain management coexist in the market, the more the combined green supply chain management

and traditional supply chain management diffusion rate is higher than the traditional supply chain management diffusion rate. When $r_1 < r_2$ is smaller—although there is the phenomenon of the coexistence of green supply chain management and traditional supply chain management—i.e., the incentive for the government to implement green supply chain management is smaller than the pollution tax levied on the implementation of traditional supply chain management, green supply chain management will spread to the whole market and tend to be stabilized, and the rate of the diffusion of traditional supply chain management will be a new downward inflection point, and will gradually withdraw from the market with the evolution of time.

5. Discussion

The proliferation of green supply chain management requires the joint efforts of the government, core enterprises, and the public. Based on the numerical simulation analysis above, the optimal strategies for the three parties are the government, core enterprises, and the public adopting the environmental regulation strategy, the green supply chain management strategy, and the participation strategy, respectively. From the perspective of government environmental regulation, the government continuously increases the incentives for core enterprises to adopt green supply chain management and levies heavier pollution tax on core enterprises that cause environmental pollution by adopting the common supply chain, which will continuously motivate core enterprises to carry out green technological innovation and improve supply chain management. Therefore, strict governmental environmental regulations, on the one hand, encourage core enterprises to adopt green supply chain management strategies, and on the other hand, encourage the public to choose participation strategies. From the perspective of the public, public participation not only supervises the core enterprises adopting green supply chain management, but also creates a large demand for green products on the market, and with the stimulation of these two factors, the core enterprises are more willing to adopt green supply chain management for their own interests. The core enterprises' green supply chain management, public participation, not only positively responded to the current national green development and green economic growth call, but also has also brought huge economic benefits and social benefits to society.

The sustainable development of green supply chains not only needs efficient decision-making, but also needs to focus on the influence of their diffusion. A large number of members of the public are an indispensable part of green supply chain management, and according to the simulation analysis of the above study, it can be seen that, to a certain extent, the diffusion scope of green supply chain management is closely related to the attitude of the public. Although the public's attitude towards the development of green supply chains is generally supportive, in practice, there are individual differences in the public influenced by the degree of consumption concept and environmental protection awareness, which will lead to different preferences for traditional supply chains or green supply chains, which will in turn directly affect the degree of diffusion of green supply chains. Therefore, government departments need to pay more attention to public attitudes and further enhance citizens' environmental awareness. In addition to enhancing citizens' awareness and labeling green products, appropriate subsidies for green products could also enhance citizens' preference for green supply chains.

This study has improved compared with previous research results. (1) In the evolutionary game of the three parties involved, this study took the diffusion of green supply chain management as an innovation point from which to explore the scope of environmental regulation intensity based on the optimal strategy. Based on the tripartite evolutionary game of government, enterprise, and public in previous studies (Chen, W., 2020) (Long, Q., 2021) [32,33], survival evolution was added to carry out the study on the diffusion of green supply chain management, which provided a new research perspective for this kind of research. (2) The public's preference for green supply chain management was positively correlated with the development of green supply chain diffusion, which is in line with

the findings of previous scholars (He, J., 2019) [43]. However, the research of this study is based on exploring the game relationship between traditional supply chain management and green supply chain management, and through evolutionary simulation to derive the coexistence and complete diffusion scenarios, to explore the impact of public preference on the diffusion of green supply chain management, and to realize the impact of public preference from a new perspective. (3) For the impact of environmental regulation, firstly, compared with previous scholarly studies (Liu, Z., 2022) (Zhou, Z., 2022) [24,28], our study divided the intensity of regulation into three categories according to the degree. Second, on the basis of public preference for green supply chain management, we explored the impacts of different environmental regulatory intensities on the game of traditional and green supply chain management, and derived the government's choice of strategies to cope with the proliferation of green supply chain management from a new perspective on the basis of previous strategy studies (Yuan, X., 2020) (Liu, K., 2022) [38,40], which provided a theoretical reference and managerial insights for the further development of green supply chains.

6. Conclusions

In order to promote the proliferation of green supply chain management, to alleviate and improve the traditional supply chain brings resource consumption and environmental pollution. This paper integrates the evolutionary game results of the government, the public, and enterprises in search of the optimal solution into the study of green supply chain management diffusion as a whole, and by constructing the survival evolutionary game model and solving and analyzing the model, it derives the game process among the three parties, and studies in depth the real situation represented behind the game process. On this basis, the following three conclusions are drawn:

(1) According to the evolutionary model, the evolutionary process of green supply chain management diffusion will have a confrontational evolution with traditional supply chain management, and there are three phases: pre-competition, mid-term coexistence, and late stabilization. There are four stable evolutionary states: preliminary diffusion, extinction, semi-diffusion, and full diffusion. In the evolution process, the public preference for green or traditional supply chain management will have a greater impact on the final stable state. The construction of green supply chains is the inevitable trend of future enterprise development, so the government should advocate for the public to form a green concept to help green supply chains to be in an advantageous position in the process of evolution, so that the enterprises implementing green supply chain management can obtain a high market share, and ultimately realize the sustainable development of the whole society and economy.

(2) The intensity of government environmental regulatory policies (incentives r_1, pollution taxes r_2) also affects the evolutionary trajectory of green supply chain management diffusion. Based on the predominance of green supply chain management in the evolution, when the incentive policy r_1 intensity is high, it will make the diffusion of the green supply chain management approach in the market reach the highest point; and then, the diffusion rate decreases and the inflection point occurs, and ultimately part of the traditional supply chain management approach still exists. When the pollution tax r_2 intensity is high, the green supply chain management approach will continue to diffuse until it occupies the whole market, and the larger the absolute value of the two, the faster the evolution; the larger the absolute value difference, the more stable the evolution result. Therefore, the government chooses the combination strategy of incentive strategy and pollution tax in parallel and with higher intensity of pollution tax policy, which can promote the popularization of green supply chains better and more quickly.

(3) All three parties, the government, the core business, and the public, are critical to the system evolution. According to the model analysis, the system evolution results will vary with the initial values of the profit and loss variables and converge to eight special equilibrium points. In the long run, the initial value of the profit and loss variable is $(1, 1, 1)$,

i.e., when the core enterprise chooses the construction strategy, the government adopts the regulation strategy, and the public chooses the participation strategy, and only then can the three parties ultimately obtain the highest benefit. Any other initial situation of the P and L variables will lead to an imbalance in the evolution process, which will ultimately lead to an extreme evolutionary outcome, with only some of the subjects or even none of the parties obtaining high benefits. From the government's point of view, the tripartite evolutionary system of core enterprises, the government, and the public will develop towards a benign state only if strong regulation is realized, environmental protection knowledge is popularized, rewards are given to the public for monitoring behaviors, and enterprises are guided to adopt a green supply chain strategy by means of taxation, public opinion, and multiple other means.

The conclusion of the above study concludes the optimal strategy of the evolutionary game between the government, core enterprises, and the public in the implementation of green supply chain management and explores the evolutionary steady state of the diffusion of green supply chain management, which results in a more suitable environmental regulation intensity. Regarding the degree of public preference and the intensity of the government's environmental regulation, and their impact on the traditional and green supply chain management of the game to explore the government's effective combination of strategies, the research question has been fully answered. This paper takes the proliferation of green supply chain management as a new research perspective in theoretical research, and studies the game strategies of the government, core enterprises, and the public in the evolution process from a macro perspective. On this basis, the public's choice preference and the government's environmental regulation are extracted for detailed study, and the survival status of green supply chain management and traditional supply chain management is discussed in various scenarios, which supplements part of the theoretical research on the diffusion of green supply chain management. In terms of practical significance, the optimal combination of governmental strategies for the diffusion of green supply chain management is obtained through simulation analysis, which can promote the popularization of green supply chain management better and more quickly, and also provide certain decision-making support for governmental departments to formulate relevant policies.

The research in this paper still has some limitations. In future research, it will be necessary to further refine the subjects involved in the whole process of the supply chain, subdividing suppliers, producers, distributors, retailers, consumers, etc., and exploring the detailed impacts of the game between the subjects on the diffusion of green supply chain management. In addition to the three parties involved in this paper, how the diffusion of green supply chain management will evolve when the core enterprise cooperates with international suppliers and distributors needs to be further revised by empirical evidence or multi-model derivation.

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