Multi-stakeholder Strategic Interactions in Promoting the Green Belt and Road Initiative

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Abstract. The green Belt and Road Initiative (BRI) holds critical strategic importance for participating countries in addressing shared global sustainability challenges. This study develops a quadripartite evolutionary game framework involving four core stakeholders: the Chinese government, host governments, Chinese financial institutions, and Chinese enterprises. By employing computational simulations, the paper systematically identify key factors affecting the collaborative governance mechanisms essential for achieving green BRI objectives. These findings provide empirically recommendations for accelerating the development of green BRI.

Keywords: Green Belt and Road Initiative; Multi-stakeholder; Evolutionary Game.

1 Introduction

The Belt and Road Initiative (BRI) serves as a global economic cooperation platform to strengthen infrastructure development, improve comprehensive connectivity across regions, and cultivate new momentum for worldwide economic growth ([1], [2]). The BRI has achieved significant global engagement, with China signing more than 200 collaboration agreements involving 152 partner countries and 32 international organizations by August 2023. The major participating countries of the BRI are developing countries and their economic development is more dependent on fossil energy and resource-intensive industries. The massive consumption of fossil energy for industrialization and economic development leads to high carbon emissions and environmental degradation ([3]). By following the traditional economic development model, BRI countries would contribute to up to 66% of the total global carbon emission by 2050 ([4]).To achieve new vision of green development and United Nations'2030 Agenda for Sustainable Development, the green BRI has been promised by China's President in 2017 and established to promote new BRI investment projects emphasizing environmental friendliness.

China has issued a series of green investment policies and regulations, including the "The Belt and Road Ecological and Environmental Cooperation Plan" in 2017, the "Green Investment Principles" (GIP) in 2018, "Guidance on promoting investment and

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financing to address climate change" in 2020, "Green Development Guidelines for Overseas Investment and Cooperation" in 2021, and "Opinions on Jointly Promoting Green Development of the Belt and Road" in 2022, to promote green BRI construction. In 2023, Chinese President announced eight major steps to support joint pursuit of high-quality Belt and Road cooperation in the third Belt and Road Forum for International Cooperation. However, the development of green BRI is often affected by many kinds of policy objectives, and there is often a multi-stakeholder game behind the policy formulation. In addition to conventional policy factors such as climate, energy, the environment and people's livelihood, countries also have various laws and regulations tailored to their specific national circumstances. Therefore, this paper establishes a four-party evolutionary game model of the Chinese government, host governments, Chinese financial institutions and Chinese enterprises, and investigates multi-stakeholder strategic interactions in promoting the green BRI.

2 Methodology and Data Source

2.1 Methodology

Evolutionary game theory, which emerged from applying game theory to biological evolution, examines collective behavior under conditions of bounded rationality and emphasizes the dynamic equilibrium processes that arise through strategic interactions within populations ([5]). Recently, evolutionary game approach has been used to analyze the influence of various factors on each agent's strategy behavior in the field of Chinese green development. Most researches involved evolutionary game model with different combinations among the government, enterprises and consumers, and introduced different simulation models to examine the impact of Chinese government, Chinese enterprises and Chinese consumers on the strategic evolution of each agent ([6], [7], [8]).However, even though evolutionary game models have been widely used, few studies has applied it to the green BRI. Therefore, this paper systematically investigates the strategic interactions and evolutionary dynamics of multi-stakeholder collaboration under green BRI.

2.2 Problem Description and Basic Assumptions

The development of green BRI constitutes a multidimensional undertaking requiring coordinated efforts among multiple stakeholders, including the Chinese government, Chinese financial institutions, Chinese enterprises, and host country. While China's green investment policy framework has demonstrated notable evolution in regulatory sophistication and financing instrument innovation, implementation challenges persist due to heterogeneous national conditions across participating countries. These challenges manifest particularly in divergent sustainability prioritization levels within host governments, and institutional gaps in green infrastructure ecosystems. This complex environment creates a paradoxical landscape where emerging green financing mechanisms simultaneously confront structural barriers and unlock novel value-creation opportunities. The decision-making matrix governing development of green BRI re-

veals dynamic game-theoretic relationships, wherein stakeholders' strategic choices are continually reshaped by evolving incentive structures and risk perceptions. Based on the above reality background, the following basic assumptions are proposed, which involves parameter settings and definitions as shown in Table 1.

Hypothesis 1. According to the purpose of this research, there are four participants in quadrilateral evolutionary game model: Chinese government, host governments, Chinese financial institutions and Chinese enterprises. They are all limited rational and have found the optimal strategic solution through multiple games.

Hypothesis 2. The strategies of Chinese government are (active guidance, weak guidance). The Chines government and Chinese enterprises actively participate in green co-construction help to enhance the image of the country and obtain the overall income B_1. The proportion of overall income brought by the investment friendly policy environment is λ; When there is policy support, the total environmental income of green investment is E, and the environmental income when there is no support policy is $E_1(E_1<E)$, the proportion of China's income is α_1. When the Chinese government actively guides green investment and financing, it will gain P_1 due to the improvement of public reputation, otherwise it will lose P_1. The regulatory cost of the Chinese government and the subsidy cost for green investment enterprises are C_1 and S_1 respectively. The expected risk loss faced by Chinese enterprises when they make green investment is shared by the Chinese government, Chinese financial institutions and enterprises, and the Chinese government accounts for β_1.

Hypothesis 3. The host governments' strategic choice is (positive action, weak action). The overall income of the host government is B_2. Proportion of environmental benefits α_2, and the impact of public willingness on the host governments is P_2. The implementation cost of actively creating a good investment environment is C_2, and the cost of encouraging Chinese enterprises to make green investment is S_2.

Hypothesis 4. The strategies of Chinese financial institutions are (providing green financial support, not providing green financial support). When financial institutions carry out green financial business, the interest rate of green investment is θ_1, the traditional investment interest rate is $\theta_2(\theta_1<\theta_2)$. The business cost of green finance is C_3, and the business cost without green finance support is C_4 ($C_4 < C_3$). Obtain performance incentive W from the government, and income from public reputation is P_3. The share of expected risk loss of Chinese enterprise green investment shared by Chinese financial institutions is β_2.

Hypothesis 5. Chinese enterprises' strategic choice is (green investment, traditional investment). On the premise that consumers have a preference for green products, the operating income of enterprises choosing green investment and traditional investment is G_1 and G_2 respectively ($G_1 > G_2$). The operating costs of green investment and traditional investment are C_5 and C_6 respectively ($C_5 > C_6$), and the expected risk loss under the two investment situations is L_1 and L_2 respectively ($L_1 > L_2$). The impact of public willingness on Chinese enterprises is P_4. When Chinese financial institutions don't provide green financial support, the additional financing cost of enterprises is I.

Hypothesis 6. The probability of Chinese government choosing “active guidance” is x ($0 \le x \le 1$), then the probability of “weak guidance” is 1-x. Similarly, y($0 \le y \le 1$) represents the possibility of the host government selecting the strategy of “positive

action", while 1-y represents the possibility of the strategy of "weak action". $Z(0 \leq z \leq 1)$ represents the possibility of Chinese financial institutions selecting "providing green financial support", the possibility of "not providing green financial support" is 1-z. Finally, $v(0 \leq v \leq 1)$ is the possibility of Chinese enterprises choosing "green investment", then 1-v is the possibility of "traditional investment".

Table 1. Parameter symbols and meanings

Stakeholders	Parameters	Definitions
Chinese government	E	Total environmental benefits
	E_1	Environmental benefits of green investment without policy support
	α_1	China's proportion of environmental benefits
	P_1	Public willingness
	B_1	Overall benefits
	λ	Proportion of overall benefits brought by friendly policy environment
	C_1	Regulatory cost
	S_1	Subsidy cost
	β_1	Government share of expected risk loss of enterprise green investment
Host governments	α_2	Proportion of environmental benefits of the host governments
	P_2	Public willingness
	B_2	Overall benefits
	C_2	Execution cost
	S_2	Subsidy cost
Chinese financial institution	P_3	Public willingness
	W	Central Bank performance incentive
	θ_1	Green investment interest rate
	θ_2	Traditional investment interest rate
	C_3	Business cost of providing green financial support
	C_4	Business costs without green financial support
	β_2	Financial institutions share of expected risk loss of enterprise green investment
Chinese enterprises	G_1	Green investment operation income
	G_2	Traditional investment operation income
	P_4	Public willingness
	C_5	Input cost of green investment
	C_6	Input cost of traditional investment
	I	Extra financing costs
	L_1	Expected risk loss of green investment
	L_2	Expected risk loss of traditional investment

2.3 Data Source

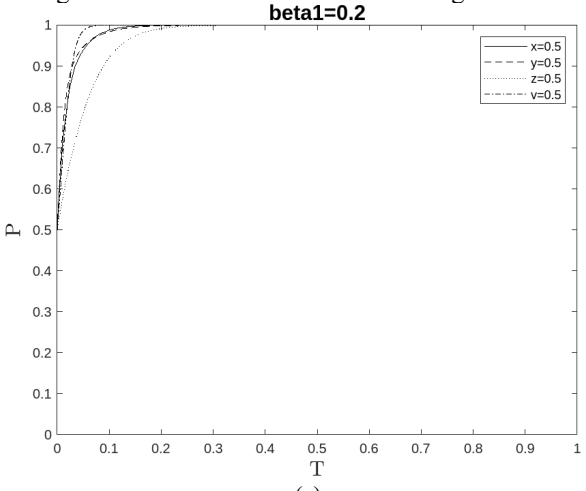
In order to intuitively analyze the influence of key factors in the replication dynamic system on the evolution process and results of quadrilateral evolutionary game of green BRI cooperation, this paper uses MATLAB_ R2021b simulates the evolution trajectories of all parties. When $E_{16}(1, 1, 1, 1)$ strategy combination is formed, the system has achieved an ideal stable state at the current stage, that is, Chinese government chooses "Active guide", the host governments choose "Positive action", Chinese financial institutions choose "Providing green financial support", and Chinese enterprises choose "Green investment".

The paper chooses to conduct simulation analysis on the process of each parameter affecting the strategy selection of the game players under the scenario $E_{16}(1, 1, 1, 1)$. Referring to the assignment method in this literature, the initial values of key variables are set as follows: $E=50$, $E_1=30$, $\alpha_1=0.3$, $\alpha_2=0.5$, $P_1=15$, $P_2=18$, $P_3=20$, $P_4=30$, $B_1=100$, $B_2=120$, $\lambda=0.4$, $C_1=10$, $C_2=15$, $C_3=36$, $C_4=35$, $C_5=114$, $C_6=86$, $S_1=16$, $S_2=16$, $\beta_1=0.3$, $\beta_2=0.3$, $W=3.6$, $\theta_1=0.4$, $\theta_2=0.5$, $G_1=200$, $G_2=150$, $I=20$, $L_1=100$, $L_2=50$.Let the horizontal axis represent time (t), and the vertical axis represent the probability (p) that the Chinese government (x), the host government (y), the Chinese financial institutions (z) and the Chinese enterprises (v) choose their own strategies.

3 Empirical Research

3.1 Influence of Key Parameters on Chinese Government's Decision

This section analyzes the impact of subsidy cost S_1, Chinese government share of expected risk loss of Chinese enterprise green investment β_1, public willingness's evaluation of Chinese government P_1 and overall benefits B_1 on the system evolution under the condition that other parameters keep unchanged. The influence of key parameters on Chinese government's decision is shown in Figure 1.



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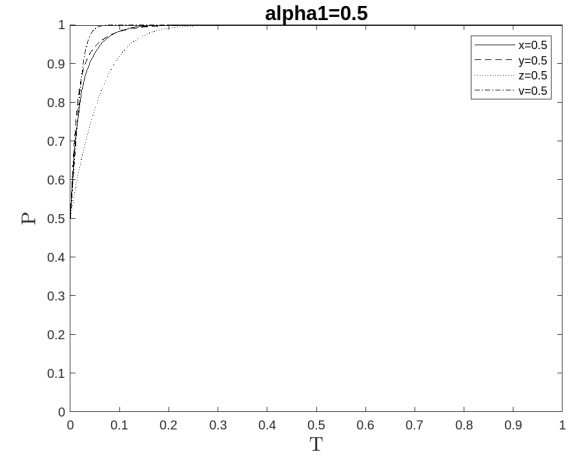

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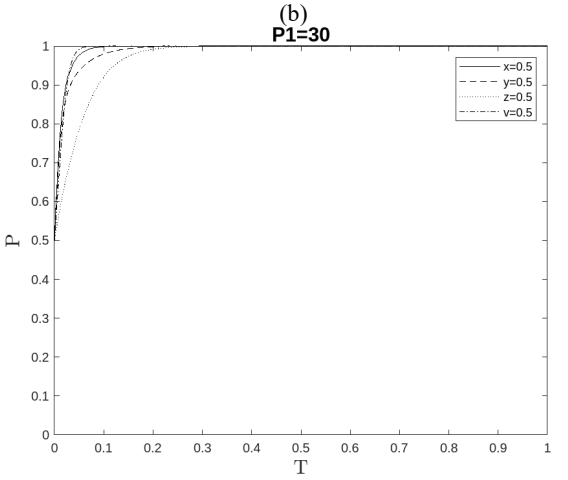

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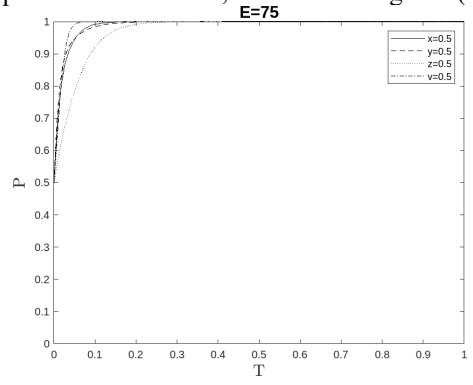
Fig. 1. Influence of key parameters on Chinese government's decision

As shown in the Figure 1, when the proportion of investment risks shared by the Chinese government decreased from β_1=0.3 to β_1=0.2, the Chinese government enhanced its willingness to actively participate in green co-construction and even reached stable strategies ahead of schedule at a rate higher than that of the host country. Meanwhile, the Chinese government's sharing of investment losses has increased the probability of formulating positive guiding policies, providing guarantees for Chinese enterprises and Chinese financial institutions. The influence of the change in public willingness P_1 on the decision-making of the Chinese government is obvious among the three parameters. When P_1 increases from 15 to 30, the Chinese government reaches the stable strategy at t=0.1, indicating that public willingness plays a significant role in motivating the Chinese government to choose positive guidance and achieve good interaction of the system.

3.2 Influence of Key Parameters on Host Governments' Decision

This section analyzes the influence of proportion of overall benefits brought by friendly policy environment λ, environmental benefits of green investment without policy support E_1, public willingness P_2 and subsidy cost S_2 on the system evolution under the condition of other parameters remain unchanged. The influence of key parameters on host government's decision is shown in Figure 2.

When the environmental benefit E increased from 50 to 75, both the Chinese government and host governments achieved positive guidance and evolutionary stable strategies in advance at t=0.15 and t=0.2 respectively, as shown in Figure 2(a). Meanwhile, the increase in public willingness P_2 also prompts the host governments to be more inclined to choose active actions as shown in Figure 2(b). The performance of the government and Chinese enterprises in green construction jointly determines the direction and intensity of the green transformation. When the proportion of the overall benefits of the host country's sustainable development restricted by government policies increases, that is, λ rises from 0.4 to 0.6, the tendency of the Chinese government and host governments actively participate in green co-construction further strengthens. However, the impact on the evolution paths of Chinese financial institutions and enterprises is not obvious, as shown in Figure 2(c).



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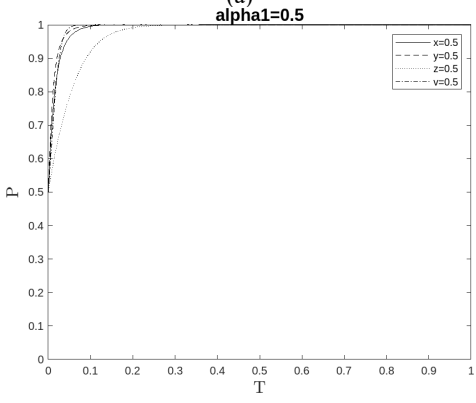

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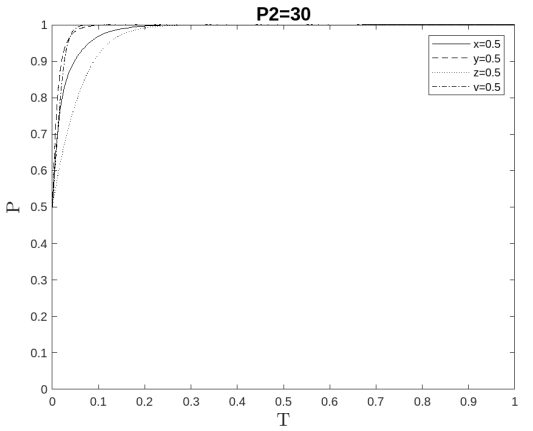

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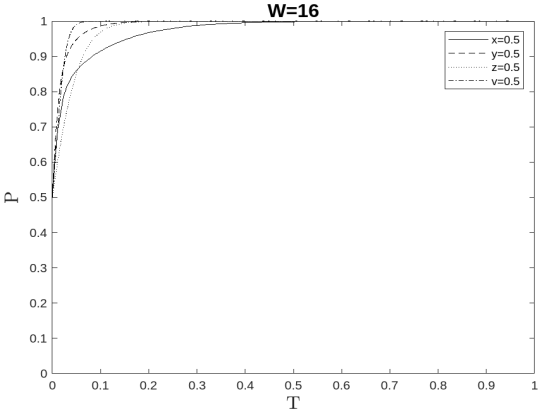
Fig. 2. Influence of key parameters on host governments' decision

3.3 Influence of Key Parameters on Chinese Financial Institutions' Decision

This section analyzes the impact of Chinese financial institutions share of expected risk loss of Chinese enterprise green investment β_2, public willingness P_3 and Central Bank performance incentive W on the system evolution under the condition of other parameters keep unchanged. The influence of key parameters on Chinese financial institutions' decision is shown in Figure 3.The changes in the three parameters have all enhanced the tendency of Chinese financial institutions to provide green financial support. When P_3 was raised from 20 to 30, the speed at which Chinese financial institutions evolved towards the evolutionary stable strategy exceeded that of the Chinese government and the host governments. The variations of W and β_2 have certain promoting effect on the participation of Chinese financial institutions. However, the increase in performance incentives and the risk of expected losses have expanded the supervision cost of the Chinese government, thereby weakening its enthusiasm for participating in green BRI.



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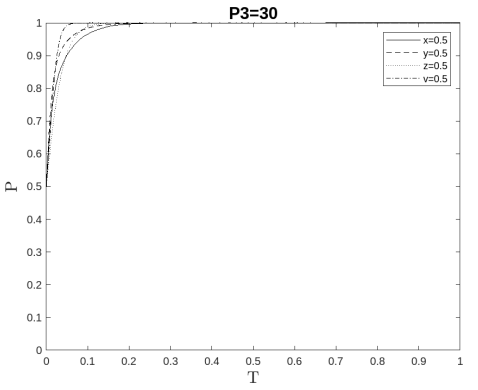

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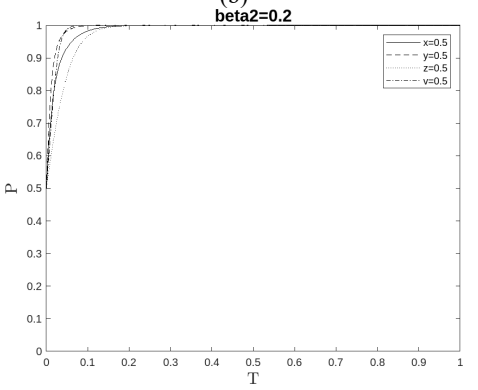

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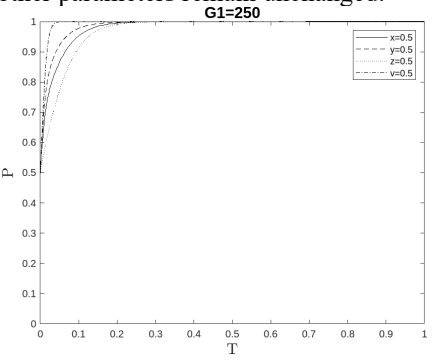
Fig. 3. Influence of key parameters on Chinese financial institutions' decision

3.4 Influence of Key Parameters on Chinese Enterprises' Decision

This section analyzes the influence of green investment operation income G_1, Extra financing costs I and expected risk loss of green investment L_1 on the system evolution under the condition of other parameters remain unchanged.



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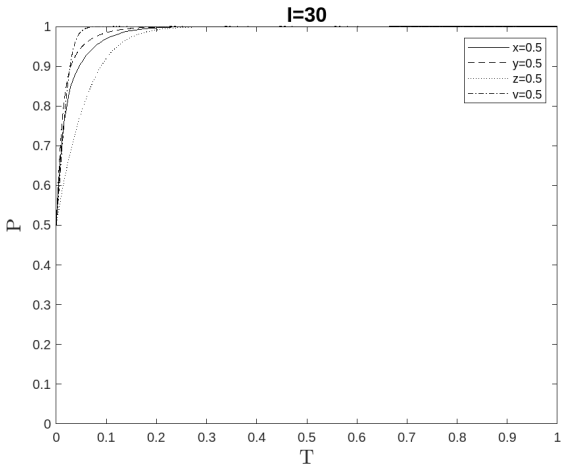

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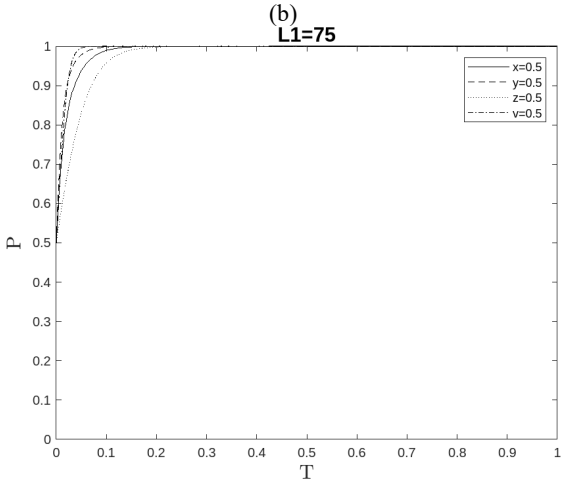

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Fig. 4. Influence of key parameters on Chinese enterprises' decision

Figure 4(a) shows the evolution path of the four-party game when the G_1 of green investment operation income increases from 200 to 250. When the market recognition of green investment projects generally improves, the expected return increases, and the operational uncertainty decreases, the probability of Chinese financial institutions and Chinese enterprises choosing to provide green financial support and make green investments significantly increases. When I increases to 30, Chinese enterprises exhibit a moderated inclination to engage in green investments. As shown in Figure 4(c), even when the anticipated risk losses associated with green investments rise, the evolutionary outcomes do not deteriorate under the condition that the Chinese government fully utilizes subsidies and incentive measures. This indicates that the active guidance of Chinese government has become the key factor to the positive interaction of the dynamic system.

4 Conclusion

This paper constructs a four-party evolutionary game model including Chinese government, the host governments, Chinese financial institutions and Chinese enterprises. Based on the model analysis and simulation results, the important factors affecting the strategic choices of each actor are systematically analyzed, and the following important conclusions are obtained. Firstly, in the early stages of green BRI, the strategic decisions of all participating entities exhibit significant interdependence. When Chinese enterprises and Chinese financial institutions display a weak initial willingness to engage in practical efforts, the Chinese government and the host governments can effectively drive the strategic choice direction of market entities through institutional design. Secondly, the risk-loss sharing mechanism in green investment and financing enhances evolutionary stability by mitigating uncertainties. It is critical to emphasize that the government's financial burden should remain within an optimal range. Thirdly, the improvement of green investment and operation returns is the important driving force for Chinese enterprises to practice green investment, while the effective control of risk losses can significantly enhance the system's evolution stability towards an ideal equilibrium state. Finally, the improvement of public willingness can not only accelerate the convergence of the system towards the optimal strategy combination, but also enhance the collaborative participation level of the four parties through the social supervision mechanism.

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