Research on Regulatory Strategies of Green Finance and Optimization of Corporate Green Behavior under the Framework of Circular Economy

Jingxi Guo [1], Ouwen Lin [2], Keying Ye [3], Jianbo Guan [2], Xue Lei [4]

[1] International Business School, Yunnan University of Finance and Economics, Kunming, China

[2] Business School, Guangzhou College of Technology and Business, China

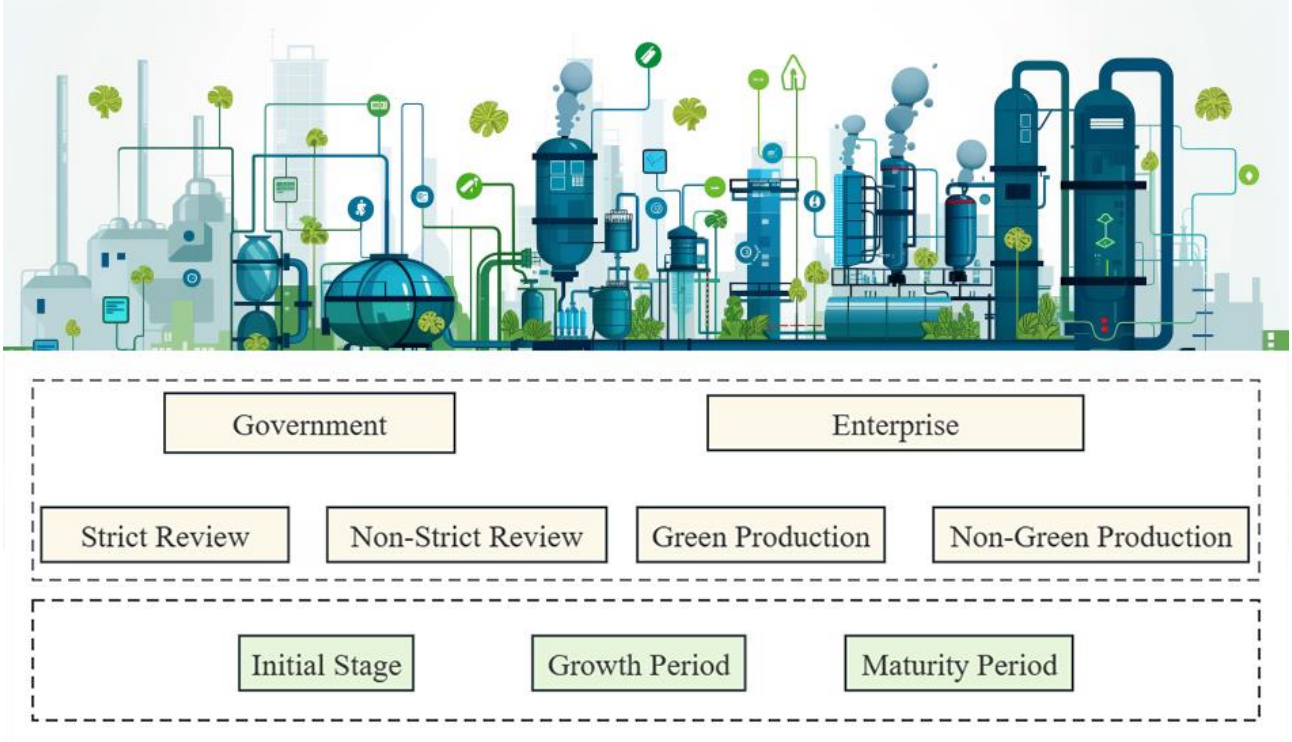
[3] School of Economics, Guangdong Ocean University, Zhanjiang, China

[4] School of Management, Shanghai University, China

[*]Corresponding author: Xue Lei

E-mail: leixue@stu.shmtu.edu.cn

Graphical abstract



ABSTRACT

The green finance market, as an integral part of the circular economy, significantly influences environmental protection and sustainable development. This study explores regulatory issues concerning corporate "greenwashing" behavior in this market, aiming to devise effective regulatory strategies to promote genuine green economic activities. By applying evolutionary game theory, this paper constructs a game model of interaction between the government and enterprises. Through numerical simulation analysis, it reveals the dynamic characteristics of the green finance market in three different stages: initial, growth, and maturity, and their impact on system stability. The study suggests that strengthening regulatory measures, enhancing transparency in information disclosure, establishing unified green assessment standards, and improving incentive policies are key measures to curb corporate greenwashing behavior and promote green transformation. The implementation of these strategies not only enhances the market's green reputation but also encourages active participation of enterprises in circular economic activities, thereby achieving a win-win situation for environmental and economic benefits. The research findings of this paper have important

theoretical and practical implications for guiding the healthy development of the green finance market and formulating circular economy policies.

Keywords: Green Finance, Corporate Green Behavior, Circular Economy, Evolutionary Game, Sustainable Development

1. Introduction

Since the beginning of the reform and opening up, the Chinese economy has grown rapidly alongside industrialization and urbanization (Cheng et al., 2023; Hirsh, 2023). However, the environmental problems arising from this growth have become increasingly severe, posing threats to human survival and development (He et al., 2023; Yuan et al., 2023). Building an ecological civilization and raising awareness of environmental protection have gradually gained attention in China. Particularly after the concept of "Beautiful China" was first proposed by the Chinese government, emphasis has been placed on placing environmental protection in an important position in economic development (Qin et al., 2023; Wang et al., 2023). Green finance, as an important means to promote green transformation, has attracted considerable attention (Chen et al., 2023; Zhong et al., 2023). However, despite some progress made by China in green finance, the market is still in its infancy, with issues such as unclear environmental standards, incomplete incentive measures, and inadequate information disclosure (Feng et al., 2023; T. Zhang, 2023).

Of particular concern is the phenomenon of corporate "greenwashing" in the green finance market, where companies exploit regulatory loopholes to include non-green projects in the green finance category to obtain policy support (Feng et al., 2023; T. Zhang, 2023). This behavior may hinder the healthy development of green finance (Feridun, 2023; D. Zhang, 2023). However, there is a lack of in-depth research on the impact of government regulation on corporate greenwashing behavior and how regulatory measures can guide enterprises to engage in genuine green innovation. Therefore, this study aims to explore the impact of government regulation on corporate greenwashing behavior in the green finance market from the perspective of evolutionary game theory, and propose corresponding regulatory measures to promote the healthy development of the green finance market. Specifically, this paper will use interdisciplinary knowledge of management and finance to construct an evolutionary game model of government-enterprise interaction in the green finance market, analyze the strategic choices faced by the government and enterprises in regulation and production, and discuss the main factors influencing their decisions.

The marginal contribution of this paper lies in providing suggestions for optimizing regulatory methods for the government through studying the impact of government regulation on corporate greenwashing behavior. It also provides a theoretical basis for establishing unified access standards and improving the regulatory mechanism for greenwashing behavior, while also expanding the application of evolutionary game theory in green finance. Ultimately, the results of this study are expected to provide valuable reference for the healthy development of the green finance market and environmental governance, promoting path towards green and sustainable development.

2. Literature Review

Green finance, as an important tool to promote sustainable development, has experienced rapid development globally in recent years. The green finance market provides financial support to enterprises to promote environmental protection and the construction of a resource-saving society. Green bonds, as an important component of green finance, provide a new financing channel for green projects, accelerating the green transformation of industries (Lyu et al., 2024; Wan et al., 2023). However, with the rapid expansion of the green finance market, the inadequacy of market regulation has gradually become apparent, especially in areas such as information disclosure and the uniformity of green standards, leading to the emergence of greenwashing, which not only damages the healthy development of the market but also affects the efficiency and effectiveness of green finance (Guo et al., 2024; Wang et al., 2024).

To address this issue, scholars have proposed various regulatory strategies and suggestions. Strengthening market supervision and increasing the external costs of corporate greenwashing behavior are considered effective measures (Zhang et al., 2024). In addition, strengthening information disclosure requirements and establishing unified green assessment standards are also key measures to promote the high-quality development of the green finance market (Wu et al., 2024). These studies provide theoretical basis and practical guidance for policymakers, helping to build a more perfect and efficient green finance market.

In the context of the circular economy and sustainable development, the role of green finance is particularly important. Through the support of green finance, efficient use of resources and recycling can be promoted, driving industries towards more environmentally friendly and sustainable directions (Han et al., 2024). Green finance not only helps to address environmental issues but also provides impetus for achieving win-win situations for the economy and the environment by promoting technological innovation and industrial upgrading (Makpotche et al., 2024).

However, research on corporate greenwashing behavior in the green finance market is still limited, especially literature using game theory methods for research is scarce. Greenwashing behavior not only damages the credibility of green finance but also affects the effective operation of the market. Therefore, in-depth study of the motives, influencing factors, and regulatory strategies of corporate greenwashing behavior is of great significance for improving the regulatory system of the green finance market and promoting circular economy and sustainable development. This paper aims to fill this research gap by constructing an evolutionary game model of government-enterprise regulation of greenwashing behavior in the green finance market and conducting numerical simulation analysis, providing a new theoretical perspective and policy suggestions for the healthy development of the green finance market.

3. Materials and Methods

3.1. Problem Description

Given the urgency and complexity of governance of corporate greenwashing behavior in the Chinese green finance market, considering the effective role of enterprises in driving the green industry, while also considering the supervision and coordination role of the government as a regulator, this paper focuses on the construction of green industries in specific regions, with the main groups being the government and enterprises, both of which are large-scale and bounded rationality after a long period of mutual influence and behavioral learning, the decision-making behavior of each group will tend to be stable within the system. Among them, enterprises include

various forms of enterprises such as state-owned enterprises, collectively-owned enterprises, private enterprises, and joint-stock enterprises in different fields; the government includes provincial, autonomous region, and municipal securities regulatory commissions and ecological environmental protection departments, with the government representing the above groups in this paper. In this paper, we focus on studying the behavior of enterprises implementing green projects through issuing green bonds and analyzing the game decision-making process between enterprises and the government.

3.2. Model Assumptions

Based on the real situation, this paper makes the following assumptions about the evolutionary game model of "government-enterprise" regulation of greenwashing behavior in the green finance market:

H1: The subjects participating in the game are bounded rational. In a specific region, the two groups maintain relative stability, and the group sizes can be standardized to 1. In the initial stage of the game, the probability that the government group chooses a strict review strategy is denoted as u, and the probability that the enterprise group chooses a green production strategy is denoted as v. Here, $0 \leq u \leq 1$ and $0 \leq v \leq 1$.

H2: The government is represented by participant 1, and enterprises are represented by participant 2. The government actively conducts inspections and urges enterprises to engage in green production through methods such as punishment or incentives. The government has two strategies: strict review and relaxed review, denoted as (SR_1, SR_2); enterprises have two strategies: green production and greenwashing production, denoted as (GP_1, GP_2). Green production can be described as a production method aimed at energy conservation, consumption reduction, and pollution reduction, utilizing green management and technology throughout the production process to minimize the generation of pollutants. Greenwashing production refers to enterprises using funds raised from the financial market for non-green projects, allocating funds for green projects below policy standards, or portraying a green image to obtain operating funds without engaging in green

industry operations, resulting in social benefits of green projects being lower than expected or even causing certain losses.

H3: When the government chooses to strictly review enterprise project applications and fund management, the operating cost is denoted as C_1. If the government finds that an enterprise engages in greenwashing behavior, it imposes a certain penalty, including environmental penalties and penalties for greenwashing behavior, denoted as P_1. Conversely, if the government chooses to be inactive or relax its scrutiny of enterprises, $C_1 = 0$. In addition, regardless of whether the enterprise engages in greenwashing behavior or not, the government will provide financial market services, tax incentives, and fiscal subsidies to enterprises. Therefore, this model does not elaborate on this cost further.

H4: The total revenue of the project in which the enterprise participates in green projects is denoted as S. If the enterprise chooses green production and, at this time, the government chooses a strict review strategy, when social welfare such as environmental improvement and energy utilization improves significantly, the government will promptly commend the enterprise's green production behavior. The enterprise will also gain positive social effects, accumulating advantages for the enterprise to undertake green projects in subsequent stages, with potential benefits denoted as R. After the green project is completed with quality and quantity guaranteed, the entire society gains benefits denoted as G_1. Since the social benefits brought by green projects belong to public goods and have social attributes, the government's revenue will increase by G_1, and the increase in social benefits obtained by the enterprise will be $bG_1(0 < b < 1)$. If the government chooses to relax supervision, enterprises can still spontaneously engage in green production, indicating that the effectiveness of the green finance market is very high and the access standards for green projects are high, which amplifies the increase in social benefits. In this case, the government's revenue will increase by $AG_1(A > 1)$, and the increase in social benefits obtained by the enterprise will be $bAG_1(A > 1, 0 < b < 1)$, achieving the ideal state of the system, namely the strategy (SR_2, GP_1),

where the government relaxes supervision and enterprises spontaneously engage in green production, forming a virtuous cycle.

H5: If the enterprise adopts strategy GP_2, it will cause certain environmental damage, resulting in a loss of social benefits denoted as L_1. If the government chooses strict supervision, its revenue will also decrease by L_1, and the loss of social benefits for the enterprise will be bL_1. Conversely, if the government chooses to relax supervision, it will drive enterprise greenwashing behavior to some extent, continuously fostering greenwashing behavior in enterprises, disrupting the normal order of the green finance market, and causing the loss of social benefits to be further expanded compared to the strict supervision strategy, denoted as $-AL_1$ for the government's revenue. At this time, the enterprise's revenue is the greenwashing revenue S_1 generated by packaging non-green projects as green projects in the green finance market or not fully using raised funds for green projects, plus the project's total revenue minus the social benefit loss bAL_1. If the government chooses a strict review strategy, enterprises will incur greenwashing costs denoted as C_2. Table 1 presents the relevant parameter assumptions and their meanings in the evolutionary game model, with all parameter values greater than 0.

Table 1. Relevant Parameters and Meanings:

Parameters	Meanings
R	Potential benefits for enterprises to accumulate advantages by undertaking green projects in the green market after completing green projects.
C_1	Operating costs for the government to strictly review enterprise application materials and fund management.
P_1	Fine imposed by the government on enterprises for engaging in greenwashing behavior.
S	Total revenue for enterprises in constructing and implementing green projects.
G_1	Benefits obtained by the entire society after the completion of green projects with quality and quantity guaranteed.
L_1	Loss of social benefits for the entire society after the completion of green projects under greenwashing behavior.
S_1	Greenwashing revenue for enterprises after engaging in greenwashing behavior.
C_2	Greenwashing costs incurred by enterprises after engaging in greenwashing behavior.
A	Amplification factor of environmental benefits and losses under the government's relaxed supervision strategy.
b	Conversion coefficient of social benefits between the government and enterprises.

3.3. Game strategy

To establish the evolutionary game model, this paper analyzes four possible combinations of strategies and payoff situations. Table 2 presents the strategy combinations and their payoff matrices for both sides in various game combinations. For instance, in the strategy combination $(\mathrm{SR}_1, \mathrm{GP}_1)$, the government adopts a strict review strategy (SR_1), actively supervising enterprises' green project applications and fund usage to ensure compliance with green production standards. The payoff for this regulatory behavior consists of the social benefits (G_1) obtained by the government from green projects, minus the operational costs (C_1) incurred due to regulation, and the reward (R) given by the government to enterprises for their green production behavior, i.e., $-C_1 + G_1 - R$. At the same time, enterprises respond to the government's strict supervision by choosing the green production strategy (GP_1), dedicated to implementing energy conservation, emission reduction, and pollution control in their production processes. The enterprise's payoff consists of the total revenue (S) after completing green projects, the reward (R) from the government for their green production behavior, and a portion of the increase in social benefits (bG_1), i.e., $S + R + bG_1$. This strategy combination reflects the positive interaction between the government and enterprises in the green finance market, jointly promoting the development of the green economy and improvement of the social environment.

Table 2. Payoff Matrix

Strategy Combination	Government	Enterprise
$(\mathrm{SR}_1, \mathrm{GP}_1)$	$-C_1 + G_1 - R$	$S + R + bG_1$
$(\mathrm{SR}_2, \mathrm{GP}_1)$	AG_1	$S + bAG_1$
$(\mathrm{SR}_1, \mathrm{GP}_2)$	$-C_1 + P_1 - L_1$	$S - P_1 - bL_1 - C_2 + S_1$
$(\mathrm{SR}_2, \mathrm{GP}_2)$	$-AL_1$	$S + S_1 - bAL_1$

4. Results

4.1. Copy dynamic equation

The replicator dynamics describe the evolution of the distribution of different strategies within a population over time (Ionescu-Kruse & Ivanov, 2023; Peng, 2023). An evolutionarily stable strategy refers to a strategy that, during the evolutionary process, can resist any small disturbance and maintain stability. Below are constructed the replicator dynamics equations for both the

government and enterprises. Let the expected payoff for the government choosing the SR_1 strategy be denoted as U_{SR}, the expected payoff for choosing the SR_2 strategy be denoted as $\bar{U}_{SR}$, and the average expected payoff be denoted as U_G. If $M(u)$ represents the replicator dynamics equation for government behavior strategy, then we have:

$$U_{SR} = (-C_1 + G_1 - R)v + (-C_1 + P_1 - L_1)(1 - v) \#(1)$$

$$\bar{U}_{SR} = AG_1 v + (-AL_1)(1 - v) \#(2)$$

$$U_G = uU_{SR} + (1 - u)\bar{U}_{SR} \#(3)$$

$$M(u) = \frac{du}{dt} = u(U_{SR} - U_G) = u(u - 1) \quad \#(4)$$
$$(C_1 + L_1 - P_1 - G_1 v - L_1 v + P_1 v + Rv - AL_1)$$

Similarly, let the expected payoff for enterprises choosing the GP_1 strategy be denoted as U_{GP}, the expected payoff for choosing the GP_2 strategy be denoted as $\bar{U}_{GP}$, and the average expected payoff be denoted as U_E. If M(v) represents the replicator dynamics equation for government behavior strategy, then we have:

$$U_{GP} = (S + R + bG_1)u + (S + bAG_1)(1 - u) \#(5)$$

$$\bar{U}_{GP} = (S - P_1 - bL_1 - C_2 + S_1)u + (S + S_1 - bAL_1)(1 - u) \#(6)$$

$$U_E = vU_{GP} + (1 - v)\bar{U}_{GP} \#(7)$$

$$M(v) = \frac{dv}{dt} = v(U_{GP} - U_E) = -v(v - 1) \quad \#(8)$$
$$(C_2 v - S_1 + P_1 u + Ru + AG_1 b + AL_1 b + G_1 bu + L_1 bu - AG_1 bu - AL_1 bu)$$

4.2. Equilibrium point analysis

Setting M(u)=0 and M(v)=0 yields five equilibrium points for the government and enterprise evolutionary game, including four pure strategy equilibrium points (0,0)、(1,0)、(0,1)、(1,1), and one mixed strategy equilibrium point (x^*, y^*). The region M enclosed by these four pure strategy points represents the equilibrium solution domain of the game, i.e., $M = ((u, v) \mid 0 \leqslant u \leqslant 1, 0 \leqslant v \leqslant 1)$. The stability of equilibrium points depends on parameter settings, with mixed strategy equilibrium points being unstable. Therefore, only the stability of pure strategy equilibrium points is discussed. Each equilibrium point in this system corresponds to an evolutionary game equilibrium.

Substituting the equilibrium points into the Jacobian matrix (Naranjo-Noda & Jimenez, 2023; Pei et al., 2023), as shown in Formula (9), and using Lyapunov's first method to analyze the stability of each equilibrium point (Jiang & Cao, 2023; Mehdipour & Razi, 2024). Table 3 shows the eigenvalues after substituting the equilibrium points into the Jacobian matrix. If all eigenvalues are less than 0, the equilibrium point is stable (ESS).

$$J = \begin{bmatrix} \frac{\partial M(u)}{\partial u} & \frac{\partial M(u)}{\partial v} \\ \frac{\partial M(v)}{\partial u} & \frac{\partial M(v)}{\partial v} \end{bmatrix} \#(9)$$

Table 3. Stability Analysis of Equilibrium Points

ESS	λ_1	λ_2
(0,0)	$AG_1b - S_1 + AL_1b$	$P_1 - L_1 - C_1 + AL_1$
(1,0)	$C_1 + L_1 - P_1 - AL_1$	$C_2 + P_1 + R - S_1 + G_1b + L_1b$
(0,1)	$S_1 - AG_1b - AL_1b$	$G_1 - C_1 - R - AG_1$
(1,1)	$C_1 - G_1 + R + AG_1$	$S_1 - P_1 - R - C_2 - G_1b - L_1b$

According to the given game model and the stability analysis of equilibrium points, we can conduct theoretical analysis to explore the evolution of these four equilibrium points:

For the point (0,0), when satisfying $AG_1b - S_1 + AL_1b < 0$ and $P_1 - L_1 - C_1 + AL_1 < 0$, indicating that both the government and the enterprises choose not to take action. According to stability analysis, when all eigenvalues are less than 0, this equilibrium point is stable. In this case, the government will not incur costs for inspection, and the enterprises will not choose green production as they will neither be penalized nor rewarded. Therefore, they will maintain the status quo, which may lead to environmental degradation and imbalance in the green financial market. For the point (1,0), when satisfying $C_1 + L_1 - P_1 - AL_1 < 0$ and $C_2 + P_1 + R - S_1 + G_1b + L_1b < 0$, indicating that the government enforces strict scrutiny while the enterprises choose not to engage in green production. According to stability analysis, this point is stable when all eigenvalues are less than 0. In this scenario, the government incurs costs for inspection, but enterprises opt out of green production to avoid additional costs. The government may gain certain benefits, but social benefits will be compromised due to the absence of green production by enterprises. For the point (0,1), when satisfying $S_1 - AG_1b - AL_1b < 0$ and $G_1 - C_1 - R - AG_1 < 0$, indicating that the

government chooses to relax regulation while enterprises opt for green production. According to stability analysis, this point is stable when all eigenvalues are less than 0. In this scenario, the government does not incur costs for inspection, and enterprises choose green production to obtain social benefits. This situation represents the most ideal state, where the government does not need to regulate, and enterprises engage in green production. As for the point (1,1): $C_1 - G_1 + R + AG_1 > 0$, it does not meet the equilibrium point conditions, thus it is not a potential equilibrium point.

Overall, the evolution of these equilibrium points depends on the game strategies between the government and enterprises, as well as the influence of environmental benefits, penalty costs, and other factors. Dynamic changes and adjustments may occur during evolution to seek the optimal game strategy. According to theoretical analysis, the equilibrium point (0,1) may be the most ideal state as both the government and enterprises benefit from it, leading to an increase in social benefits. However, actual situations may be influenced by many other factors, thus requiring a comprehensive consideration of various factors to determine the optimal strategy.

5. Discussion

5.1. Numerical Simulation

Based on the theoretical analysis and constraints, Matlab tools are employed to conduct numerical simulations of the evolving interaction between the government and enterprises. The simulations analyze the impact of parameter variations on the evolutionary results. Taking the case of the (0,0) scenario as an example, the dynamic evolution of the government and enterprises is analyzed. Let u and v represent the initial proportions of the government choosing the SR_1 strategy and enterprises choosing the GP_1 strategy, respectively. The initial time is set to 0, the end time of evolution is set to 100, and the initial state is (0.5,0.5). The parameter values are set as follows: $\mathrm{R} = 1, \mathrm{C}_1 = 8, \mathrm{P}_1 = 3, \mathrm{S} = 4, \mathrm{G}_1 = 2, \mathrm{L}_1 = 1, \mathrm{S}_1 = 4, \mathrm{C}_2 = 1, \mathrm{A} = 2, \mathrm{b} = 0.2$. Why these values are chosen? Because they satisfy that the eigenvalues in Table 3 are all less than 0, so the game will evolve towards ESS(0,0). The simulation experiment is shown in Figure 1, which verifies the analysis of ESS(0,0).

This indicates that in the early stage of establishing the green financial market, if the government adopts a policy of relaxing regulations and allowing the market to develop naturally, enterprises will choose the strategy of floating green production. Under unchanged parameters, when the government chooses the strategy of strict inspection with a certain probability, enterprises will switch production methods and eventually stabilize at v=1. Therefore, as the green financial market continues to improve and the penalties for enterprise floating green behavior increase, along with the continuous increase in the cost of enterprise floating green behavior, after long-term selection game, the ESS(0,0) state is unlikely to persist for a long time. We refer to this stage as the initial stage.

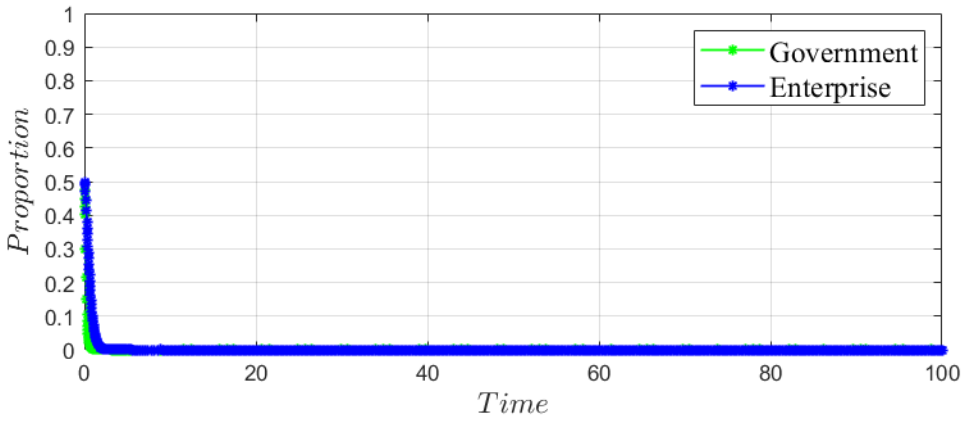


Figure 1. Dynamic Evolution Simulation in the Initial Stage

5.2. Sensitivity Analysis

We assume that there is a certain lag in policy communication, and as the green financial market develops, the government's awareness of preventing the risk of greenwashing in the market continues to increase, leading to an increasing probability of the government choosing strict inspection. However, the strategy of enterprises remains unchanged, aiming to stabilize the system at ESS(1,0). We adjust C_1=2 and S_1=10, while keeping the other parameters consistent with the original ones, i.e., reducing the operating costs of the government's strict inspection of enterprise application materials and fund management, and increasing the floating green income after implementing floating green behavior by enterprises. Since all eigenvalues in Table 3 are less than 0, the game will evolve towards ESS(1,0). The simulation experiment is shown in Figure 2, which

validates the analysis of ESS(1,0). Although the government chooses the strategy of strict inspection and increases the penalties for floating green enterprises, the floating green income of enterprises is still high, exceeding the floating green costs, floating green penalties, potential benefits of green production, the increase in benefits from implementing green production, and the loss of benefits from floating green production. Therefore, enterprises will still choose floating green production, thereby stabilizing the entire system, forming a phased balance. We refer to this stage as the growth period.

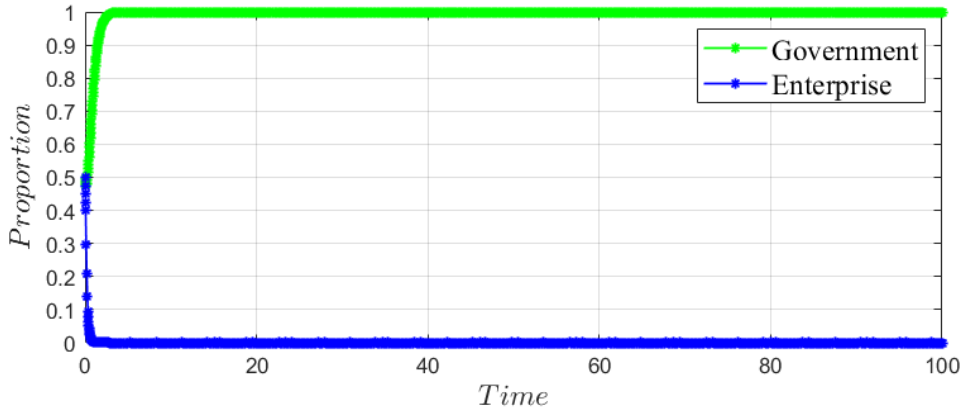


Figure 2. Dynamic Evolution Simulation in the Growth Period

Similarly, if enterprises choose to upgrade traditional production techniques and implement green production, the floating green income of enterprises is lower than the increase in social benefits after completing green projects and the decrease in social benefits after implementing floating green behavior, ESS(0,1) will stably exist. Therefore, we adjust the parameter S_1=1, while keeping the other parameters consistent with the original ones, i.e., reducing the floating green income of enterprises after implementing floating green behavior. Since all eigenvalues in Table 3 are less than 0, the game will evolve towards ESS(0,1). The simulation experiment is shown in Figure 3, which validates the analysis of ESS(0,1). Thus, with the continuous learning and evolution of enterprises and the government, the entire evolutionary game system will eventually stabilize at the evolutionary stable state of ESS(0,1). Since the government chooses to relax inspection, there are no inspection operating costs. Meanwhile, if the floating green income of enterprises is reduced, lower than the increase in benefits from implementing green production and the loss of benefits

from floating green production, enterprises will choose green production, thereby achieving the ideal state of the entire system. We refer to this stage as the maturity period. The effects of variations in other parameters on the game can also be experimented with in the same manner, as long as the stability point conditions in Table 3 are satisfied; hence, they will not be reiterated here.

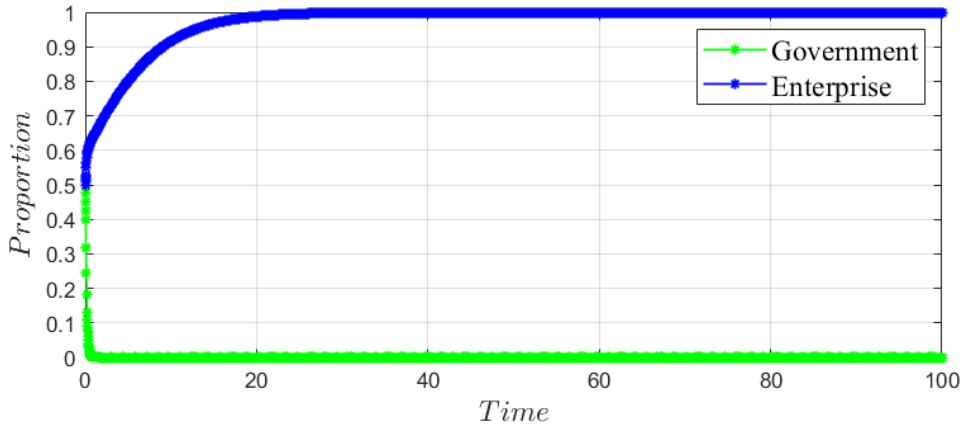


Figure 3. Dynamic Evolution Simulation in the Maturity Period

6. Conclusions and Suggestions

6.1. Conclusions

This study constructs an analytical framework based on evolutionary game theory to explore the interaction between the government and enterprises in the green financial market and its impact on greenwashing behavior. The study reveals three stages of the green financial market: the initial stage, growth period, and maturity period, and analyzes the mutual relationship between system stability and key parameters in each stage. In the initial stage, due to lack of regulation, enterprises may tend to engage in greenwashing behavior; in the growth period, although the government strengthens regulation, enterprises may still benefit from greenwashing behavior; while in the maturity period, under the background of relaxed government regulation, enterprises can spontaneously engage in green production, achieving sustainable development.

6.2. Suggestions

Based on the above conclusions, strategic suggestions are proposed to promote the healthy development of the green financial market and drive macroeconomic transformation towards green:

(1) Strengthen Market Supervision Mechanisms: Increase the external costs of enterprise greenwashing behavior to create effective regulatory pressure and incentivize enterprises to actively implement green production. This entails establishing stricter regulations to penalize companies falsely claiming participation in green projects, essential for laying down basic rules and standards for healthy market development.

(2) Enhance Information Disclosure Requirements: Emphasize transparent information disclosure to provide solid evidence for regulatory decisions and promote market standardization. Transparent disclosure becomes increasingly significant as the green finance market expands and becomes more complex, aiding in better identification and assessment of corporate green actions, thus reducing greenwashing.

(3) Establish Unified Green Assessment Standards: Clarify criteria for identifying green projects to plug regulatory loopholes and purify the market environment. Unified green assessment standards are crucial in the maturity phase of the green finance market to maintain stability and predictability, fostering long-term stability and sustainable development.

(4) Continuously Improve Incentive Policies: Increase the benefits of green production and invest more in green technology research and development to provide continuous momentum for corporate green transformation. Incentive policies are particularly crucial in the maturity phase of the market, encouraging enterprises to invest in green technologies and production processes for environmental and economic benefits.

Through these comprehensive measures, the green finance market can be effectively guided towards a more mature and stable direction, contributing to the achievement of global sustainable development goals. These recommendations consider the current state of the green finance market and explore the versatility and effectiveness of proposed regulatory strategies.

Research limitation

In this research, despite the in-depth exploration of regulatory strategies in the green finance market and corporate green behavior through theoretical models and evolutionary game theory, there are

still several critical limitations. Firstly, the study failed to validate the models based on empirical data, thereby restricting the empirical analysis of model effectiveness. Secondly, the model assumptions may not fully capture the complexity and diversity of the real world, especially concerning the dynamic interaction between government regulation and corporate behavior. Additionally, the research primarily focused on the Chinese market, which may not be directly applicable to other countries and market environments. Future research should consider collecting and analyzing empirical data, exploring the applicability in different market environments, and validating the conclusions of this study in a broader international context. Through these approaches, it will be possible to more accurately assess and optimize regulatory strategies in the green finance market, thereby promoting corporate green transformation and sustainable development.

Acknowledgments

This work was supported by 2021 Guangdong Province Key Construction Discipline Research Capacity Enhancement Project (Grant Number: 2021ZDJS121), 2023 Guangdong Province Philosophy and Social Sciences Project (Grant Number: GD23YYJ23), 2023 Guangzhou City Philosophy and Social Sciences Project (Grant Number: 2023GZGJ44) and 2023 Foshan City Social Science Project (Grant Number: 2023-GJ102).

References

Chen, D., Hu, H., & Chang, C.-P. (2023), Green finance, environment regulation, and industrial green transformation for corporate social responsibility, *Corporate Social Responsibility and Environmental Management*, **30**, 2166-2181.

Cheng, J., Chen, M., & Tang, S. (2023), Shenzhen-A typical benchmark of Chinese rapid urbanization miracle, *Cities*, **140**,

Feng, W., Bilivogui, P., Wu, J., & Mu, X. (2023), Green finance: current status, development, and future course of actions in China, *Environmental Research Communications*, **5**,

Feridun, M. (2023), Green finance: do innovation, fintech and financial transparency play a role? , *Applied Economics Letters*

Guo, X. Y., Yang, J. Y., Shen, Y., & Zhang, X. W. (2024), Impact on green finance and environmental regulation on carbon emissions: evidence from China, *Frontiers in Environmental Science*, **12**,

Han, Y. F., Zhao, F., & Zhao, B. Y. (2024), Navigating a sustainable transition: green digital finance in manufacturing, *Economic Change and Restructuring*, **57**,

He, Y., Zhao, X., & Zheng, H. (2023), How does the environmental protection tax law affect firm ESG? Evidence from the Chinese stock markets, *Energy Economics*, **127**,
Hirsh, M. (2023), The Transnational Origins of China's Aviation Infrastructure, *China Quarterly*, **255**, 663-678.
Ionescu-Kruse, D., & Ivanov, R. (2023), Nonlinear two-dimensional water waves with arbitrary vorticity, *Journal of Differential Equations*, **368**, 317-349.
Jiang, K., & Cao, F. (2023), Lyapunov-type stability criterion for periodic generalized Camassa-Holm equations, *Nonlinear Analysis-Real World Applications*, **74**,
Lyu, Y., Bai, Y., & Zhang, J. (2024), Green finance policy and enterprise green development: Evidence from China, *Corporate Social Responsibility and Environmental Management*, **31**, 414-432.
Makpotche, M., Bouslah, K., & M'Zali, B. (2024), Corporate governance and green innovation: international evidence, *Review of Accounting and Finance*
Mehdipour, P., & Razi, M. (2024), Lyapunov Exponents and Hyperbolic periodic orbits for endomorphisms, *Journal of Mathematical Analysis and Applications*, **530**,
Naranjo-Noda, F. S., & Jimenez, J. C. (2023), Jacobian-free High Order Local Linearization methods for large systems of initial value problems, *Applied Numerical Mathematics*, **187**, 158-175.
Pei, X., Du, J., & Chen, G. (2023), Accelerated nonlinear finite element method for analysis of isotropic hyperelastic materials nonlinear deformations, *Applied Mathematical Modelling*, **120**, 513-534.
Peng, H. (2023), Statistical fluid mechanics: Dynamics equations and linear response theory, *Physics of Fluids*, **35**,
Qin, C., Su, J., Xiao, Y., Qiang, Y., & Xiong, S. (2023), Assessing the Beautiful China Initiative from an environmental perspective: indicators, goals, and provincial performance, *Environmental Science and Pollution Research*, **30**, 84412-84424.
Wan, Y., Sheng, N., Wei, X., & Su, H. (2023), Study on the spatial spillover effect and path mechanism of green finance development on China's energy structure transformation, *Journal of Cleaner Production*, **415**,
Wang, Q., Wang, S. Y., Wang, C. Y., & Hu, D. (2024), How digital finance impacts listed companies' green innovation in China: a product market perspective, *Environmental Science and Pollution Research*
Wang, X., Zhang, M., Jie, S., Zhang, M., & Zhang, Z. (2023), Exploring the Coordinated Evolution Mechanism of Regional Sustainable Development and Tourism in China's "Beautiful China" Initiative, *Land*, **12**,
Wu, G. L., Liu, X., & Cai, Y. L. (2024), The impact of green finance on carbon emission efficiency, *Heliyon*, **10**,
Yuan, M., Yang, Y., & Yi, H. (2023), Environmental condition, cultural worldview, and environmental perceptions in China, *Journal of Risk Research*, **26**, 748-777.
Zhang, D. (2023), Does green finance really inhibit extreme hypocritical ESG risk? A greenwashing perspective exploration, *Energy Economics*, **121**,
Zhang, M., Li, C. R., Zhang, J. S., & Chen, H. W. (2024), How Green Finance Affects Green Total Factor Productivity-Evidence from China, *Sustainability*, **16**,
Zhang, T. (2023), Can green finance policies affect corporate financing? Evidence from China's green finance innovation and reform pilot zones, *Journal of Cleaner Production*, **419**,
Zhong, S., Peng, L., Li, J., Li, G., & Ma, C. (2023), Digital finance and the two-dimensional logic of industrial green transformation: Evidence from green transformation of efficiency and structure, *Journal of Cleaner Production*, **406**,