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Original Research

The Impact of Environmental Regulations on Green Collaborative Innovation in China: An Analysis Based on an Evolutionary Game Perspective

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Abstract

Reasonable environmental regulation is beneficial to promote green innovation and sustainable development, but the current lack of research of environmental regulation and collaborative innovation intention. Based on this, this paper constructs an evolutionary game model of green collaborative innovation between enterprises and financial institutions from the perspective of enterprise information disclosure and financing constraints, and explores the specific effects of different types of environmental regulation through case analysis and numerical simulation. Case studies show that the cooperation between enterprises and financial institutions is conducive to the realization of green innovation, but there is still no effective restraint mechanism. The numerical simulation results show that the combination of market-incentive and command-controlled environmental regulation can better stimulate the willingness of collaborative innovation, but the former has more significant incentive effect. Further, for enterprises, the government's cost subsidy or revenue incentive coefficient positively affects the cooperative innovation willingness of both parties. Similarly, the improvement of the cost subsidy or income incentive or even punishment coefficient by the government to financial institutions also has the same effect; increasing the cost subsidy coefficient is more significant, and enterprises are more sensitive to this. This paper provides reference for Chinese government to make reasonable environmental policy.

Keywords: sustainable development, green collaborative innovation, environmental regulation, evolutionary game

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Introduction

Environmental protection has been at the forefront of international concern [1]. The 2030 Agenda for Sustainable Development issued by the United Nations states that economic growth cannot come at the expense of the environment. It can be seen that the coordinated development of economy and environment is the theme of the new era, and it is also the requirement of China's sustainable development [2-4]. In recent years, China has gradually implemented a green economic transformation and development strategy to promote the coordinated development of economy and environment [5-6]. Green innovation theory points out that green innovation can maintain economic growth while ensuring ecological benefits [7], which is an important way to achieve sustainable economic development. Presently, green collaborative innovation has become a new paradigm of green innovation, which is conducive to breaking the phenomenon of "isolated islands" of innovation, promoting green knowledge sharing [8-10], and is an important means to achieve sustainable development. According to the theory of planned behavior, intention is the key to determine the subject's behavior [11]. Therefore, increasing the willingness of green collaborative innovation participants to cooperate is conducive to promoting the success of green innovation and realizing the green transformation of China's economy.

Environmental regulation (ER) is a tool for the government to implement environmental policies [12-14], and it is also one of the main means to promote green collaborative innovation in China. Through clear rules and incentive measures, part of the cost of green innovation is reduced and the willingness of participants in green collaborative innovation is improved. Yang et al. [15] points out that ER can promote enterprises and universities to adopt collaborative innovation strategies. Guo et al. [16] pointed out that effective environmental regulation is conducive to promoting enterprises and R&D institutions to carry out green technology R&D. Therefore, reasonable ER is conducive to promoting green collaborative innovation. However, different types of environmental regulations differ in their environmental protection goals and implementation [11, 17]. Chen et al. [18] and Shen et al. [19] at the provincial level, demonstrated differences in the impact of different types of ER on green innovation. Liu et al. [20] pointed out that various environmental regulations implementation situation is different, lead to differences between green innovation progress rate. He et al. [21] found that environmental penalties have a greater impact on enterprise environmental investment than subsidies. Shi and Li [22] found that each type of ER has different impacts on enterprise green technology innovation. Sun et al. [23] pointed out that heterogeneous ER would play different roles in enterprise innovation. In other words, in order to promote green collaborative innovation and improve the development quality of green innovation in China, the government needs to design targeted support systems and differentiated policy arrangements for participants in green collaborative innovation.

According to the theory of green innovation, the interest conflicts of stakeholders will hinder the realization of green innovation [24]. Nevertheless, green collaborative innovation involves multiple stakeholders and many conflicts of interest, which will cause great obstacles to its realization. Therefore, the formulation of ERs should be combined with the interests of innovation subjects to reduce their potential conflicts of interest and improve their willingness to participate in cooperation. In view of this, the premise of the formulation of ER by the government is to clarify the main participants of collaborative innovation and their interest relationships. Enterprises are the main body of green collaborative innovation [23], but the cycle of green innovation is long, the risk is great, and the social benefit is greater than the personal benefit [25-26], so the green innovation of enterprises often faces high financing constraints [27]. At this time, enterprises will reduce green innovation to maximize their own interests. Encouraging financial institutions to participate in green collaborative innovation can provide sufficient funds for enterprises' green innovation [28]. However, in the process of collaborative innovation, due to the information asymmetry with enterprises, the investment risk is too high [29], which will reduce their investment willingness. In other words, enterprises' information disclosure will affect financial institutions' choice of green investment. Strengthening government supervision and urging enterprises to disclose environmental information will help improve financial institutions' willingness to invest and overcome obstacles to green financing of enterprises [30-31]. Meanwhile, the government can also reduce the cost of financial institutions and enterprises to participate in green innovation through subsidies and other means, and improve the willingness to cooperate [32].

In summary, green collaborative innovation can promote resource sharing and increase the possibility of successful green innovation, which is an important approach to successful economic green transformation. Among others, enterprises and financial institutions are important participants in green collaborative innovation, and strengthening the information disclosure of enterprises would facilitate the realization of collaborative innovation of enterprises and financial institutions. But in reality, enterprises often withhold information for their own interests, which reduces the willingness of financial institutions to make green investments. In order to improve the willingness of both sides to cooperate, it is necessary for the government to guide enterprise information disclosure and promote green investment of financial institutions through environmental regulation. At present, the academic circle has confirmed the positive role of ER in the process of green collaborative innovation [15], and also proved that different types of ER have different effects

on green innovation [18-20, 22]. However, the specific role of different types of ER from the perspective of green collaborative innovation willingness is still lacking. In this case, this article aims to analyze the interest relationship between enterprises and financial institutions in green collaborative innovation from the perspective of enterprise information disclosure and financing constraints, and explore the impact of China's current major environmental policy tools on the strategic choice of both parties. The theoretical research on the relationship between ER and green innovation will be enriched from the perspective of collaborative innovation willingness, and it will provide reference for Chinese government to formulate reasonable ER.

Specifically, the main contributions of this paper are as follows: First, this paper explores the impact of different types of ER on green innovation from the perspective of cooperation willingness of participants in green collaborative innovation, enriching the theoretical research on the relationship between ER and green innovation. Second, from the perspective of enterprise information disclosure and financing constraints, the evolutionary game model of green collaborative innovation between enterprises and financial institutions under different ERs is constructed to analyze the evolutionary process of their collaborative innovation interests and strategic choices. Third, through case analysis and numerical simulation, it identifies the main factors that influence the choice of green collaborative innovation strategy between enterprises and financial institutions under different ERs, and provides reference for the government to formulate and reasonably adjust the intensity of ER policy.

The rest of the article is arranged as follows. Section 2 discusses the rationality of the application of research methods and constructs an evolutionary game model. Section 3 presents the case analysis and numerical simulation results, and discusses the results. Section 4 summarizes the conclusions of this study and further puts forward policy suggestions and research limitations.

Material and Methods

Basis of the Evolutionary Game Model

The evolutionary game theory originated from the game analysis of the conflict and cooperation behaviors of animals and plants by genetic ecologists. Since then, it has been widely used in various disciplines other than biology and has been continuously seen in academic research in multiple fields [33-35]. Unlike the perfect ideal hypothesis of the classical game theory, the evolutionary game theory assumes that players choose different strategies and then dynamically influence the choices of other players. The evolutionary game theory not only realizes behavioral analysis and prediction of multiple players' strategy choices but also analyzes the possibility of each player choosing a particular strategy [36]. When the balance achieved by game participants is not in line with the maximization of collective interests, the evolutionary game model can introduce government incentives, punishments, and other measures to ensure that the strategy choices of game participants achieve ideal equilibrium [35, 37]. At present, evolutionary game theory has been widely used to discuss the equilibrium strategy [15, 38], evolution law [39-40] and the influence mechanism of strategy selection of cooperative participants [32]. It provides a theoretical basis for this paper.

The main participants of green collaborative innovation in this study include the government, enterprises and financial institutions. The government plays a role of supervision in collaborative innovation, mainly through command-controlled environmental regulation (CER) and market-incentive environmental regulation (MER) to improve the willingness of enterprises and financial institutions to innovate collaboratively [11]; there are two main strategies for enterprises in the innovation process, namely disclosing information and concealing information; financial institutions also have two strategies, investment and not investment. In the process of strategy selection, enterprises and financial institutions are ultimately based on maximizing their own interests, and their main interests are shown in Fig. 1. By implementing environmental regulation strategies, the government urges enterprises to actively disclose environmental information [31], reduces the risk of green investment by financial institutions, improves the recognition of green development by financial institutions, and promotes green collaborative innovation between enterprises and financial institutions [32]. It can be seen that the interests of enterprises and financial institutions are affected by the strategic choice of the other party. Therefore, based on the relationship between the interests of both parties, analyzing and predicting their collaborative innovation strategy selection behavior is conducive to better clarifying the specific impact of different types of ER on green collaborative innovation.

Evolutionary game theory is applicable to research on the evolutionary process and rules of strategy choice of multiple players with interests. It can also realize the ideal state of strategy evolutionary balance of game players by introducing government incentives, punishments and other measures [35, 37, 41], which can theoretically solve the research problems of this paper. Specifically, from an economic perspective, the green collaborative innovation of enterprises and financial institutions mainly involves the interest game of the two parties. In addition, green innovation has a long period for profit realization and a higher social income than personal income [26]. Therefore, the government should conduct environmental supervision to achieve the ideal stable state of game between enterprises and financial institutions. The government has different strategies for ER [11], and the evolutionary game model can replicate

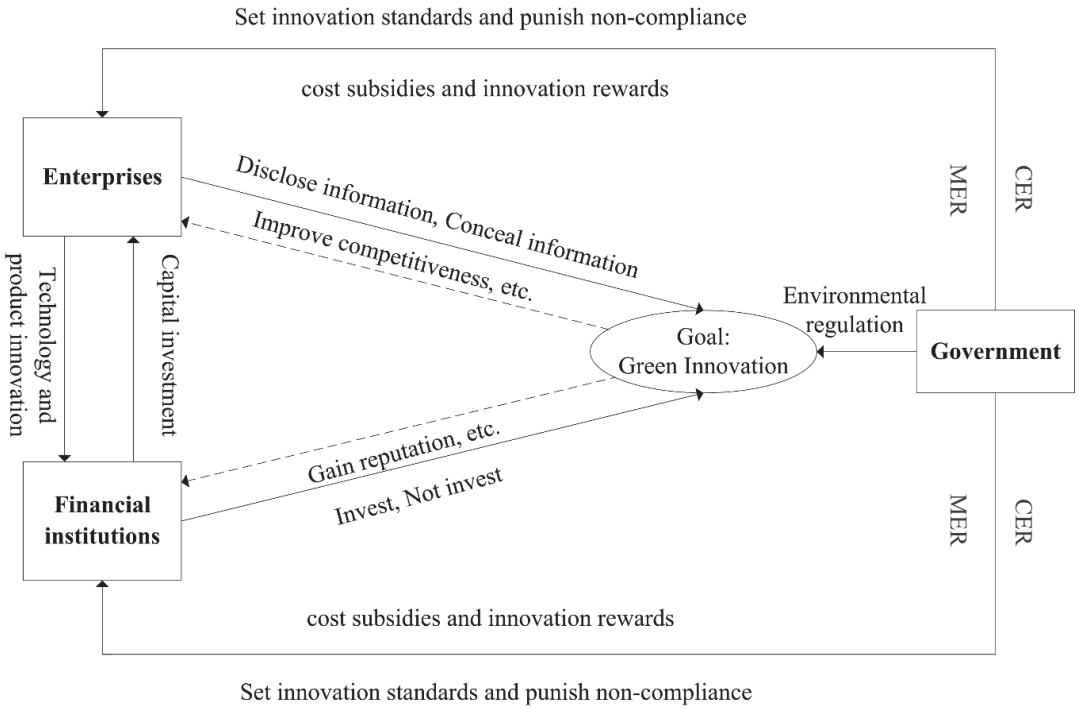

Fig. 1. The relationship between the main stakeholders in the green collaborative innovation.

the dynamic equation to simulate the adjustment process of enterprises' and financial institutions' strategies when the government adopts different types of ER [36]. From a practical perspective, the different types of government environmental regulation policy, in the actual process of quantitative is difficult, and in this paper, based on the evolutionary game model to construct, using case analysis and numerical simulation research method of combining, from the perspective of combination of qualitative and quantitative methods clear government implement multiple effects of different types of environmental regulation strategy. Accordingly, building different types of ER, enterprises and financial institutions green collaborative innovation evolutionary game model, can well reflect the evolution path of both behavior and the stable strategies, and implement different government environmental regulation strategy implementation process simulation, for the government reasonably adjust the environmental regulation strategy, promote green collaborative innovation has an important significance.

It should be emphasized that although most existing studies take the government as the main body of the game to study the role of ER [16, 38], this paper considers that the government as the main body of collaborative innovation in the evolutionary game model only considers its demands for economic interests, while ignoring its emphasis on social interests. Therefore, different from most previous studies, this paper takes government regulatory measures as the external innovation environment [15]. Based on the perspective of enterprise financing constraints and information disclosure, the evolutionary game model of enterprises and financial institutions without environmental regulation (No ER), CER, MER and hybrid environmental regulations (CER&MER) is constructed to explore the impact of different types of environmental regulatory measures adopted by the government on the choice of green collaborative innovation strategies between enterprises and financial institutions. It provides reference for the government to formulate a combination of differentiated environmental policy system and reasonably adjust the intensity of different environmental policy tools.

Problem Description, Assumptions and Notations

CER and MER adopted by the government are the main driving forces for enterprises and financial institutions to participate in green collaborative innovation. Among them, CER, also known as compulsory control policy methods, generally refer to environmental management methods through which administrative authorities formulate various environmental standards to improve environmental quality in accordance with specific laws, regulations, rules, and other environmental regulatory documents [42]. MER, also known as market-based regulatory tools, means that administrative authorities internalize social costs and benefits into production costs and benefit outputs by introducing market mechanism, and guide producers and consumers to re-evaluate the costs and benefits of green products, so as to realize the purpose of environmental protection [11]. In order to construct the evolutionary game model of green

collaborative innovation between enterprises and financial institutions under different ERs, it is necessary to clarify the interest relationship between enterprises and financial institutions under different strategic choices of green collaborative innovation. Based on this, the following basic assumptions are proposed:

Assumption 1: The subjects of this game analysis include enterprises and financial institutions in green collaborative innovation. We set the enterprises as *A* and the financial institutions as *B*. The behavioral decision of enterprises (*A*) in the process of green collaborative innovation is to disclose or conceal information, and financial institutions (*B*) in the process of green collaborative innovation is to invest or not invest.

Assumption 2: Both enterprises' information disclosure and financial institutions' green investment require certain costs, and both parties will get different benefits under multiple strategies.

Assumption 3: Referring to the study of CER by Ren et al. [5] and Tang et al. [42], it is set that when the government adopts CER, it will establish the green collaborative innovation standard and implement certain punishment measures when the subjects of collaborative innovation do not meet the standard.

Assumption 4: Referring to the study of MER by Ren et al. [5], Peng et al. [11], and Pan et al. [43], and in order to be different from CER, it is set that when the government adopts MER, it mainly exists in the form of green subsidy and innovation reward. Simultaneously, if there is a negative attitude towards green collaborative innovation, it will bear the cost subsidy and income reward of the other party.

The notations of the variables and the parameters used in this study are as follows:

x: The probability that the enterprises disclose information.

y: Probability of investment by financial institutions.

p_1: The income of the enterprises when the financial institutions invest.

p_2: The income of the enterprises when the financial institutions do not invest ($p_1 > p_2$).

q_1: Financial institutions' investment income when enterprises disclose information.

q_2: Financial institutions' investment returns when enterprises conceal information ($q_1 > q_2$).

q_3: Financial institutions do not invest income.

C_1: The cost of enterprises disclosure information.

C_2: Investment costs of financial institutions.

G_1: Green innovation standards set by the government for enterprises.

G_2: Green innovation standards set by the government for financial institutions.

a_1: The government's penalty factor for non-compliance enterprises ($a_1 \geq 0$).

a_2: The government's penalty factor for non-compliant financial institutions ($a_2 \geq 0$).

β_1: The government's cost subsidy coefficient for enterprises ($0 \leq \beta_1 \leq 1$).

β_2: The government's cost subsidy factor for financial institutions ($0 \leq \beta_2 \leq 1$).

η_1: The government's income incentive coefficient for enterprises ($\eta_1 \geq 0$).

η_2: The government's income incentive coefficient for financial institutions ($\eta_2 \geq 0$).

Payment Matrix Analysis of Game Subject under Different ERs

According to the basic assumptions of the game model above, payment matrices with multiple strategies of enterprises and financial institutions under different ERs are constructed, as shown in Table 1.

According to Table 1, are calculated respectively under different ERs replicated dynamic equation of enterprises and financial institutions.

For No ER:

Suppose that E_{A1} is the expected income of enterprises when they choose to "disclose information", then E_{A2} is the expected income of enterprises when they choose to "conceal information". The equation expressing this is as follows:

$$E_{A1} = y(p_1 - C_1) + (1-y)(p_2 - C_1) \tag{1}$$

$$E_{A2} = yp_1 + (1-y)p_2 \tag{2}$$

The replicator dynamics equation of enterprise replication is as follows:

$$F(x) = \frac{dx}{dt} = x(1-x)(-C_1) \tag{3}$$

Similarly, the replicator dynamics equation of financial institution replication is as follows:

$$F(y) = \frac{dx}{dt} = y(1-y)\left[x(q_1 - q_2) + q_2 - q_3 - C_2\right] \tag{4}$$

Equations (3) and (4) constitute the two-dimensional dynamic system of enterprises and financial institutions.

In the same way, the replicator dynamics equation of enterprises and financial institutions can be obtained under CER:

$$F'(x) = \frac{dx}{dt} = x(1-x)(-C_1) \tag{5}$$

$$F'(y) = \frac{dx}{dt} = y(1-y)\Big[x\left(q_1 - q_2 + \alpha_2 q_1 - \alpha_2 q_2\right) + q_2 - q_3 - \alpha_2 q_3 - C_2 + \alpha_2 q_2\Big] \tag{6}$$

Table 1. The payment matrix of the primary strategy under different ERs.

			Financial institution (B)	
			Invest (y)	Not invest (1–y)
No ER	Enterprise (A)	Disclose information (x)	$p_1 - C_1$ $q_1 - C_2$	$p_2 - C_1$ q_3
		Conceal information (1- x)	p_1 $q_2 - C_2$	p_2 q_3
CER	Enterprise (A)	Disclose information (x)	$p_1 - C_1 - \alpha_1(G_1 - p_1)$ $q_1 - C_2 - \alpha_2(G_2 - q_1)$	$p_2 - C_1 - \alpha_1(G_1 - p_2)$ $q_3 - \alpha_2(G_2 - q_3)$
		Conceal information (1- x)	$p_1 - \alpha_1(G_1 - p_1)$ $q_2 - C_2 - \alpha_2(G_2 - q_2)$	$p_2 - \alpha_1(G_1 - p_2)$ $q_3 - \alpha_2(G_2 - q_3)$
MER	Enterprise (A)	Disclose information (x)	$p_1 - C_1 + \beta_1 C_1 + \eta_1 p_1$ $q_1 - C_2 + \beta_2 C_2 + \eta_2 q_1$	$p_2 - C_1 + \beta_1 C_1 + \eta_1 p_2$ $q_3 - \beta_1 C_1 - \eta_1 p_2$
		Conceal information (1- x)	$p_1 - \beta_2 C_2 - \eta_2 q_2$ $q_2 - C_2 + \beta_2 C_2 + \eta_2 q_2$	p_2 q_3
CER& MER	Enterprise (A)	Disclose information (x)	$p_1 - C_1 - \alpha_1(G_1 - p_1) + \beta_1 C_1 + \eta_1 p_1$ $q_1 - C_2 - \alpha_2(G_2 - q_1) + \beta_2 C_2 + \eta_2 q_1$	$p_2 - C_1 - \alpha_1(G_1 - p_2) + \beta_1 C_1 + \eta_1 p_2$ $q_3 - \alpha_2(G_2 - q_3) - \beta_1 C_1 - \eta_1 p_2$
		Conceal information (1- x)	$p_1 - \alpha_1(G_1 - p_1) - \beta_2 C_2 - \eta_2 q_2$ $q_2 - C_2 - \alpha_2(G_2 - q_2) + \beta_2 C_2 + \eta_2 q_2$	$p_2 - \alpha_1(G_1 - p_2)$ $q_3 - \alpha_2(G_2 - q_3)$

In the same way, the replicator dynamics equation of enterprises and financial institutions can be obtained under MER:

$$F^{''}(x) = \frac{dx}{dt} = x(1-x)\left[y\left(\eta_1 p_1 - \eta_1 p_2 + \beta_2 C_2 + \eta_2 q_2\right) - C_1 + \beta_1 C_1 + \eta_1 p_2\right] \quad (7)$$

$$F^{''}(y) = \frac{dx}{dt} = y(1-y)\left[x\left(q_1 + \eta_2 q_1 - q_2 - \eta_2 q_2 + \beta_1 C_1 + \eta_1 p_2\right) + q_2 - q_3 - C_2 + \beta_2 C_2 + \eta_2 q_2\right] \quad (8)$$

In the same way, the replicator dynamics equation of enterprises and financial institutions can be obtained under CER&MER:

$$F^{'''}(x) = \frac{dx}{dt} = x(1-x)\left[y\left(\eta_1 p_1 - \eta_1 p_2 + \beta_2 C_2 + \beta_2 C_2 + \eta_2 q_2\right) - C_1 + \beta_1 C_1 + \eta_1 p_2\right] \quad (9)$$

$$F^{''}(y) = \frac{dy}{dt} = y(1-y)\begin{bmatrix} x\left(q_1 + \alpha_2 q_1 + \eta_2 q_1 - q_2 - \alpha_2 q_2 - \eta_2 q_2 + \beta_1 C_1 + \eta_1 p_2\right) + q_2 - C_2 \\ + \alpha_2 q_2 - \alpha_2 q_3 + \beta_2 C_2 + \eta_2 q_2 - q_3 \end{bmatrix} \quad (10)$$

Asymptotic Stability Analysis of Game Subject under Different ERs

Step 1. Calculate the stability points and Jacobian matrix of enterprises and financial institutions under different ERs.

For No ER: let $F(x) = 0$ and $F(y) = 0$. Then, the evolutionary stability point of enterprises and financial institutions can be obtained by $E_1(0,0)$, $E_2(0,1)$, $E_3(1,0)$, E_4 (1,1). To further determine the state of the four points, the partial derivation of Equations (3) and (4) can be computed to obtain the following Jacobian matrix of the evolutionary system of the game subject under No ER:

$$J_1 = \begin{bmatrix} (1-2x)(-C_1) & 0 \\ y(1-y)(q_1 - q_2) & (1-2y)\left[x(q_1 - q_2) + q_2 - q_3 - C_2\right] \end{bmatrix} \quad (11)$$

For CER: let $F'(x) = 0$, $F'(y) = 0$; then, the evolutionary stability points of enterprises and financial institutions can be obtained as $E_1(0,0)$, $E_2(0,1)$, E_3 (1,0), and $E_4(1,1)$. To further determine the state of the four points, the

partial derivation of Equations (5) and (6) can be computed to obtain the following Jacobian matrix of the evolutionary system of the game subject under CER:

$$J_2=\begin{bmatrix}(1-2x)(-C_1) & 0\\ y(1-y)(q_1-q_2+\alpha_2q_1-\alpha_2q_2) & (1-2y)\begin{bmatrix}x(q_1-q_2+\alpha_2q_1-\alpha_2q_2)\\+q_2-q_3-\alpha_2q_3-C_2+\alpha_2q_2\end{bmatrix}\end{bmatrix} \tag{12}$$

For MER: let $F''(x) = 0$, $F''(y) = 0$, and for the convenience of calculation, let $A^*=\frac{-q_2+q_3+C_2-\beta_2C_2-\eta_2q_2}{q_1+\eta_2q_1-q_2-\eta_2q_2+\beta_1C_1+\eta_1p_2}$ and $B^*=\frac{C_1-\beta_1C_1-\eta_1p_2}{\eta_1p_1-\eta_1p_2+\beta_2C_2+\eta_2q_2}$, the evolutionary stability points of enterprises and financial institutions can be obtained as E_1 (0,0), E_2(0,1), E_3(1,0), E_4(1,1) and $E_5(A^*, B^*)$, respectively. For further estimation, the Jacobian matrix of the game subject evolution system under MER can be obtained through the partial derivative of Equations (7) and (8) as follows:

$$J_3=\begin{bmatrix}(1-2x)\begin{bmatrix}y\begin{pmatrix}\eta_1p_1-\eta_1p_2\\+\beta_2C_2+\eta_2q_2\end{pmatrix}\\-C_1+\beta_1C_1+\eta_1p_2\end{bmatrix} & x(1-x)\begin{pmatrix}\eta_1p_1-\eta_1p_2\\+\beta_2C_2+\eta_2q_2\end{pmatrix}\\ y(1-y)\begin{pmatrix}q_1+\eta_2q_1-q_2-\eta_2q_2\\+\beta_1C_1+\eta_1p_2\end{pmatrix} & (1-2y)\begin{bmatrix}x\begin{pmatrix}q_1+\eta_2q_1-q_2-\eta_2q_2\\+\beta_1C_1+\eta_1p_2\end{pmatrix}\\+q_2-q_3-C_2+\beta_2C_2+\eta_2q_2\end{bmatrix}\end{bmatrix} \tag{13}$$

For CER&MER: let $F''(x) = 0$, $F''(y) = 0$, and for the convenience of calculation, let $A^*=\frac{-q_2+q_3+C_2-\beta_2C_2-\eta_2q_2-\alpha_2q_2+\alpha_2q_3}{q_1+\alpha_2q_1+\eta_2q_1-q_2-\alpha_2q_2-\eta_2q_2+\beta_1C_1+\eta_1p_2}$, $B^*=\frac{C_1-\beta_1C_1-\eta_1p_2}{\eta_1p_1-\eta_1p_2+\beta_2C_2+\eta_2q_2}$, then the evolutionary stability point of enterprises and financial institutions can be obtained as E_1(0,0), E_2(0,1), E_3(1,0), E_4(1,1), and $E_5(A^*, B^*)$. For further estimation, the following Jacobian matrix of the game subject evolutionary system under CER&MER can be obtained through the partial derivative of Equations (9) and (10):

$$J_4=\begin{bmatrix}(1-2x)\begin{bmatrix}y\begin{pmatrix}\eta_1p_1-\eta_1p_2\\+\beta_2C_2+\eta_2q_2\end{pmatrix}\\-C_1+\beta_1C_1+\eta_1p_2\end{bmatrix} & x(1-x)\begin{pmatrix}\eta_1p_1-\eta_1p_2\\+\beta_2C_2+\eta_2q_2\end{pmatrix}\\ y(1-y)\begin{pmatrix}q_1+\alpha_2q_1+\eta_2q_1\\-q_2-\alpha_2q_2-\eta_2q_2\\+\beta_1C_1+\eta_1p_2\end{pmatrix} & (1-2y)\begin{bmatrix}x\begin{pmatrix}q_1+\alpha_2q_1+\eta_2q_1\\-q_2-\alpha_2q_2-\eta_2q_2\\+\beta_1C_1+\eta_1p_2\end{pmatrix}\\+q_2-C_2+\alpha_2q_2\\-\alpha_2q_3+\beta_2C_2\\+\eta_2q_2-q_3\end{bmatrix}\end{bmatrix} \tag{14}$$

Step 2. Local stability analysis of stable point.

The determinant of the matrix is *DetJ*, the trace is *TrJ*. When *DetJ*<0 and *TrJ* is uncertain, it is a saddle point; *DetJ*>0, *TrJ*>0 is an unstable point; if *DetJ*>0, *TrJ*<0 is a stable point (*ESS*) [44]. Based on this, the local stability of evolutionary games of game subjects under different ERs are analyzed, as shown in Table 2.

Table 2 shows that under No ER or CER, enterprises will choose to "conceal information" in any case, which ultimately fails to realize the optimal state of enterprise disclosure information and financial institutions' investment in enterprises. This is because under No ER or CER, it is not guaranteed that when financial institutions invest, enterprises will gain more from disclosing information than concealing information. It can be seen that ER is a necessary condition for promoting green collaborative innovation between enterprises and financial institutions, but CER does not play a decisive role in the strategic choice of enterprises and financial institutions.

As shown in Table 2, the stable point conditions of MER and CER&MER are constant, and the evolutionary game model achieves the ideal state when the conditions (a), (g), and (h) are satisfied; when conditions (b) are met, the ideal state of enterprise disclosure and financial institutions investing in enterprises may be realized. It can be seen that the necessary condition to achieve the ideal state is to ensure the benefits of both parties participating in green collaborative innovation. Because MER can guarantee the return of enterprises and financial institutions under certain conditions, MER can change the strategic choice of enterprises and financial institutions. In addition, since the local stability of the evolutionary game between enterprises and financial institutions in CER&MER is consistent with that in MER, it is verified that CER does not affect the final result of the strategic choice of enterprises and financial institutions, while MER can change the strategic choice of enterprises and financial institutions.

Results and Discussion

Case Choice and Simulation Parameter Settings

Case studies help solve problems from a practical point of view and increase the usability of research. Currently, case studies have been applied to innovation partner selection and the impact of ER [45-46]. In order to effectively promote green collaborative innovation between enterprises and financial institutions, we conducted numerical simulation analysis in the form of case study to further verify the above conclusions and the main influencing factors and effects of strategic choice of enterprises and financial institutions. This study involves the behavior choice of multi-stakeholder in the cooperation of green collaborative innovation between government, enterprises and financial institutions. Therefore, we need to select cases that meet the requirements of multi-stakeholder green collaborative innovation. After research and investigation, we choose China First Heavy Group Co., LTD., one of the members of Green Manufacturing Technology Innovation Alliance, to carry out case analysis.

Table 2. Local stability analysis of equilibrium points under different ERs.

	Situation	(a)			(b)			(c)		
		No ER: ①>②; CER: ①>②; ③>④			①<②; ③>④			No ER: ③<④; CER: ①<②; ③<④		
No ER or CER	Balance	*DetJ*	*TrJ*	Stability	*DetJ*	*TrJ*	Stability	*DetJ*	*TrJ*	Stability
	(0,0)	–	*N*	Saddle point	+	–	*ESS*	+	–	*ESS*
	(0,1)	+	–	*ESS*	–	*N*	Saddle point	–	*N*	Saddle point
	(1,0)	+	+	Unstable point	+	+	Unstable point	–	*N*	Saddle point
	(1,1)	–	*N*	Saddle point	–	*N*	Saddle point	+	+	Unstable point
	Situation	(a)			(b)			(c)		
		①>②; ③>④; ⑤>⑥; ⑦<⑧			①<②; ③>④; ⑤>⑥; ⑦<⑧			①<②; ③<④; ⑤>⑥; ⑦<⑧		
	Balance	*DetJ*	*TrJ*	Stability	*DetJ*	*TrJ*	Stability	*DetJ*	*TrJ*	Stability
	(0,0)	–	*N*	Saddle point	+	–	*ESS*	+	–	*ESS*
	(0,1)	–	*N*	Saddle point	+	+	Unstable point	+	+	Unstable point
	(1,0)	+	+	Unstable point	+	+	Unstable point	–	*N*	Saddle point
	(1,1)	+	–	*ESS*	+	–	*ESS*	–	*N*	Saddle point
	(A^*, B^*)	+	0	Saddle point	–	0	Saddle point	+	0	Saddle point
	Situation	(d)			(e)			(f)		
		①>②; ③>④; ⑤<⑥; ⑦<⑧			①<②; ③>④; ⑤<⑥; ⑦<⑧			①<②; ③<④; ⑤<⑥; ⑦<⑧		
MER or CER& MER	Balance	*DetJ*	*TrJ*	Stability	*DetJ*	*TrJ*	Stability	*DetJ*	*TrJ*	Stability
	(0,0)	–	*N*	Saddle point	+	–	*ESS*	+	–	*ESS*
	(0,1)	+	–	*ESS*	–	*N*	Saddle point	–	*N*	Saddle point
	(1,0)	+	+	Unstable point	+	+	Unstable point	–	*N*	Saddle point
	(1,1)	–	*N*	Saddle point	–	*N*	Saddle point	+	+	Unstable point
	(A^*, B^*)	–	0	Saddle point	+	0	Saddle point	–	0	Saddle point
	Situation	(g)			(h)			(i)		
		①>②; ③>④; ⑤>⑥; ⑦>⑧			①<②; ③>④; ⑤>⑥; ⑦>⑧			①<②; ③<④; ⑤>⑥; ⑦>⑧		
	Balance	*DetJ*	*TrJ*	Stability	*DetJ*	*TrJ*	Stability	*DetJ*	*TrJ*	Stability
	(0,0)	+	+	Unstable point	–	*N*	Saddle point	–	*N*	Saddle point
	(0,1)	–	*N*	Saddle point	+	+	Unstable point	+	+	Unstable point
	(1,0)	–	*N*	Saddle point	–	*N*	Saddle point	+	–	*ESS*
	(1,1)	+	–	*ESS*	+	–	*ESS*	–	*N*	Saddle point
	(A^*, B^*)	–	0	Saddle point	+	0	Saddle point	–	0	Saddle point

Note: ① investment income of financial institutions when enterprises conceal information; ② financial institutions do not invest income when enterprises conceal information; ③ investment income of financial institutions when enterprises disclose information; ④ financial institutions do not invest income when enterprises disclose information; ⑤when financial institutions invest, enterprises disclosure information income; ⑥ when financial institutions invest, enterprises conceal information income; ⑦ when financial institutions do not invest, disclosure information income; ⑧ when financial institutions do not invest, conceal information income.

Located in Qiqihar, Heilongjiang Province, China First Heavy Group Co., LTD. is one of the important state-owned backbone enterprises managed by the central government, which is related to the national security and the lifeline of the national economy. It firmly sets up the concept of "safe development and green development" and financial services is one of the five sectors of business. Over the past 70 years, China First Heavy Group Co., LTD. has developed more than 400 new products, filled in more than 400 technological gaps in domestic industrial products, and created hundreds of "firsts". In recent years, China First Heavy Group Co., LTD. has brought together financial institutions such as Bank of China and China Merchants Bank to cooperate and innovate, and strive to develop green cold chain logistics, biomass power generation,

and new energy vehicles to achieve breakthroughs in green innovation.

Among them, the cooperative financial institutions represented by Bank of China are the only banks in China that have been in continuous operation for more than 100 years, and also the banks with the highest degree of internationalization and diversification in China. Following closely the 14th Five-Year Plan, the Bank of China has put into practice the development strategy of green finance. Heilongjiang Bank of China fully supports China First Heavy Industry Group Co., LTD. with financial means. In view of the deep and diversified business needs of green innovation, tailor-made financial service programs, improved and accelerated approval of credit line, timely met its capital needs, and actively cultivated China First Heavy Group Co., LTD. new industries and new driving forces. Financial support will be provided to promote the optimization and upgrading of traditional industries and achieve sustainable development. In the process of cooperation, the Bank of China will help to reduce the cost of bad debt disposal and reduce the risk of green innovation investment.

Based on the survey and analysis, the selected cases are basically consistent with the assumptions in the game. Therefore, according to the possibility of the future development of China First Heavy Group Co., LTD. and the cooperation with Bank of China, we conducted an interview survey on the middle management of the enterprise to further understand the development of the enterprise (mainly involving the Department of Safety and Environmental Protection, the Department of Strategic Planning and Investment and the Department of Finance). The main reason for choosing this part of the personnel for investigation is that the middle management personnel play a bridging role in the enterprise and grasp more comprehensive information. Among them, the Department of Safety and Environmental Protection and the Department of Strategic Planning and Investment are related to green innovation projects, while the staff of the Financial Department are familiar with the capital input and external financing of various projects. In addition, on this basis, we further interviewed and investigated 10 experts engaged in related researches from Harbin Engineering University, the Publicity Department of Heilongjiang Provincial Party Committee and the General Office of Harbin Municipal Party Committee, and set game simulation parameters from the perspective of academic research and government policy making. The setting of all simulation parameters considers the sensitivity of the change in various related factors to the game's main strategy choice; it does not represent the payment or income value of each participant in the actual green collaborative innovation. For general considerations, it is assumed that all exogenous variables are positive. See Table 3 for the parameter settings.

Numerical Simulations

The simulation results under different ER scenarios are shown in Fig. 2. When there are No ER, as shown in Fig. 2a), enterprises choose to conceal information and financial institutions choose not to invest in enterprises. CER is shown in Fig. 2b), which is the

Table 3. Initial values of the scenario simulation.

Variables	Assignment description	Initial value
C_1	The cost of enterprises disclosure information.	5
C_2	Investment costs of financial institutions.	4
p_1	The income of the enterprises when the financial institutions invest.	10
p_2	The income of the enterprises when the financial institutions do not invest.	7
q_1	Financial institutions' investment income when enterprises disclose information.	8
q_2	Financial institutions' investment income when enterprises conceal information.	6
q_3	Financial institutions do not invest income.	5
G_1	Green innovation standards set by the government for enterprises.	10
G_2	Green innovation standards set by the government for financial institutions.	8
α_1	The government's penalty factor for non-compliance enterprises.	1.2
α_2	The government's penalty factor for non-compliant financial institutions.	1.1
β_1	The government's cost subsidy coefficient for enterprises.	0.5
β_2	The government's cost subsidy factor for financial institutions.	0.3
η_1	The government's income incentive coefficient for enterprises.	0.2
η_2	The government's income incentive coefficient for financial institutions.	0.2

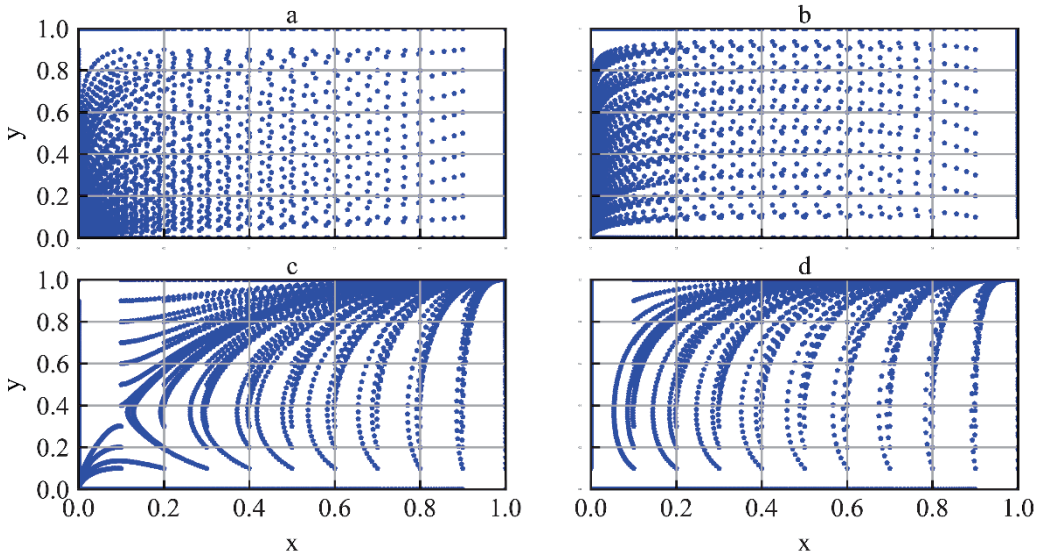

Fig. 2. Simulation diagram under different ERs.

same as the final state of evolution stability under No ER. Nevertheless, CER compared with No ER will slow down the speed of financial institutions to reach the stable state of non-investment, and has no influence on the investment decision choice of enterprises. Fig. 2c) shows that MER can change the ultimate state of evolution of enterprises and financial institutions. When the initial input value is small, enterprises will conceal information and financial institutions will ultimately choose to not invest in enterprises. As the initial value input increases, enterprises and financial institutions gradually evolve to an ideal stable state. The larger the initial value input is, the faster the stable state of enterprises information disclosure and green investment of financial institutions will be achieved. As shown in Fig. 2d), CER&MER increase the possibility of enterprise disclosing information and financial institutions investing in enterprises more than other single types of ER. Simultaneously, compared to the case of only MER, it speeds up financial institutions reaching the steady state of investment enterprises but makes no change in the speed at which enterprises reach a steady state. It is again proved that CER cannot change the final strategic choice of enterprises and financial institutions, while MER can.

This study focuses on the strategy selection of collaborative innovation between enterprises and financial institutions under different ERs. In this case, we only change the implementation intensity parameters of ERs, and take the profit and cost coefficients of enterprises and financial institutions participating in green innovation as control variables. In addition, the replication dynamic equation analysis above found that among the implementation parameters of ERs, only the penalty coefficient of financial institutions, the profit incentive coefficient of enterprises and financial institutions and the cost subsidy coefficient would affect their strategy selection, and had nothing to do with the penalty coefficient of enterprises and the green innovation standard set by the government. Therefore, the punishment coefficient of enterprises and the green innovation standard set by the government are the control variables. Based on the parameters set by CER&MER, this paper discusses how the government can better set the intensity of ER by modifying the penalty coefficient of financial institutions, profit incentive coefficient and cost subsidy coefficient of enterprises and financial institutions.

Under different penalty coefficients applied to financial institutions, the changes in the strategic choices of enterprises and financial institutions are shown in Fig. 3. With the increase of finance institutions' penalty coefficient, the dual stable state of enterprises and financial institutions gradually evolved into a stable state where only enterprises disclose information and financial institutions invest in enterprises. An increase in the financial institutions' penalty coefficient will shorten the wait-and-see time of financial institutions' strategic choices and reduce the volatility of strategic choices, thereby speeding up the time financial institutions take to reach a stable state of investing in enterprises as well as the time taken to reach a stable state of enterprise information disclosure. Therefore, the increase of financial institutions' penalty coefficient will promote enterprises and financial institutions to participate in green collaborative innovation.

Figs 4 and 5 respectively show the simulation results when enterprises' and financial institutions' green collaborative innovation income reward coefficients take different values. Fig. 4 shows that with the increase in the government's green innovation income reward coefficient for enterprises, enterprises will eventually choose to disclose information. It also shortens the time for enterprises to reach a stable state of information disclosure and financial institutions to reach the stable

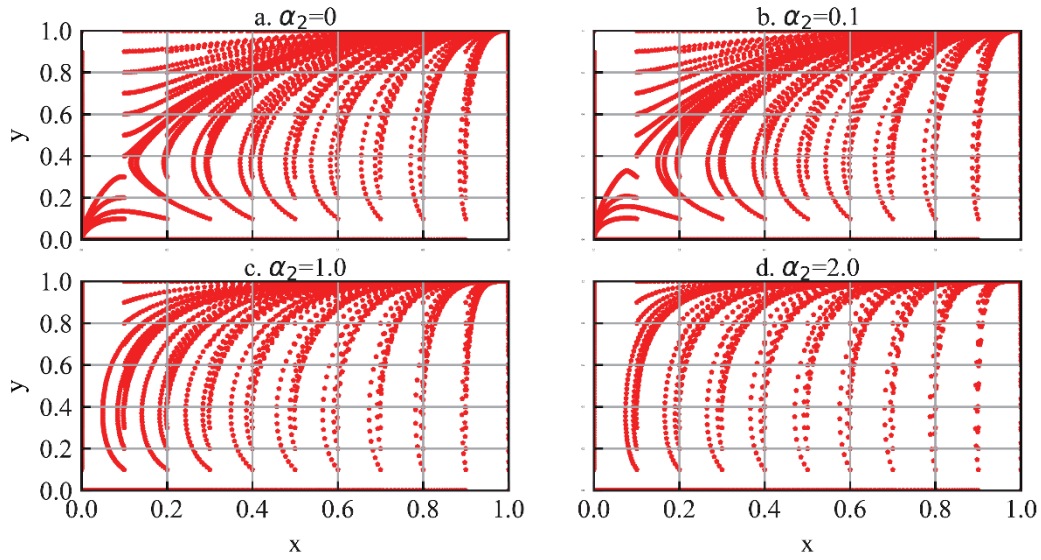

Fig. 3. Different penalty coefficients of financial institution.

state of investment in enterprises. However, when the enterprise innovation yield coefficient is small, financial institutions' willingness to invest is greater than enterprises' willingness to disclose information. With the continuous improvement of the government's incentive coefficient for enterprises' green collaborative innovation income, the willingness of enterprises to disclose information grows more quickly, even exceeding the willingness of financial institutions to invest. In addition, with the continuous improvement of the government's incentive coefficient for financial institutions' green innovation income, enterprises increase their willingness to disclose information and financial institutions invest in enterprises. Moreover, the time to stabilize is also accelerated. However, it takes a long period of "slow climbing" for enterprises disclosure information willingness to stabilize compared to financial institutions investment (see Fig. 5). As a result, regardless of whether the enterprises or financial institutions' green collaborative innovation income reward coefficient changes, it will affect their strategic choices. However, their strategic choices are sensitive to the change of their own green collaborative innovation return coefficient.

The simulation results for when the government sets different values for the cost subsidy coefficients for enterprises and financial institutions are shown in Figs 6 and 7. Fig. 6 illustrates that when enterprises' cost subsidy coefficient is very small, they will choose to conceal information. As the cost subsidy coefficient increases, enterprises gradually change their strategy and choose to disclose information, but the wait-and-see

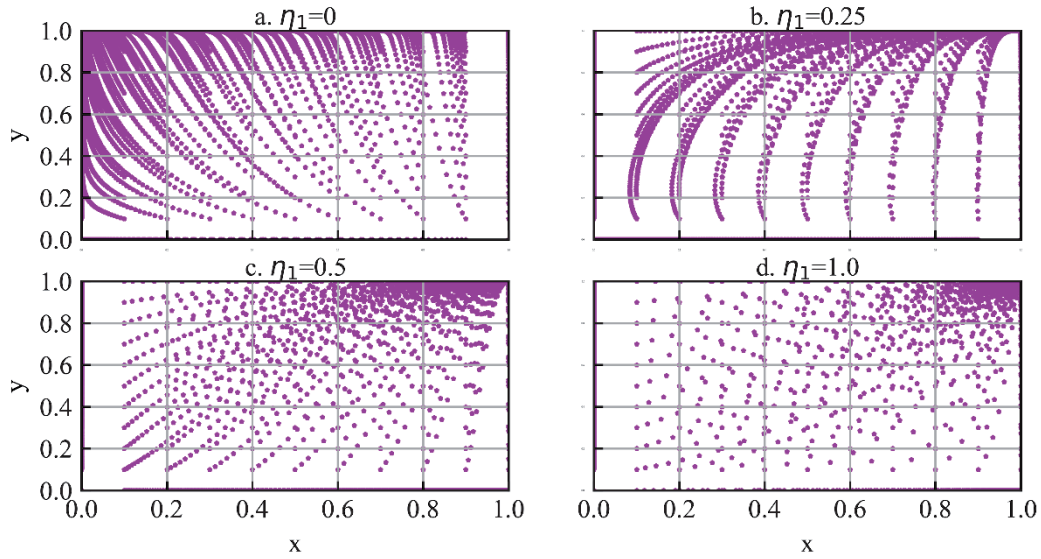

Fig. 4. Different reward coefficients of enterprises' collaborative innovation income.

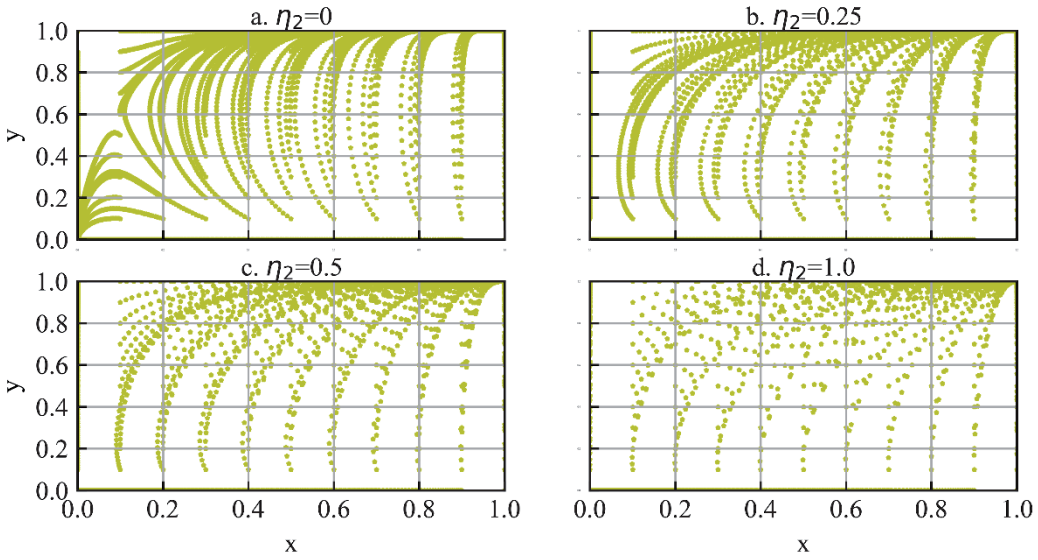

Fig. 5. Different reward coefficients of financial institution's collaborative innovation income.

time is longer. As the cost subsidy coefficient continues to increase, enterprises will reduce the wait-and-see time by working with financial institutions to quickly reach a stable state of enterprise information disclosure and financial institutions investment, thereby achieving collaborative innovation. As shown in Fig. 7, when financial institutions' cost subsidy coefficient is small, a large initial value is required to achieve enterprises' disclosure information and financial institutions' investment enterprises. Further, the increase of the cost subsidy coefficient and the effect of low initial value will be offset, causing enterprises to realize the benefits of disclosing information, reducing the length of the wait-and-see time, accelerating the evolution of enterprises to disclose information and financial institutions to invest in enterprises, and ultimately achieving stability. From an analytical perspective, the cost subsidy coefficient has a greater influence on enterprises' strategic choices.

Assuming that the government gives enterprises and financial institutions a certain degree of economic incentive, that is, the sum of cost subsidy and green innovation income is certain, the different combinations of cost subsidy coefficient and green innovation income coefficient are shown in Figs 8 and 9 respectively. When the government has a certain degree of total MER, as the cost coefficient decreases and the green collaborative innovation income reward coefficient of the government to enterprises and financial institutions increases, enterprises' wait-and-see time continues to grow longer; the time it takes to reach a stable state

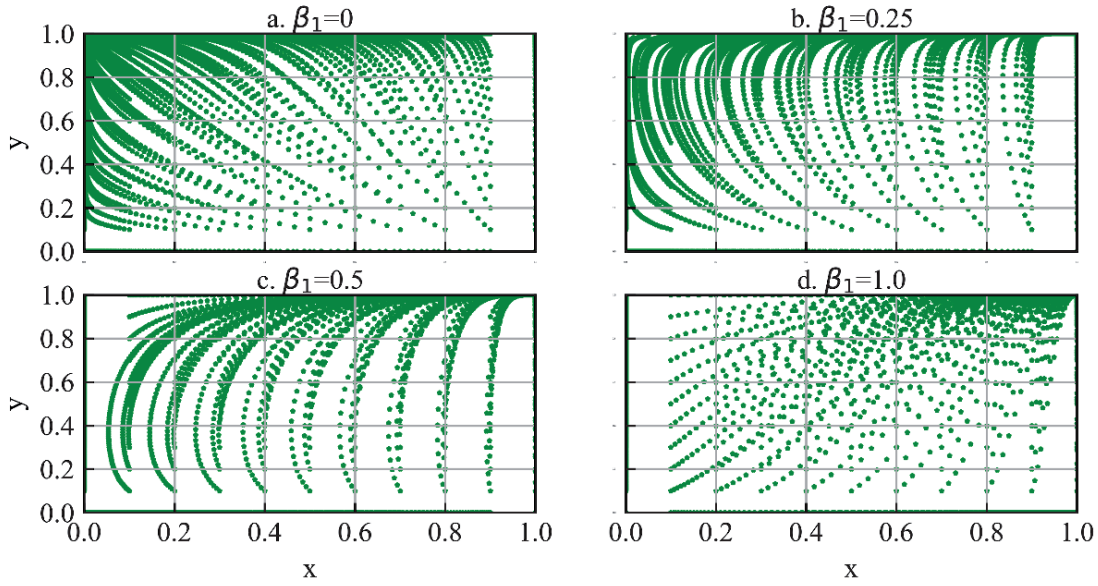

Fig. 6. Different cost subsidy coefficients of enterprises.

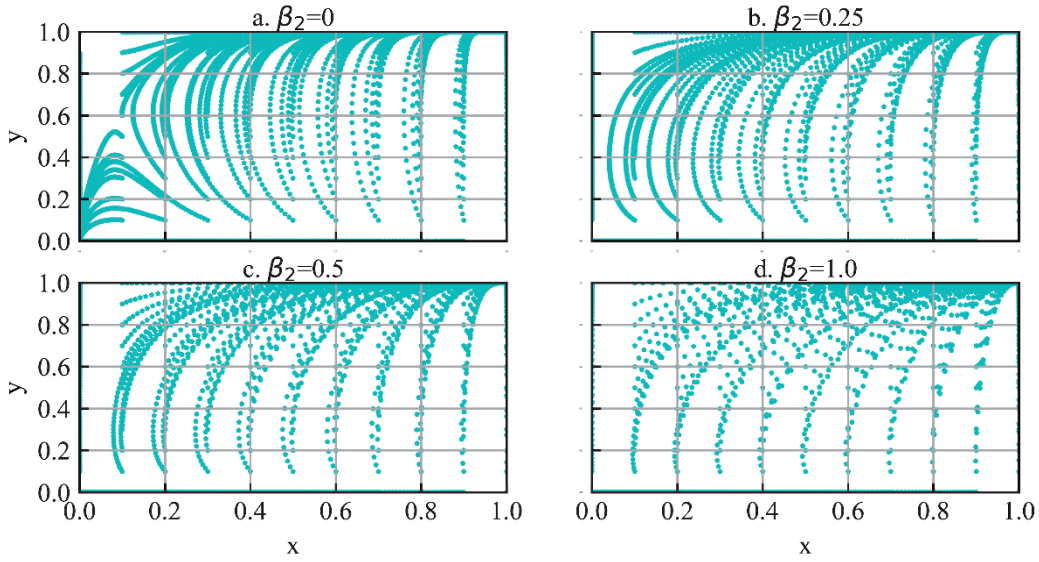

Fig. 7. Different cost subsidy coefficients of financial institutions.

for disclosure of information will also be prolonged. However, financial institutions' strategy evolution does not undergo obvious changes. In other words, cost subsidies and changes in the benefits of green collaborative innovation will have a greater impact on enterprises' strategic choices, but the impact on those of financial institutions will be low. Cost subsidy can promote enterprises and finance to achieve green collaborative innovation more than profit incentive. Additionally, changing the combination of enterprises' cost subsidy coefficient and green collaborative innovation income coefficient has a greater impact on strategy evolution than changing the combination of financial institutions' cost subsidy coefficient and green collaborative innovation income coefficient.

Discussion

This paper uses evolutionary game model to explore the impact of different types of ER on the willingness of enterprises and financial institutions to green collaborative innovation and the main influencing factors. A lot of research attention has been paid to the ER of multiple strategies have different effects on green innovation effect, such as environmental penalties and subsidies have different influences on enterprise investment environment [21], heterogeneous ER has different effects on green innovation [20, 22]. Some scholars also studied the relationship between ER and green innovation from the perspective of collaborative innovation [15, 29], and brought financial institutions into the main body of collaborative innovation [29].

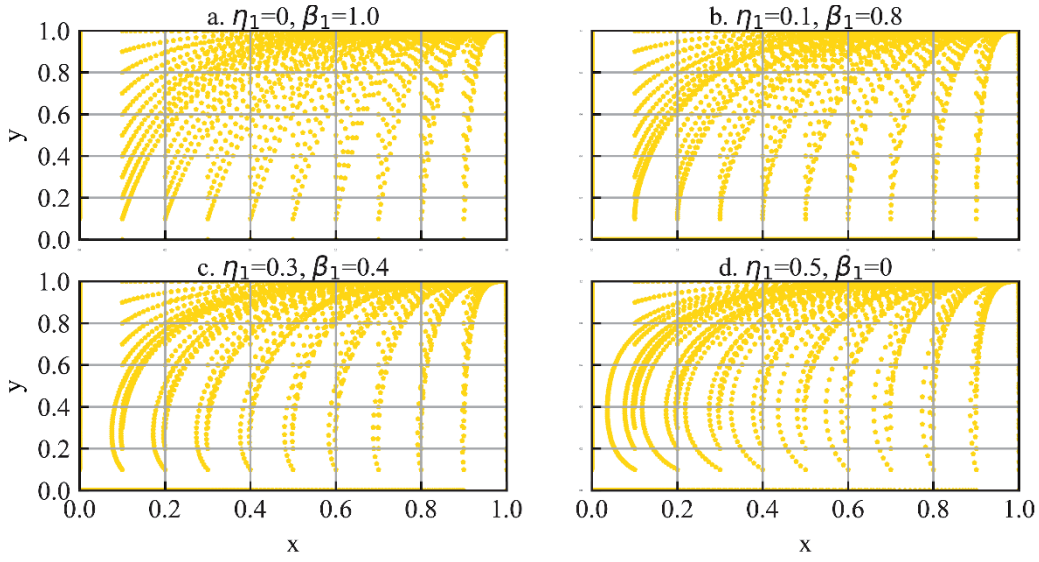

Fig. 8. Different combinations of enterprises' cost subsidy and income reward coefficient.

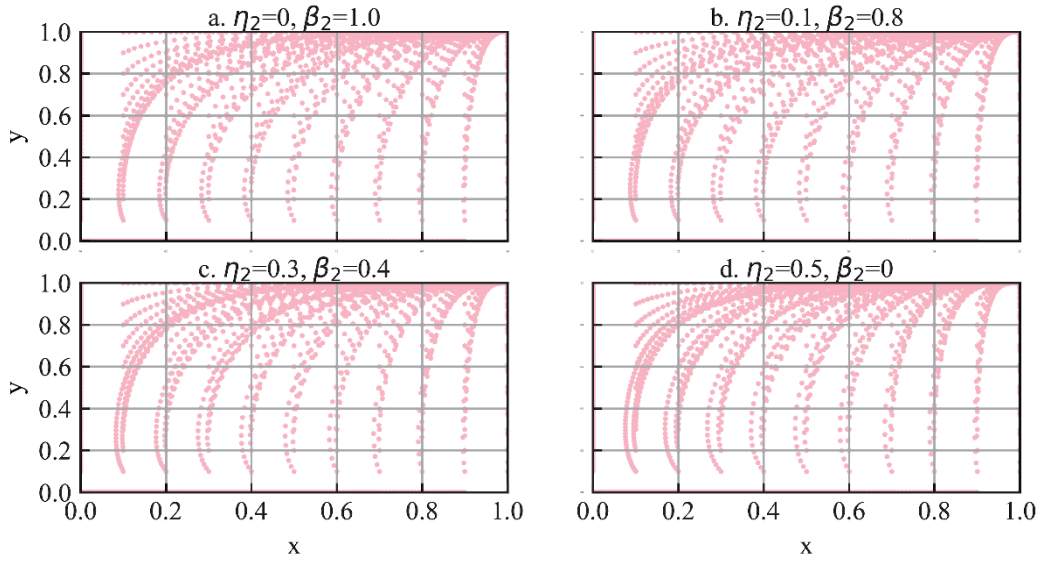

Fig. 9. Different combinations of financial institution cost subsidy and income return coefficient.

This demonstrates the important role of government regulation and easing financing constraints in the process of green innovation. Meanwhile, some studies have pointed out that insufficient enterprise information disclosure and increased green investment risks are the key obstacles to green investment by financial institutions [29-30]. In other words, exploring how the government implements ER can effectively promote enterprise information disclosure and alleviate financing constraints is of great significance to the realization of green innovation. However, as far as the existing literature is concerned, the research on the relationship between different types of ER and green innovation still lacks a research perspective that combines enterprise information disclosure with financing constraints. In the investigation and study of China First Heavy Group Co., LTD., we find that on the one hand, the cooperation between enterprises and financial institutions provides stable and sufficient financial support for green innovation, and financial institutions can also learn more about enterprises through cooperation, so as to reduce the risk of green investment. On the other hand, lack of effective restraint mechanism is also one of the main obstacles to collaborative innovation. Therefore, based on the perspective of enterprise information disclosure and financing constraints, we construct an evolutionary game model of green collaborative innovation between enterprises and financial institutions, and discuss the impact of different ERs on both parties' willingness to innovate in green collaborative innovation and the main influencing factors, enriching the theoretical research on environmental regulations and green cooperative innovation willingness.

It is worth noting that in the study of the specific impact of different types of ER on green innovation, we find that CER cannot change the final choice of green collaborative innovation strategy between enterprises and financial institutions, while MER can. Sun et al. [23] found that compared with CER, MER has a more significant incentive effect on enterprise innovation, which is the same as the opinion of this study. However, Peng et al. [11] research shows that the influence of CER on the willingness to cooperate on green innovation is more significant than that of MER, which is contrary to the conclusion of this paper. The analysis finds that although both the papers analyze the impact of ER on green innovation willingness, the perspective of this paper is based on the collaborative innovation intention of enterprise information disclosure and financing constraints, which is different from enterprise technological innovation intention and behavior perspective proposed by Peng et al. [11]. In the game model constructed in this paper, the enterprises' desire to participate in the green innovation depends primarily on the enterprises and financial institutions' the costs and benefits of innovation. Moreover, through cost subsidies and revenue incentives, MER can significantly reduce the cost of green collaborative innovation. Therefore, MER has a more significant incentive effect on enterprises' participation in green collaborative innovation. In addition, we find that increasing the subsidy coefficient of green innovation costs is conducive to improving the willingness of enterprises and financial institutions to participate in green collaborative innovation. Yang et al. [15] found that government innovation subsidies are positively correlated with the stability of green innovation ecology, which is consistent with our view.

It can be seen that there are certain differences in the effect of different types of ER on green innovation, which is beyond doubt, but the specific impact is affected by the interests of collaborative innovation participants. Therefore, when formulating environmental regulation strategies, the government should focus on the interests of different participants in green collaborative innovation, formulate a combination of differentiated

environmental policy systems, reasonably adjust the intensity of different environmental policy tools, and improve the cooperation willingness of participants in green collaborative innovation.

Conclusions

Main Conclusions

This study integrates the evolutionary game theory, green innovation theory, and behavioral science to construct a green cooperative innovation game model for enterprises and financial institutions from the perspective of enterprise disclosure information and financing constraints. Through case analysis and simulation, this paper explores the impact of different environmental regulations on the willingness of enterprises and financial institutions to green cooperation innovation and the main influencing factors. The conclusions are as follows.

(1) Without environmental regulation, enterprises and financial institutions cannot achieve collaborative innovation. CER has no decisive influence on the choice of green collaborative innovation strategy of enterprises and financial institutions, while MER can change the choice of green collaborative innovation strategy of enterprises and financial institutions. Therefore, MER plays a more significant role in improving the willingness of green collaborative innovation.

(2) The green collaborative innovation between enterprises and financial institutions is mainly affected by the government's penalty coefficient on financial institutions, the government's cost subsidy coefficient on enterprises and financial institutions, and the profit incentive coefficient of green innovation, but has a limited relationship with the government's penalty coefficient on enterprises and the government's setting of green innovation standards. However, compared with the benefit incentive coefficient of green innovation, increasing the cost subsidy coefficient is more conducive to promoting green collaborative innovation between enterprises and financial institutions.

(3) The combination of CER and MER can further improve the willingness of enterprises and financial institutions to green collaborative innovation. In addition, to a certain value, on the basis of government incentives and subsidies, to promote collaborative green innovation between enterprises and financial institutions, it is more effective to adjust the combination of enterprises cost subsidy coefficient and green innovation income coefficient than to adjust the coefficient of financial institutions. Therefore, enterprises are more sensitive to government cost subsidies.

First, our results prove the necessity of environmental regulation in the process of green collaborative innovation between enterprises and financial institutions. Second, it clarifies the specific effects and influencing factors of different types of environmental regulation on green collaborative innovation strategy. Third, it provides reference for the government to formulate environmental regulation strategies by adjusting the intensity of government environmental regulation.

Policy Recommendations

Based on the above research results, in order to improve the rationality of government environmental regulation policy making, the following suggestions are proposed from two aspects of policy making and implementation:

(1) In general, the government should combine CER and MER to better play the role of environmental regulation. The specific implementation intensity should follow the principle of small CER proportion, large MER proportion, large cost subsidy and small green income incentive to implement environmental regulation policies.

(2) For the participants of green collaborative innovation, the government should make differentiated environmental regulation strategies. For enterprises, the government should pay more attention to how to reduce the cost of green innovation and strengthen the policy of cost subsidy. For financial institutions, the government should pay more attention to how to increase the benefits of green innovation of financial institutions, and give more support to the reward system of green benefits.

(3) To reduce the cost of green innovation for enterprises, on the one hand, the government can provide direct cost subsidies. Specifically, enterprises that develop green technologies and products and use green materials can be qualified for green subsidies and receive free green innovation subsidy vouchers. On the other hand, it can also improve the enterprises green information disclosure system, clarify the content and template of information disclosure, strengthen the evaluation, supervision, guidance and incentive of enterprises environmental information disclosure, form a mature environment of enterprises environmental information disclosure, and reduce the cost of enterprises information disclosure. At the same time, the government regularly publishes objective and accurate green information of enterprises to build a good image of enterprises, enhance consumers' recognition of enterprises' products and financial institutions' willingness to invest in enterprises' green.

(4) Financial institutions to improve green revenue, on the one hand, the government can through the proportion of financial institutions to implement green innovation benefits to reward, in particular, may set up special funds for financial institutions to invest heavily in green financial reward, and the green financial products, such as type, size, quantity and performance aspects of diversified management, supervision, and examination of implementation. On the other hand,

the government can enhance the publicity of green innovation to the public, improve the infrastructure and system construction of green financial institutions, strengthen international cooperation in green financing, and increase the extra income of financial institutions participating in green collaborative innovation. In addition, the government can take the lead to establish the risk compensation fund for green innovation loans of financial institutions and non-financial enterprises and the risk compensation mechanism for green financing guarantee business, so as to reduce the investment risk of green innovation of financial institutions.

Limitations and Future Research

We discuss the choice of green collaborative innovation strategies and the main influencing factors of enterprises and financial institutions under different types of environmental regulation, which enriches the theoretical research on the relationship between environmental regulations and green innovation. However, the following deficiencies still exist:

(1) Although the research results of this paper are demonstrated by combining empirical and simulation methods, the single case study still has shortcomings such as insufficient reliability compared with multi-case study. In the future, a large number of cases can be collected and analyzed to improve the credibility of empirical results and obtain more general theoretical basis.

(2) Only the enterprises information disclosure is considered to be the main factor to attract financial institutions investment. Other influencing factors, such as financial institutions' risk preference when investing in the investee are not considered. In the future, more influencing factors of green collaborative innovation between enterprises and financial institutions can be introduced to comprehensively analyze the influencing factors of strategic choice of both parties.

(3) The research focuses on the impact of government environmental regulation on the choice of collaborative innovation strategies between enterprises and financial institutions, but does not take into account factors such as internal green innovation management and strategies, which is also one of our future research directions.

(4) The participants of green collaborative innovation discussed in this paper include the government, enterprises and financial institutions, but in real life, universities, research institutions and consumers are all important stakeholders of green collaborative innovation. In the future, based on this, the multi-party interest game situation can be explored, and a more comprehensive evolutionary game model of green collaborative innovation can be constructed to explore how to promote the realization of green collaborative innovation.

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Conflict of Interest

The authors declare no conflict of interest.

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