Research on Green Credit Regulatory Strategy Based on Evolutionary Game

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Abstract: China's green finance is in the development stage, and green credit is the main form of green finance. In order to supplement the theoretical research in this regard, this paper establishes the theoretical model of evolutionary game between the rewards and punishments of regulatory authorities, the work efficiency level of banks, and the participation of enterprises, analyzes the influence of the three parties on each other when their respective decision-making changes, and explores the stable equilibrium solution of the three parties in the process of evolutionary game. The results show that the technical level of pollution treatment and the environmental awareness of enterprises affect the strategic choice of the tripartite game subjects, and the regulatory authorities play different roles in different stages of the development of green credit business. With the gradual improvement of pollution treatment technology and corporate environmental awareness, the regulatory authorities will reduce intervention and evolve into relaxed supervision, so as to realize the endogenous profitability of the regulatory authorities. This study provides a theoretical basis for formulating an effective green credit regulatory strategy, which can better promote the steady development of green credit.

1. Introduction

The rapid development of the economies of countries around the world has been accompanied by the increasing contradiction between the economy and the environment, and the rapid expansion of industrialization has brought many environmental problems, such as air pollution, water pollution, soil pollution, etc. These environmental problems not only have a negative impact on people's quality of life, but also reduce the rate of economic development of the country. China has always been at the forefront of reform and opening up, and its economic growth rate has always been at the world's leading level, but the ecological imbalance caused by economic growth in recent years has also been more prominent [1-2]. In the process of environmental law enforcement, some problems have gradually been exposed in the implementation of the regulation and control policies of individual departments of environmental protection agencies, such as the limited scope of regulation, insufficient regulation and control efforts, and insufficient control methods, which not only affect the implementation of environmental protection policies, but also bring challenges to China's environmental protection work [3]. All of the above shows that the regulators are "more than willing but not enough" to balance the economy and the environment [3]. In order to solve the conflict between economic development and environmental pollution, people have begun to pay attention to

sustainable development, and environmental protection has also been incorporated into the overall strategy of national development. In 2016, the People's Bank of China, the Ministry of Finance, the National Development and Reform Commission, the Ministry of Environmental Protection, the China Banking Regulatory Commission, the China Securities Regulatory Commission, and the Insurance Regulatory Commission jointly issued the Guiding Opinions on Building a Green Financial System, which put forward the definition, objectives, principles and policy measures of green finance, and clarified the role of green finance. Through the form of green finance, it can inject green funds into the upgrading and transformation of traditional industries, promote industrial transformation and upgrading, and also promote the development of environmental protection industries to achieve a win-win situation for the economy and the environment. China has initially established a green financial system, in which green credit is the main tool of green finance, which is an effective means to optimize capital allocation, encourage the development of environmental protection enterprises, and restrict the expansion of high-polluting enterprises [1]. However, when environmental factors are incorporated into green credit, what kind of credit supervision policy should the regulator adopt for green credit due to the increasing difficulty of environmental assessment, the inability to accurately judge the sustainability of the project, the greater policy risk and market risk, and the information asymmetry, which leads to more complex credit risk. That is, how to implement the rewards and punishments of the regulatory authorities in order to effectively reduce the credit risk of green credit and promote the steady development of green credit is a common concern of the regulatory authorities and scholars.

The existing research and analysis mainly focus on the risk assessment of green credit, the impact of green credit on commercial banks, and the management of green credit for small and medium-sized enterprises. Based on the credit risk assessment model of random forest, Wang Xiaoxiao empirically tested the effect of the model through real data, and concluded that the sources of green credit risk include environmental risks in addition to business risks, and the addition of environmental risk refinement indicators to the traditional credit risk assessment index system can make a more accurate prediction of green credit default risk [4]. Based on the relevant theories, Du Dongling analyzed how green finance can reduce bank risks, and proposed that commercial banks can reduce the risk level of banks by carrying out green credit business, and the improvement of non-performing loan ratio, liquidity ratio, and asset-liability ratio can promote the positive correlation between green credit business and bank risk[5]; Qiu Jie conducted a questionnaire survey to obtain data, and put forward the hypothetical factors affecting the green credit default of small and medium-sized enterprises, and verified the five research hypotheses by analyzing the correlation of data with the chi-square test of principal components and logistic regression analysis, and concluded that the hypothesis of the impact of cognitive factors, financial factors, decision-making factors and credit factors on the green credit default of small and medium-sized enterprises was established, and finally obtained "education", "financial product understanding", "science and technology enterprise", "environmental protection enterprise", "green credit", "asset-liability ratio" and "current ratio". The 10 indicators of "quick ratio", "independent decision-making" and "guarantee method" have a significant impact on the green credit default of SMEs, providing a mathematical basis for banks to develop high-quality customers and reduce non-performing loans [6].

In recent years, the research on green credit in China has developed rapidly, but most of them focus on the qualitative and static analysis between banks and enterprises, and there is a lack of detailed research on the dynamic relationship [7]. Therefore, this paper will introduce three relevant variables of regulators, banks and enterprises through the analysis of the tripartite evolutionary game of green credit risk, and study the dynamic evolution process of each subject's strategy in the tripartite game of "regulators-banks-enterprises". Compared with game theory, evolutionary game theory can better analyze the evolutionary stability equilibrium of bounded rational agents' strategy selection behavior

in games. The contributions of this paper are: 1) the application of evolutionary game method to analyze the stable equilibrium solution of the strategy evolution of all parties in the game at different stages of green credit business development; 2) A premium allocation decision-making model based on evolutionary game theory is established to analyze the impact of incentives and penalties of regulatory authorities, bank work efficiency, and corporate environmental protection level on the evolution of green credit, so as to provide a theoretical reference for regulatory authorities to formulate development policies, which has important theoretical and practical significance.

2. Analysis of the tripartite evolutionary game theory of green credit

In this section, the evolutionary game model of green credit participants is constructed through the game strategy selection between the performance of regulatory responsibilities by regulatory authorities, bank credit business, and corporate green credit participation.

2.1 Model assumptions

2.1.1 The main body of the game

Regulatory authorities, banks, and enterprises are selected as the main players of the game, and it is assumed that the three parties have bounded rationality.

2.1.2 Behavioral strategies

Regulatory Authorities. In the face of the credit factors that have the greatest impact on green credit, local regulatory authorities and central regulatory departments comprehensively consider the social and environmental benefits obtained and the cost of regulatory administrative actions to determine the intensity of green credit supervision, and the regulatory authorities can choose strict supervision and relaxed supervision, strict supervision refers to the establishment of a clear regulatory system by the regulatory authorities, increase the intensity of supervision, invest in greater regulatory costs, reward enterprises with good or excellent green credit performance, and give severe penalties to enterprises with failed credit performance. Set the probability of strict supervision by the regulatory authorities as $x(0 \leq x \leq 1)$ and the probability of relaxed supervision as $1-x$.

Bank. Credit has always been one of the main businesses of commercial banks, China adheres to the policy of sustainable development, builds green credit, and adds environmental protection conditions and mechanisms for traditional credit, and banks also need to undertake the business of green credit and carry out efficient green credit business for enterprises, but affected by the bank's internal management mechanism and the enthusiasm of the staff, some staff of the bank may be passive and slack off, so that the efficiency of the green credit business is reduced, the probability of working efficiently is $y(0 \leq y \leq 1)$ and the probability of working inefficiently is $1-y$.

Enterprise. Based on this, the default of small and medium-sized enterprises and non-standard enterprises in the process of green credit is significantly affected by many factors, while large and standardized enterprises will try to avoid default in the process of green credit, and the awareness of environmental protection will be stronger, based on this, assuming that the strategy set of enterprises is participation and non-participation, the probability of choosing to participate is $z(0 \leq z \leq 1)$, and the probability of non-participation is $1-z$.

2.1.3 Construction of profit and loss variables

P&L variables for regulators. When the regulatory authorities adopt strict regulatory strategies, in order to encourage banks to actively carry out green credit and comply with green credit regulations,

financial and tax subsidies will be provided to banks with efficient green credit business; At the same time, on the one hand, banks that conduct inefficient green credit business will be punished with a penalty of P, and on the other hand, they will severely crack down on negative or other major bank behaviors and increase the cost of green credit for such banks, resulting in the income of $(1-\mu) Rcn$ from enterprises participating in non-standard treatment of pollution, which μ indicate the strength of the regulatory authorities to supervise such enterprises to carry out pollution compliance treatment; The cost of strict supervision by the regulatory authorities is Cg, and at the same time, the local regulatory authorities can obtain rewards from the higher authorities and obtain the Rg of improving the credibility of the regulatory authorities; If banks carry out green credit business efficiently, it will bring green benefits to the regulatory authorities due to the social externalities of green credit business Re; When the regulatory authorities carry out lax management, some enterprises will not carry out or reduce the amount of pollution treatment, resulting in environmental pollution and resource loss, and the cost of environmental treatment by the regulatory authorities is Ci. However, in the context of the country's vigorous implementation of sustainable development strategy and emphasis on environmental protection, the rewards and credibility enhancement of strict supervision by the regulatory authorities will outweigh the costs, so assume that the Rg>Cg.

The profit and loss variable of the bank. The operational cost of efficient green credit by banks is Cm, including the total expenditure of testing costs, execution costs and opportunity costs. Banks vigorously promote green credit and respond to green development, which can obtain potential benefits such as the improvement Rm of the bank's social image and popularity. Banks create derivatives of green credit through green credit, such as issuing green credit cards, providing environmental consulting services, etc., and the benefits obtained are kRmr, where k represents the maximum benefit of green credit business, $k \in (0, 1)$ indicates the bank's innovation level of green credit business model and financial products, and the closer K value is to 1, the higher the level of innovation. However, due to the strict requirements of green credit on financial derivatives and other aspects, the construction cost of green credit is high, and the cost of actively promoting green credit is higher than the potential benefits obtained by banks, so it is assumed to be Cm>Rm.

The profit and loss variable of the enterprise. If the enterprise actively deals with pollution, adheres to green development, and the industrial process is pollution-free and green, the green credit income to the enterprise is βL, where L represents the maximum benefit of green pollution treatment by green environmental protection enterprises, and $\beta \in (0, 1)$ indicates the degree of perception of the enterprise, which is defined as the enterprise's green credit awareness, and the closer the β value is to 1, the higher the enterprise's green credit awareness.Rc If the enterprise carries out non-standard pollution treatment, it can obtain the Rcn of benefits, because the enterprise carries out informal environmental protection treatment of pollution, which reduces the cost that must be consumed in the treatment process, that is, Rcn>Rc, when the enterprise chooses to actively respond to the green environmental protection strategy, the positive external impact of green credit and green environmental protection, the benefit of enterprise participation is greater than the income of non-participation, then it is assumed that Rc+βL >Rcn.

2.2 Build a payment matrix

Based on the basic assumptions of the above model, the benefits of the three parties in the process of green credit business can be obtained, as shown in Table 1.

Table 1: In the process of green credit business, the tripartite payment matrix is gamed

Gambling strategy	Strict regulatory regulation (x)		Loose Regulatory Oversight (1-x)	
	Corporate Engagement (Z)	Businesses do not participate (1-z)	Corporate Engagement (Z)	Businesses do not participate (1-z)
Efficient green credit business for banks (Y)	$R_m - C_m + kR_{mr} + T$	$R_m - C_m$	$R_m - C_m + kR_{mr}$	$R_m - C_m$
	$R_c + \beta L$	$(1-\mu)R_{cn}$	$R_c + \beta L$	R_{cn}
	$R_e + R_g - C_g - T$	$R_g - C_g - C_i$	R_e	$-C_i$
Inefficiency of banks in conducting green credit business (1-y)	$-P$	$-P$	0	0
	R_c	$(1-\mu)R_{cn}$	R_c	R_{cn}
	$R_g - C_g + P$	$R_g - C_g + P - C_i$	0	$-C_i$

2.3 Copy dynamic equations and equilibrium points

Based on the payment matrix of the three parties in the process of green credit business in Table 1, the expected return Em1 and Em2 and average return Em of banks choosing to conduct green credit business with high efficiency and green credit business with low efficiency can be obtained.
The expected return Em1 is:

$$E_{m1} = zx(R_m - C_m + kR_{mr} + T) + x(1-z)(R_m - C_m)$$
$$+z(1-x)(R_m - C_m + kR_{mr})$$
$$+ (1-x)(1-z)(R_m - C_m) \tag{1}$$

The expected return Em2 is:

$$E_{m2} = zx(-P) + x(1-z)(-P) \tag{2}$$

The average return Em is:

$$E_m = yE_{m1} + (1-y)E_{m2}$$
$$= Tyzx + kR_{mr}yz + Pyx + (R_m - C_m) - Px \tag{3}$$

Therefore, it can be concluded that the replication dynamic equation for banks to choose efficient green credit business is as follows:

$$F_m(y) = y(E_{m1} - E_m)$$
$$= y(1-y)(C_m - R_m - kR_{mr}z - Tzx - Px) \tag{4}$$

In the same way, if an enterprise chooses to participate in green credit, the replication dynamic equation to support the green transformation of the enterprise is as follows:

$$F_c(z) = z(E_{c1} - E_c)$$
$$= z(1-z)(\beta Ly + \mu R_{cn}x + R_c - R_{cn}) \tag{5}$$

Among them, Ec1 is the expected income of enterprises participating in green credit, and Ec represents the average income of enterprises.

The dynamic equation for replication chosen by the regulator for strict regulation is:

$$F_g(x) = x(E_{g1} - E_g)$$
$$= x(1 - x)(Tyz + Py + C_g - P - R_g) \tag{6}$$

Among them, Eg1 represents the expected return of strict supervision by the regulatory authorities, and the Eg is the average income of the regulatory authorities.

The replication dynamic equations Fm(y), Fc(z), and Fg(x) are combined to obtain the evolutionary game replication dynamic system of regulators, banks, and enterprises:

$$\begin{cases} F_m(y) = y(1 - y)(C_m - R_m - kR_{mr}z - Tzx \\ \qquad\qquad -Px) \\ F_c(z) = z(1 - z)(\beta Ly + \mu R_{cn}x + R_c - R_{cn}) \\ F_g(x) = x(1 - x)(Tyz + Py + C_g - P - R_g) \end{cases} \tag{7}$$

Finding the partial derivatives for x, y, and z respectively gives the corresponding Jacobian matrices:

$$\begin{bmatrix} \begin{matrix} 2(y-1)(C_m - R_m \\ - kR_{mr}z - Tzx \\ - Px) \end{matrix} & \begin{matrix} y(y-1)(-kR_{mr} \\ - Tx) \end{matrix} & y(y-1)(P + Ty) \\[2ex] z(1-z)\,\beta L & \begin{matrix} z(1-2z)\,(\beta Ly \\ + \mu R_{cn}x + R_c - R_{cn}) \end{matrix} & z(1-z)\,\mu R_{cn} \\[2ex] x(x-1)(P + Tz) & x(1-x)yT & \begin{matrix} (2x-1)(Tyz + Py \\ + C_g - P - R_g) \end{matrix} \end{bmatrix} \tag{8}$$

Regulators, banks and corporations will continue to adjust their implementation strategies according to their own vested interests to promote the improvement of interests, and finally evolve a stable strategy. Assuming Fm(y)=0, Fc(z)=0, and Fg(x)=0, we can obtain 8 equilibrium points, m1 (0,0,0), m2(0,1,0), m3(0,0,1), m4(0,1,1), m5(1,0,0), m6(1,1,0), m7(1,0,1), m8 (1,1,1), and substitute these equilibrium points into the Jacobian matrix to obtain the corresponding eigenvalues, as shown in Table 2.

Table 2: Eigenvalues of equilibrium points

Equilibrium point	The eigenvalue δ1	The eigenvalue δ2	The eigenvalue δ3
m1(0,0,0)	$R_m - C_m$	$R_c - R_{cn}$	$R_g - C_g + P$
m2(0,1,0)	$C_m - R_m$	$R_c - R_{cn} + \beta L$	$R_g - C_g$
m3(0,0,1)	$R_m - C_m + kR_{mr}$	$R_{cn} - R_c$	$R_g - C_g + P$
m4(0,1,1)	$C_m - R_m - kR_{mr}$	$-R_c + R_{cn} - \beta L$	$R_g - C_g - T$
m5(1,0,0)	$R_m - C_m + P$	$R_c - (1 - \mu)R_{cn}$	$C_g - R_g - P$
m6(1,1,0)	$C_m - R_m - P$	$R_c - (1 - \mu)R_{cn} + \beta L$	$C_g - R_g$
m7(1,0,1)	$R_m - C_m + kR_{mr} + P + T$	$(1 - \mu)R_{cn} - R_c$	$C_g - R_g - P$
m8(1,1,1)	$C_m - R_m - kR_{mr} - P - T$	$(1 - \mu)R_{cn} - R_c - \beta L$	$C_g - R_g + T$

2.4 Stability analysis

According to Lyapunov's discriminant method, when the eigenvalue $\delta < 0$, the equilibrium point is a stable point, and when the eigenvalue is $\delta > 0$, the equilibrium point is an unstable point. When the eigenvalues in the Jacobian matrix contain both greater than 0 and less than 0, the equilibrium point is the saddle point. Based on this, the stability analysis of the equilibrium point was carried out.

When m5(1,0,0), Cm>Rm-P, Rc<(1-μ)Rcn, Cg<Rg+P. At this time, the cost of efficient green credit business is higher than the sum of potential benefits and penalties, and the bank chooses an inefficient strategy. The benefits of corporate participation are less than the benefits of non-participation, and enterprises choose not to participate in the strategy; The benefits of strict supervision by the regulatory authorities outweigh the costs, and the regulatory authorities choose the strategy of strict supervision. At this time, the stable evolution strategy of the system is "strict regulation, inefficiency, and non-participation".

When m8(1,1,1), Cm<R_m+kRmr+P+T, Rc+βL>(1-μ)Rcn,T<Rg-Cg. At this time, the difference between the benefits and costs of strict supervision by the regulatory authorities is greater than the subsidy, and the regulatory authorities adopt a strict supervision strategy; The cost of efficient green credit business is lower than the benefit, and banks choose efficient strategies. The benefits of corporate participation are higher than those of non-participation, and enterprises choose participation strategies. At this time, the stable evolution strategy of the system is "strict supervision, high efficiency, and participation".

When m4(0,1,1), Cm<Rm+kRmr, Rcn+βL>Rc, Rg-Cg<T. At this time, the benefits of efficient green credit business outweigh the costs, and banks choose efficient strategies. Moreover, the bank's high-efficiency strategy brings positive external benefits and price benefits to enterprises that are greater than the benefits of non-participation, so enterprises choose to participate in the strategy; The costs of tight regulation by regulators generally outweigh the benefits, but regulators will opt for an accommodative strategy due to the autonomy and initiative of banks and corporates. At this time, the stable evolution strategy of the system is "loose supervision, high efficiency, and participation".

3. Conclusions and Recommendations

3.1 Conclusion

Based on the evolutionary game model of green credit supervision established by regulators, banks and enterprises, this paper explores the choice of tripartite stability strategies according to the strategies of the three parties that change out of their own interests, and obtains the following conclusions.

The technical level of pollution treatment and the environmental awareness of enterprises affect the strategic choice of the tripartite game. Due to the high construction cost of green credit and the existence of a large number of high-pollution and high-energy-consuming enterprises, it is difficult for enterprises to carry out pollution treatment and make profits, and the limited subsidies of the regulatory authorities have no obvious incentive effect on enterprise participation.

The severity of the punishment imposed by the regulatory authorities can significantly affect the strategic choices of banks and enterprises, and promote the coordinated development of green credit business between the two. When the regulatory authorities increase the punishment of banks' inefficient behaviors, the probability of banks' inefficient behaviors increases, which can affect the strategic choice of enterprises. Similarly, when the regulatory authorities supervise non-standard pollution treatment and non-environmental protection enterprises, the greater the probability of enterprises participating in green credit, and can affect the strategy choice of banks.

At this time, green credit will enter the right track of steady development, the regulatory authorities

will reduce intervention, and the final strategy of the three parties in the game is loose supervision, high efficiency, and participation.

3.2 Recommendations

We need to establish a sound regulatory framework for green credit and promote the establishment and improvement of a green financial system. First, clarify the definition and criteria of green credit so that financial institutions can better identify and promote green projects. Second, a series of green credit policies and regulations have been introduced, including tax incentives, loan amounts, loan terms, interest rates, etc., to guide financial institutions to increase their support for green projects. At the same time, green credit regulatory guidelines should be formulated to clarify the responsibilities and obligations of financial institutions in the process of carrying out green credit business, so as to ensure the compliance and sustainability of green credit business. In order to improve the transparency and credibility of the green credit business, a third-party evaluation agency can be introduced to evaluate and audit the green credit business of financial institutions. Finally, risk assessment and monitoring should be carried out on a regular basis, and the risks of the green credit business should be regularly assessed and monitored, and risks should be identified and dealt with in a timely manner. Through the above measures, it will help ensure the healthy development of green credit business and promote the establishment and improvement of the green financial system.

References

[1] Wang Shuyi. Research on credit risk assessment of green credit based on logistic regression [D]. Anhui University, 2022. DOI:10. 26917/d. cnki. ganhu. 2021. 001878.

[2] Li Yang. Research on green finance support system for circular economy development [D]. Tianjin University of Science and Technology, 2014.

[3] Wei W , Qin Z .Research on Green Construction Supervision Mechanism Based on Evolutionary Game[J].World Journal of Social Science Research, 2018, 5(1):98.DOI:10.22158/wjssr.v5n1p98.

[4] Wang Xiaoxiao. Research on green credit risk assessment and pricing strategy [D]. Yanshan University, 2022. DOI: 10. 27440/d. cnki. gysdu. 2022. 001844.

[5] Du Dongling. Research on the impact of green credit business on the risk of commercial banks [D]. University of International Business and Economics, 2022. DOI:10. 27015/d. cnki. gdwju. 2022. 000306.

[6] Qiu Jie. Research on green credit risk management of small and medium-sized enterprises in commercial banks [D]. Southeast University, 2022. DOI:10. 27014/d. cnki. gdnau. 2022. 001312.

[7] Tong Yan, Jiang Xuejiao. The influencing mechanism of green technology innovation based on SD model—From the perspective of the evolutionary game between enterprises and regulatory authorities [J]. Journal of Shenyang University (Social Sciences), 2022, 24(01):25-33. DOI:10. 16103/j. cnki. 21-1582/c. 2022. 01. 004.