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Evolutionary game analysis of enterprises' green production behavior in the context of China's economic green transformation

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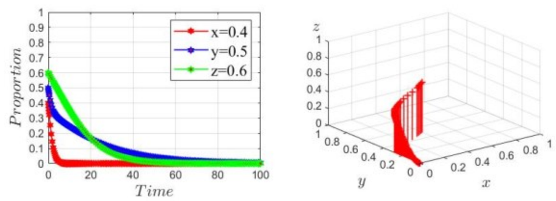
Graphical abstract



Abstract

In the context of China's critical economic transition towards sustainability, this research employs a tripartite evolutionary game model involving government, enterprises, and environmental protection social organizations to investigate the evolutionary trajectory of enterprises' green production behaviors. By elucidating the equilibrium solution of the model and validating its local stability, the study aims to identify the key factors that contribute to steering the game towards a favorable state. The findings reveal that enterprises' decisions to adopt green production practices are primarily driven by cost-benefit considerations. Meanwhile, government interventions in regulating green production are influenced by factors such as resource input, punitive measures for non-compliance, and reward incentives. Additionally, the decisions of environmental protection social organizations to monitor enterprises' green production are shaped by factors like cost, financial support, and subsidy incentives. Ultimately, the study provides policy recommendations, emphasizing stakeholder perspectives, to encourage corporate green production. These insights not only aim to foster sustainable development among enterprises but also serve as a theoretical foundation for government policy formulation.

Keywords: Environmental social organizations, corporate green production, economic green transformation, sustainability, stakeholder perspectives, policy recommendations

1. Introduction

At present, China's economy is in a critical period of green transformation, facing increasingly severe environmental challenges. In this regard, the Chinese government has set the ambitious goal of a "Beautiful China." It is committed to promoting the reform of the ecological and environmental governance system and building a new environmental governance pattern led by the government, led by enterprises, and governed by the society. However, due to the constraints of information asymmetry, it is often difficult for the government's environmental policies to stimulate the green motivation of enterprises fully, and there is an urgent need for an efficient coordination mechanism to narrow the gap between policy formulation and implementation. In this context, environmental social organizations intervene as a third-party force, providing strong support for policy transmission. Under the incentive of government environmental protection laws and the supervision of environmental protection social groups, enterprises have embarked on the road of green production, which not only increases economic gains but also improves the ecological situation, realizing a win-win effect (Kong *et al*. 2016). This not only enhances the resource efficiency of enterprises but also enhances the environmental image of enterprises (Tang *et al*. 2018).

How government environmental regulation affects the green behavior of enterprises is a hot issue of concern to scholars at home and abroad. Through different theoretical models, they have explored the incentive role of government regulations such as subsidies and carbon tax on enterprise green technology innovation, as well as the impact of government regulations and industrial robots on enterprise green production (Chen and Hu 2018; Du *et al*. 2016; Feng & Wang 2023; Nie *et al*. 2022; Wang *et al*. 2016; Xu & Xu 2015). However, these studies tend to consider only the logic of interaction between the two subjects, government, and enterprises, and discuss less about the unique perspective of environmental social organizations, a third-party supervisory force, to participate in corporate green production. Environmental and social organizations can participate in the environmental game between the government and enterprises through various ways to make up for the inadequacy of government environmental protection norms in promoting enterprises to achieve green production and effectively repair the government's inability to fully perform its duties (Binder & Neumayer 2005; Chen *et al*. 2016; Harangozó & Zilahy 2015). On the one hand, environmental social organizations can form strategic collaborative relationships with enterprises to help them establish green labels and improve their economic efficiency (Zhang 2015).

On the other hand, environmental and social organizations can also improve the environmental protection concepts of residents, enterprise employees, and consumers through publicity and education, public interest litigation, and other means, thus influencing the green production methods of enterprises (Binder & Blankenberg 2016; Kumar & Malegeant 2006; Sharma & Henriques 2005). In addition, environmental and social organizations are more capable of detecting and exposing enterprises' polluting behaviors, thereby increasing the likelihood that environmental protection supervisory departments will investigate, punish, and sanction enterprises for illegal emissions and create external constraints on the polluting behaviors of enterprises, thus prompting them to adopt green production practices (Berrone *et al*. 2013; Maggioni & Santangelo 2017). After decoupling from the government administration, environmental and social organizations such as industry associations and chambers of commerce not only ensure regulatory autonomy but also possess the missing regulatory capacity and functions of civil grass-roots organizations and can participate in the environmental game between the government and enterprises as independent third-party participants.

Based on the previous analysis, we innovatively consider environmental social organizations as a third-party force to be included in the environmental game between the government and enterprises. By constructing an evolutionary game model, we explore the evolutionary process and results of enterprises' green production behaviors, reveal the game strategies of the three parties and their interactions, and analyze the conditions and influencing factors for achieving an evolutionary stable state. The aim is to advocate for environmental and social organizations to actively participate in and lead the green production behavior of enterprises, to provide policy references for the Chinese government's environmental regulation reform, and to provide experience and inspiration for environmental governance in other countries and regions.

2. Evolutionary game model

2.1. Model assumptions

In order to analyze the game strategies of the three parties in the process of green production, the parameters of the evolutionary game model are set next, and the following assumptions are made:

H1: The game involves three limited rational groups, namely the implementer of green production - enterprises, the regulator of green production - government, and the monitor of green production - environmental and social organizations.

H2: Each participant has two possible strategies. Enterprises can choose to implement green production or introduce more environmentally friendly technology and equipment to reduce pollution emissions, or they can choose to continue with traditional polluting production methods; governments can choose to invest resources in regulating enterprises and adopt incentives or penalties, or they can choose not to intervene in the enterprises' emissions behavior, but they must pay for the cost of environmental management; environmental, social organizations can choose to monitor whether enterprises implement green production, and expose enterprises that do not implement green production; and environmental social organizations can choose to monitor whether enterprises implement green production, and expose enterprises that do not implement green production. Monitoring and exposing enterprises that do not implement green production; at the same time, when the government does not regulate the traditional production of enterprises, and expose the damage they cause to the environment, thus causing the loss of government inaction; or they can choose not to exercise their monitoring power, and be neutral or silent about the behavior of enterprises and the government.

H3: At the beginning of the game, all parties make different strategic choices according to their interests, and their choice ratios are shown as follows: the enterprise chooses green production with probability X and chooses traditional polluting production with probability 1−X; the government chooses to regulate the enterprise's green production with ratio y, and chooses to let the enterprise's emissions go unchecked with ratio 1−Y; and the environmental protection social organization chooses to monitor the enterprise's green production with ratio Z, and chooses to stay away from the enterprise's green production with ratio 1−Z. The government chooses to regulate the green production of enterprises in the proportion of y and ignore the emissions of enterprises in the proportion of 1-y. Where $0 \le X \le 1, 0 \le y \le 1, 0 \le z \le 1$.

2.2. Game strategy

This paper establishes an evolutionary game model based on the strategy choices and returns of the three parties, and analyzes eight possible game combinations. The hypotheses and meanings of relevant parameters are shown in Table 1, and the strategy combinations of the three parties under various game combinations and their return matrix are shown in Table 2. For example, under the strategy combination (T_1 implementing green production, R_1 regulating enterprise green production, M_1 monitoring enterprise green production), enterprises can not only bear the environmental protection cost C_1 of green production, but also enjoy the subsidies S_1 and S_4 from the government and environmental social organizations, as well as the benefits E_1 brought by green production; In addition to paying the cost C_3 of regulating enterprises' green production, the government can also obtain the potential benefits E_3 brought by enterprises' green production. In addition to the C_5 cost of monitoring enterprises' green production, environmental social organizations also need to obtain funding S_2 and S_3 from the government and other channels to effectively monitor enterprises' and governments' green production behaviors.

Table 1. Model parameters and their meanings

Parameter	Meaning
E_1	Benefits gained by companies implementing green production
E_2	Benefits gained by firms implementing traditional production
E_3	Potential benefits to the government from implementing green production in enterprises
C_1	Costs of implementing green production in enterprises
C_2	Costs incurred by enterprises in implementing traditional production
C_3	The resources invested by the government in personnel, materials, and capital when regulating green production in enterprises.
C_4	Costs of environmental pollution control are brought about by high energy consumption that the government has to pay when enterprises implement traditional production.
C_5	Supervision costs of environmental and social organizations in monitoring green production of enterprises
C_6	Losses caused by government inaction when the government does not regulate the traditional production of enterprises
S_1	Subsidies for enterprises adopting green production when the government regulates green production by enterprises
S_2	Subsidies from the government for environmental and social organizations to monitor green production in enterprises
S_3	Funding from other sources when environmental and social organizations monitor green production in enterprises
S_4	Subsidies for enterprises adopting green production when monitoring green production by environmental protection social organizations.
G_1	Fines imposed on companies adopting traditional production when the government regulates green production by companies
G_2	Losses incurred by traditional producers as a result of CSOs' monitoring of corporate green production

Table 2. Combination of three-party behavioral strategies and their benefit matrices

Strategy Portfolio	Enterprises	Government	Environmental Social Organizations
(T_1,R_1,M_1)	$E_1-C_1+S_1+S_4$	$E_3-C_3+S_1-S_2$	$-C_5+S_2+S_3-S_4$
(T_1,R_1,M_2)	$E_1-C_1-S_1$	$E_3-C_3-S_1$	0
(T_1,R_2,M_1)	$E_1-C_1-S_4$	E_3-S_2	$-C_5+S_2+S_3-S_4$
(T_1,R_2,M_2)	E_1-C_1	E_3	0
(T_2,R_1,M_1)	$E_2-C_2-G_1-G_2$	$-C_3-C_4-S_2+G_1$	$-C_5+S_2+S_3$
(T_2,R_1,M_2)	$E_2-C_2-G_1$	$-C_3-C_4+G_1$	0
(T_2,R_2,M_1)	$E_2-C_2-G_2$	$-C_4-S_2-C_6$	$-C_3+S_2+S_3$
(T_2,R_2,M_2)	E_2-C_2	$-C_4-C_6$	0

3. Dynamic equation and its equilibrium point

3.1. Copy dynamic equation

According to the distribution and evolution law of various strategies in a population, evolutionarily stable strategy refers to the strategy that can be maintained for a long time in the evolution process. Next, the replication dynamic equation of the tripartite behavior strategy is constructed respectively. Suppose that the expected returns of enterprises implementing green production and adhering to traditional pollution production are respectively UX_{11} and UX_{12}, and the average expected returns are UX_1, H(X) is the replication dynamic equation of enterprises implementing green production behavior, then:

$$UX_{11}=\left(E_1-C_1+S_1+S_4\right)yz+\left(E_1-C_1+S_1\right)y\left(1-z\right)+\left(E_1-C_1+S_4\right)\left(1-y\right)z+\left(E_1-C_1\right)\left(1-y\right)\left(1-z\right) \quad (1)$$

$$UX_{12}=\left(E_2-C_2-G_1-G_2\right)yz^{+}\left(E_2-C_2-G_1\right)y\left(1-z\right)+\left(E_2-C_2-G_2\right)\left(1-y\right)z+\left(E_2-C_2\right)\left(1-y\right)\left(1-z\right) \quad (2)$$

$$UX_1=xUX_{11}+\left(1-x\right)UX_{12} \quad (3)$$

$$H\left(x\right)=\frac{dx}{dt}=x\left(UX_{11}-UX_1\right)=x\left(1-x\right)\left(UX_{11}-UX_{12}\right) \quad (4)$$

Similarly, suppose that the expected returns of government regulating enterprises' green production and not interfering with enterprises' emission behavior are respectively UX_{21} and UX_{22}, and the average expected returns are UX_2, H(y) is the replication dynamic equation of government regulating enterprises' green production behavior, then:

$$UX_{21}=\left(E_3-C_3-S_1-S_2\right)xz+\left(E_3-C_3-S_1\right)x\left(1-z\right)+\left(-C_3-C_4-S_2+G_1\right)\left(1-x\right)z+\left(-C_3-C_4+G_1\right)\left(1-x\right)\left(1-z\right) \quad (5)$$

$$UX_{22} = (E_3 - S_2)xz + E_3x(1-z) + (-C_4 - S_2 - C_6)(1-x) z + (-C_4 - C_6)(1-x)(1-z) \tag{6}$$

$$UX_2 = yUX_{21} + (1-y)UX_{22} \tag{7}$$

$$H(y) = \frac{dy}{dt} = x(UX_{21} - UX_2) = y(1-y)(UX_{21} - UX_{22}) \tag{8}$$

Finally, the expected returns of environmental and social organizations monitoring the green production behavior of enterprises and not monitoring the green production behavior of enterprises are UX_{31} and UX_{32}, respectively. The average expected returns are UX_3, H(z) is the replication dynamic equation of environmental social organizations monitoring the green production behavior of enterprises, then:

$$UX_{31} = (-C_5 + S_2 + S_3 - S_4)xy + (-C_5 + S_2 + S_3 - S_4)x(1-y) + (-C_5 + S_2 + S_3)(1-x)y + (-C_5 + S_2 + S_3)(1-x)(1-y) \tag{9}$$

$$UX_{32} = 0 \tag{10}$$

$$UX_3 = zUX_{31} + (1-z)UX_{32} \tag{11}$$

$$H(z) = \frac{dz}{dt} = z(UX_{31} - UX_3) = z(1-z)(UX_{31} - UX_{32}) \tag{12}$$

3.2. System dynamics model

Based on the above replicated dynamic equations, the system dynamics stock-flow model of the enterprise's green production behavior is established through Venism software, as shown in Figure 1.

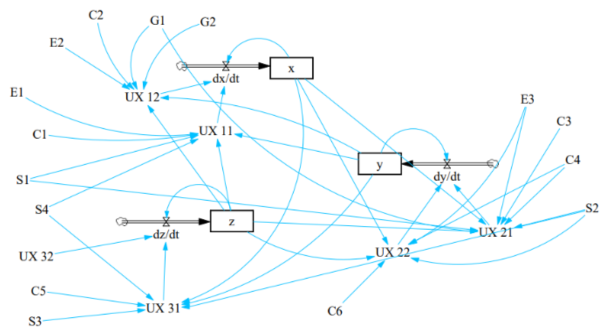


Figure 1. Evolutionary game SD model diagram

3.3. Equilibrium point analysis

By making H(x)=0, H(y)=0, and H(z)=0, 12 equilibrium points of the three-way evolutionary game are solved, of which eight are pure strategy equilibrium points, and four are mixed strategy equilibrium points. These equilibrium points constitute the equilibrium solution domain of the game D = ((X, Y, Z) $|0 \le X \le 1, 0 \le y \le 1, 0 \le z \le 1$). Since the stability of the mixed-strategy equilibrium points is affected by the parameter settings and is more unstable, this paper focuses on analyzing the stability of the pure-strategy equilibrium points. Each equilibrium point is substituted into the Jacobi matrix, i.e., Equation (13), and Table 3 demonstrates the eigenvalues of each equilibrium point after substitution. Moreover, apply Li Yapunov's first method to judge its stability. If the eigenvalues are all less than 0, the equilibrium point is stable (ESS).

$$J = \begin{bmatrix} \frac{\partial H(x)}{\partial x} & \frac{\partial H(x)}{\partial y} & \frac{\partial H(x)}{\partial z} \\ \frac{\partial H(y)}{\partial x} & \frac{\partial H(y)}{\partial y} & \frac{\partial H(y)}{\partial z} \\ \frac{\partial H(z)}{\partial x} & \frac{\partial H(z)}{\partial y} & \frac{\partial H(z)}{\partial z} \end{bmatrix} \tag{13}$$

Theoretically, for (0,0,0), if $C_6-C_3+G_1 < 0$, the cost of government regulation is greater than that of fines and fines; $S_2-C_5+S_3 < 0$, the subsidy obtained by environmental social organizations is not enough to cover the supervision cost; If $C_2-C_1 + E_1-E_2 < 0$, $E_1-C_1 < E_2-C_2$, the profit of enterprise green production is less than that of traditional production, then enterprises, governments and environmental protection social organizations will tend not to implement, regulate and supervise the strategy;

In the same way, for (1,0,0), if $C_1-C_2-E_1 + E_2(0, E_1-C_1) E_2-C_2$, enterprise profit is greater than the traditional production of green production; $S_2-C_5+S_3- S_4 < 0$, the subsidy received by environmental protection organizations is not enough to cover the supervision cost and expenditure subsidies to enterprises, then enterprises, governments and social environmental protection organizations will tend to implement, regulate and non-supervision strategies;

For (0,1,0), if $S_2-C_5+S_3 < 0$, the subsidy obtained by environmental social organizations is not enough to cover the supervision cost; When $C_3-C_6- G_1 < 0$, the cost of government control is smaller than that of fine and no control. $C_2-C_1 + E_1-E_2 + G_1 + S_1 < 0$, $(E_1-C_1) - (E_2-C_2) + G_1 + S_1 < 0$, subsidies and fine profit margin is not enough to cover enterprises adopt green production, so the three parties tend to not implement, specification and supervisory strategies;

Table 3. Equilibrium points stability analysis

Equilibrium point	Eigenvalue 1	Eigenvalue 2	Eigenvalue 3
(0,0,0)	$C_6-C_3+G_1$	$S_2-C_5+S_3$	$C_2-C_1+E_1-E_2$
(1,0,0)	$-C_3-S_1$	$C_1-C_2-E_1+E_2$	$S_2-C_5+S_3-S_4$
(0,1,0)	$S_2-C_5+S_3$	$C_3-C_6-G_1$	$C_2-C_1+E_1-E_2+G_1+S_1$
(0,0,1)	$C_5-S_2-S_3$	$C_6-C_3+G_1$	$C_2-C_1+E_1-E_2+G2+S_4$
(1,1,0,)	C_3+S_1	$S_2-C_5+S_3-S_4$	$C_1-C_2-E_1+E_2-G_1-S_1$
(1,0,1)	$-C_3-S_1$	$C_5-S_2-S_3+S_4$	$C_1-C_2-E_1+E_2-G_2-S_4$
(0,1,1)	$C_5-S_2-S_3$	$C_3-C_6-G_1$	$C_2-C_1+E_1-E_2+G_1+G_2+S_1+S_4$
(1,1,1)	C_3+S_1	$C_5-S_2-S_3+S_4$	$C_1-C_2-E_1+E_2-G_1-G_2-S_1-S_4$

For (0,0,1), if $C_5-S_2-S_3 < 0$, the subsidy obtained by environmental social organizations can cover the supervision cost; $C_6-C_3+G_1 < 0$, the cost of government control is greater than that of fine and no control; $C_2-C_1+E_1-E_2+G_2+S_4<0, (E_1-C_1)-(E_2-C_2)$ + G_2 + S_4 < 0, subsidies and fine profit margin is not enough to cover enterprises adopt green production, so the three parties tend to not implement, non-standard and supervisory strategies;

Since the eigenvalues of (1,1,0) and (1,1,1) are greater than 0, they are unstable points. Similarly, for (1,0,1), if $C_5-S_2-S_3 + S_4 < 0$, the subsidies obtained by environmental social organizations can make up for the supervision costs and expenditures of subsidies to enterprises; $C_1-C_2-E_1+E_2-G_2-S_4<0$, $(E_1-C_1)-(E_2-C_2)+G_2+S_4>0$, subsidies and fines to cover enterprises adopt green production profit margin, so the three parties tend to implement, non-standard and supervisory strategies;

Finally, for (0,1,1), if $C_5-S_2-S_3<0$, the subsidy obtained by environmental social organizations can cover the supervision cost; When $C_3-C_6-G_1<0$, the cost of government control is smaller than that of fine and no control. $C_2-C_1+E_1-E_2+G_1+G_2+S_1+S_4<0$, $(E_1-C_1)-(E_2-C_2)+G1+S1+G_2+S_4<0$, subsidies and fine profit margin is not enough to cover enterprises adopt green production, so the three parties tend to not implement, Standardize and monitor strategies.

Based on the above analysis, the stability of each equilibrium point is discussed. With the continuous development of green technology, the profit advantages of enterprises implementing green production gradually appear, and eventually evolve to ESS (1,0,1) or (1,0,0) state, that is, enterprises will choose green production mode.

4. Numerical experiment and simulation

Based on theoretical analysis, this paper uses the replication dynamic equation to simulate the interactive evolution process of enterprises, government and environmental social organizations under different constraints, and discusses the influence of various parameters on the evolution results. Taking (0,0,0) as an example, that is, enterprises, governments, and environmental social organizations do not adopt active strategies, this paper analyzes the dynamic changes of this system. Suppose that x, y and z represent the initial proportion of enterprises choosing to implement green production strategy, government choosing to regulate enterprise green production strategy, and environmental social organization choosing to monitor enterprise green production strategy, respectively. The evolution time ranges from 0 to 100, and the initial state is (0.2,0.3,0.4). Parameter Settings are as follows:

$E_1 = 0.2$, $E_2 = 0.5$, $C_1 = 1.2$, $C_2 = 0.3$, $C_3 = 0.9$, $C_5 = 0.4$, $C_6 = 0.05$, $S_1 = 0.05$, $S_2 = 0.2$, $S_3 = 0.1$, $S_4 = 0.01$, $G_1 = 0.8$, $G_2 = 0.2$. The theoretical analysis of the equilibrium point (0,0,0) is verified from both two-dimensional and three-dimensional perspectives. Figure 2 shows that in this case, the profits of enterprises in green production are lower than those of traditional production, the cost of government regulation is higher than the cost of fines and non-regulation, and the cost of supervision by environmental protection and social organizations is greater than subsidies. Therefore, this system will tend to a bad equilibrium, that is, enterprises give up implementing green production, the government gives up regulation, and environmental protection and social organizations give up supervision. It leads to a failure of organizational function.

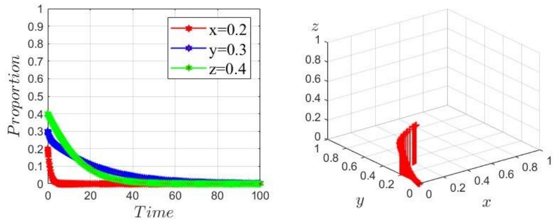


Figure 2. Simulation of the dynamic evolution of the three parties

5. Sensitivity analysis

The change of eigenvalue sign is closely related to the change of parameter, and the change of stable point depends on the change of eigenvalue sign. Therefore, the change of parameters is particularly important to the evolution results. In order to further analyze the influence of each parameter on the evolution results, the system evolution under different parameter combinations is analyzed below. In order to study the impact of government punishment on ESS, this paper increases the government's penalty on enterprises, adjusts G_1=0.95, and the other parameters remain unchanged. As Figure 3 shows, this change does not change the behavioral choices of enterprises, but only increases the government's incentive to regulate enterprises' green production. Similarly, in order to study the impact of the initial strategy on ESS, the initial probability of the three parties adopting the active strategy was increased by adjusting x=0.4, y=0.5, z=0.6, and the remaining parameters were the same as the initial state. As shown in Figure 4, this change also did not lead to a benign evolution of the system.

As can be seen from Figure 5, when the value of C_6 is gradually increased, C_6 = 0.2, C_6 = 0.4, C_6 = 0.6, that is, when the cost of government inaction is increased, the government will tend to adopt the strategy of standardization enterprises' green production, so that the system finally reaches the equilibrium state of ESS (0,1,0). Similarly, as can be seen from Figure 6, when increasing E_1 and decreasing C_1 at the same time, E_1 = 0.5, C_1 = 0.3;E_1 = 0.7,C_1 = 0.3; E_1 = 0.9, C_1 = 0, that is, when the benefit of green production is increased and the cost of green production is reduced, the enterprise will tend to adopt the strategy of implementing green production, so that the system finally reaches the equilibrium state of ESS(1,0,0). Furthermore, as can be seen from Figure 7, the values of S_2 and S_3 are gradually increased, S_2 = 0.4, S_3 =

0.3; S_2 = 0.6, S_3 = 0.5; S_2 = 0.8, S_3 = 0.7, that is, when the financial subsidies obtained by environmental, social organizations are increased, environmental, social organizations will tend to adopt the strategy of monitoring the green production of enterprises, so that the system will eventually reach the equilibrium state of ESS(0,0,1).

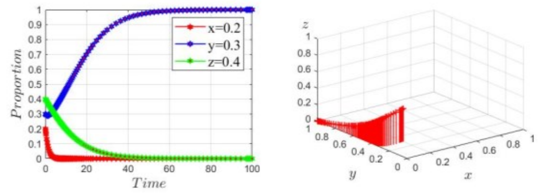


Figure 3. Simulation of upward adjustment of penalties

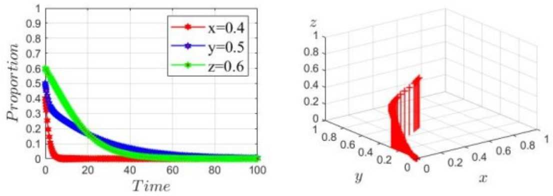


Figure 4. Simulation after initial population proportion change

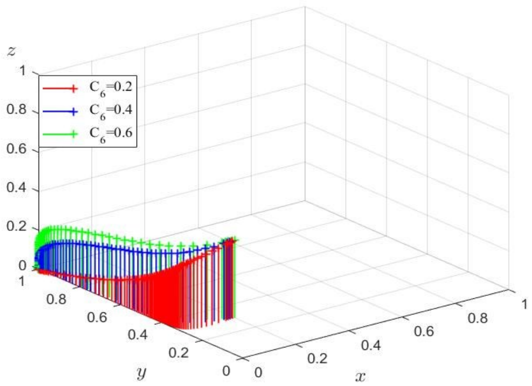


Figure 5. Impact of the cost of government inaction

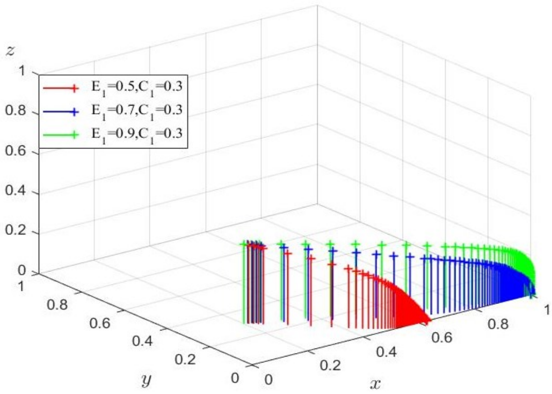


Figure 6. Impact of firms' green production profits

As can be seen from Figure 8, when the influence of factors is comprehensively considered, the system will finally reach the equilibrium state of ESS (1,0,1). At that time, the enterprise will adopt the strategy of implementing green production. These experiments show whether enterprises adopt green production methods depends on how much profit green production can bring compared with traditional production. The above methods can also be used to explore changes in evolutionary results under different scenarios, which will not be covered in this article.

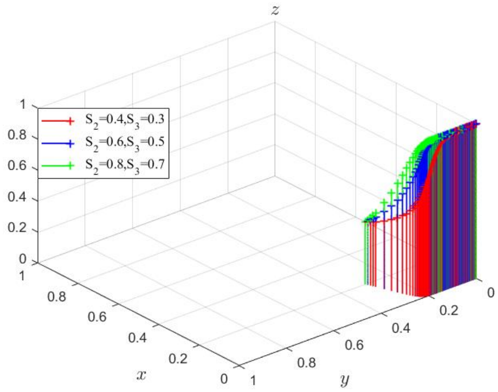


Figure 7. Impact of subsidizing environmental protection funds

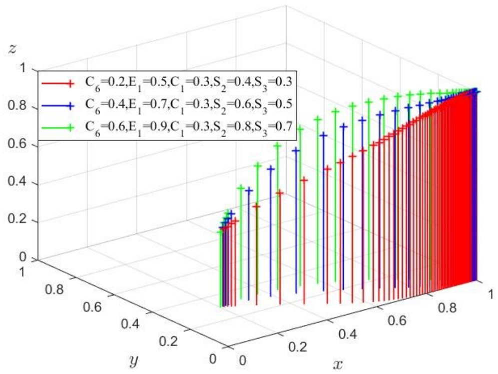


Figure 8. Combined factor impacts

6. Conclusion and Suggestion

6.1. Conclusion

Against the background that China's economy is in a critical period of green transformation, a three-party evolutionary game model of government and enterprise with the participation of environmental and social organizations is established to explore the evolutionary law of enterprises' green production behaviors. The equilibrium solution of the model is solved, and its local stability is analyzed according to the strategy selection and benefit distribution of the three parties. Then, numerical simulation methods are applied to study the evolutionary trajectories of the three parties' interactive behaviors to explore the effects of different parameters on the evolutionary results of the system, as well as the key factors and mechanisms affecting the system's evolution to reach the ideal state. Through the study, the following conclusions are drawn: (1) The choice of strategy for the implementation of green production by enterprises mainly depends on the costs and benefits brought about by the adoption of green production by enterprises. Secondly, there are factors such as the pressure and incentives exerted on enterprises by the government and environmental social organizations. (2) The choice of strategy for the government to regulate green production by enterprises depends on factors such as the resources that the government needs to invest in implementing the regulation, the losses caused by the government's laissez-faire, and the penalties and incentives that the government imposes on enterprises for both traditional and green production. (3) The choice of strategies for environmental and social organizations to monitor green production depends on the costs that environmental and social organizations need to pay to monitor enterprises, the financial support that environmental and social organizations can get to implement their monitoring strategies, and the subsidies that environmental, social organizations can provide to green production enterprises.

6.2. Suggestion

Based on this, the following possible countermeasures are proposed to address the environmental challenges facing China's economic green transformation:

(1) The government should act as a leader and coordinator of green production and environmental protection supervision, providing a favorable institutional environment and platform resources for enterprises and environmental social organizations. The government should not only incentivize enterprises to move towards green production by rewarding and punishing mechanisms and giving them subsidies and technological and communication support; it should also constrain their polluting behaviors by strengthening sewage charges and penalties and improving laws, regulations, and rules. At the same time, the government should also enhance the financial support for environmental and social organizations through the purchase of services, authorize environmental and social organizations to a certain degree of environmental protection supervision powers, and promote environmental and social organizations to take the initiative to participate in supervision.

(2) To realize green development, enterprises should improve their green production level. As the core force of green production, enterprises should take the initiative to carry out green innovation or adopt more energy-saving technology and equipment and apply the results of green production to the actual production process. With the government's encouraging policies and the innovative support of environmental and social organizations, enterprises should make full use of their resource advantages, strengthen the development of advanced technologies for green production and the promotion of green concepts, and reduce the cost of green production by improving the efficiency of resource utilization. At the same time, enterprises can increase the market demand and sales of green products through green marketing strategies, create a suitable green brand image, and obtain their competitive advantages from the perspective of market competition.

(3) Environmental social organizations are essential in promoting green production in enterprises and should strengthen their supervision and support. Environmental and social organizations can cooperate with enterprises to share environmental protection expertise and technology and help them improve production efficiency and reduce pollutant emissions. Environmental and social organizations can also build a communication platform between the government, enterprises, and the public to promote the environmental achievements and image of enterprises and create market demand for green products. In addition, environmental and social organizations can also supervise and constrain polluting enterprises that violate the law, use the media, the Internet, and other channels to expose the damage they cause to the environment, and, if necessary, initiate environmental lawsuits against them on behalf of the public interest, forcing them to assume legal responsibility.

6.3. Research limitation

While the study on China's economic green transformation presents insightful conclusions and practical suggestions, it also acknowledges limitations including the simplification of real-world dynamics, limited generalizability, data availability concerns, sensitivity to assumptions, the dynamic nature of environmental challenges, the scope of stakeholder perspectives, and the need for future research to employ more sophisticated modeling techniques and incorporate additional stakeholders' viewpoints to enhance the robustness and applicability of findings and policy recommendations.

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