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Article

Credit Risk Game Analysis and Control Model of RMSEs—Based on the Perspective of Green Credit

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Abstract: RMSEs (rural micro and small enterprises) absorb the rural surplus labor force for employment and entrepreneurship, which is an important economic growth point in rural areas in the future. However, RMSEs have narrow financing channels and difficult financing problems, which hinder the development of the rural economy. If RMSEs want to develop sustainably, they need to find effective financing channels. RMSEs no longer use traditional means of financing through commercial bank loans but are looking for newer financing modes, such as online loan platforms, investors, and so on. This paper takes RMSEs as the main body, RMSEs target rural commercial banks, online loans, and investors as funding instruments, and through building a benchmark model of the evolution game between funding instruments and RMSEs, banks, based on the perspective of green credit other investors industry competition and market regulatory mechanisms and to build a control model of credit risk of RMSEs to reduce the credit risk of RMSEs.

Keywords: RMSEs; game theory; credit risk; green credit

1. Introduction

Against the backdrop of China's vigorous promotion of its rural revitalization strategy, RMSEs, as an essential part of rural economic development, are the backbone of the rapid development of the rural economy. China's rural areas have a large number of microenterprises, which have made significant contributions to rural employment and economic growth, but RMSEs still suffer from many problems in the process of development, such as small scale of enterprises, poor operating capacity, etc., due to the lack of a complete and convincing credit record, insufficient property mortgage strength, opaque finances, and high loan operation costs of financial institutions make RMSEs difficult and expensive to obtain financing. These problems have also become bottlenecks, restricting their development and growth. How to ensure the healthy development of RMSEs has a bearing not only on the structure of the main body of enterprises in the socialist market economy but also on the rate of economic growth in China. At present, the results of China's latest national economic census show that the overall number of RMSEs in China has continued to increase, the business market has been improving, and the enterprise industry chain is more widely distributed. RMSEs have become an important and indispensable part of China's overall socio-economic market development. China's small and micro-enterprises ensure their own survival or development. However, in the process of development, the phenomenon of rural small and micro-enterprises cannot be collected at the end of the financing of the phenomenon of loans. In green finance credit support for micro and small enterprises, there have also been various credit "crises". As more than 70 percent of urban residents and more than 80 percent of rural residents in the national employment market rely on RMSEs for their survival, once a credit "crisis" occurs in RMSEs' financing and lending, not only will third-party investors suffer losses, but it will also result in turbulence in the development of the market economy and an increase in the pressure on employment.

RMSEs include rural small enterprises, rural micro-enterprises, family workshops, and rural individual industrial and commercial households. According to the classification of RMSEs by industry in the 2019 China Statistical Yearbook, while the number of retail legal entities among

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rural microenterprises is on an upward trend, its employment at the end of the year. The number of people has shown a decreasing trend in recent years. With the use of statistics and mathematics found in the assessment of credit risk in RMSEs, domestic and foreign research scholars use the method of accurate measurement and prediction (Boushnak et al., 2018). Credit risk, which is the risk that the counterparty will not honor its obligations as they fall due. The expert scoring method is the earliest method to quantitatively analyze the credit risk of RMSEs. Scholar Thomas proposed the "5C method", which is the most commonly used expert scoring method (Breeden, 2021). In recent years, under the impact of various environments, foreign research on RMSEs has been different from Berger and Black, who pointed out through research that the current behavior of larger banks in the United States is to increase financing investment for RMSEs (Mhlanga, 2021). Since 2019, foreign scientists from Evita Hayatun Nufus have begun to focus on the analysis of the credit risk of rural micro- and small enterprises in the environmental impact of COVID-19 (Blanco-Oliver et al., 2021).

With the growth of the Internet, the RMSEs develop rapidly, resulting in the development of a series of problems at the same time, attracting a number of Chinese scholars to pursue successive research. RMSEs are also involved in the development of the financing process, China has a characteristic urban and rural structural system for scholars to bring innovation in the direction of research (Nufus et al., 2021). Peng Lu (2018) used an improved BP neural network approach to model the credit risk of rural microenterprise business financing (Peng, 2018). Tan Xiaofen & Zhang Hui (2018) studied the credit analysis of RMSEs based on the improved GSO (Generic Segmentation Offload) and ELM (Extreme Learning Machines) integrated algorithm (Tan & Zhang, 2018). Zhu et al.(2019) studied the error back-propagation (BP) establishment (SME), which is mainly used in connection with the supply chain management budget model, which is used to discuss the major factors affecting micro and small enterprise financing as well as the benefits of supply chain budgeting (Zhu et al., 2019). Solving the expense problem of small and medium enterprises and the support vector machine is mainly based on solving major credit risks such as poor information transparency in small and medium-sized enterprises (Shi et al., 2019). In their research on the credit risk of RMSEs, taking rural areas as an example, Kuang et al. (2020) used the logic model to focus on the analysis of rural microenterprises, which is significant to improving the strength of rural microenterprises (Kuang et al., 2020). Abdel-Basset et al. (2020) made an empirical analysis of RMSEs (textile industry), using metrics, prediction methods, and a logistics model to build a supply chain finance for the credit risk of rural enterprises (Abdel-Basset et al. 2020). RMSEs credit risk credit status and corresponding supply chain combined. Yang et al. (2021) built a vector machine model and analyzed the unique real estate enterprises in the supply chain to verify the credit risk of RMSEs (Yang et al., 2021).

In general, relevant scholars currently use a variety of methods to analyze the credit risk game of RMSEs, which has opened up fields and circles for the research of RMSEs. The types of credit risk can be divided into Counterpart Default, Probability of Default (PD), Loss Severity (LR, Loss Rate, RR, Recovery Rate, Exposure Risk (EAD, Exposure At Default), and Settlement Risk. Specifically, existing research results provide a better foundation for this study. In terms of credit risk evaluation system, supply chain, financing banks, and other aspects, the credit status and financing status of rural microenterprises are studied. Supply chain, financing banks, etc., to study the credit status and financing status of small and micro enterprises in rural areas (Fang, 2022; He & Hu, 2018). Advantages of the current research on RMSEs: avant-garde vision, novel ideas, deep theoretical research, advanced technology. But its disadvantages are the integration of the general environment, cross-border thinking, which is more difficult in practice, and the use of technology, which is easy to involve in enterprise privacy issues. Both domestic and foreign countries have improved the research technology of RMSEs, innovated new data models, and proposed relevant decisions, but they have not proposed relevant post-control plans (Pratama et al., 2016; Serrano-Cinca et al., 2016; Shi et al., 2016; Wang et al., 2016). On research methods, it is the combination of support neural network and supply chain finance, constructing models, adopting quantitative analysis, GSO and ELM integration algorithms, based on blockchain technology, and so on. It can be found through the literature study that only a small number of scholars studied the plight of RMSE combined with the current global economic situation and the environment of the post-epidemic era in decision-making analyses. However, there are relatively few studies on the supply chain credit risk of rural small and micro-enterprise retailers (Jones et al., 2015; Li et al., 2018; Meng & Chi, 2015).

This paper proceeds from the research idea of "questioning–analyzing–solving". This study uses a variety of methods, including literature research, a questionnaire survey, which is commonly used, tripartite evolutionary game theory, and Python model verification (Gray & Rumpe, 2017; Singh & Hess, 2020). This study explores the game analysis of credit risk in the government and banks RMSEs with micro and small enterprises under the perspective of green credit. Green credit is often referred to as sustainable finance or environmental finance. The purpose of this paper is to analyze the game between sustainable supply chain retailers RMSE and commercial banks in the post-epidemic environment. Starting from the target object, this study explores the credit status of small and medium-sized enterprises (SMEs), conducts a game analysis relying on the SFC (Space Filling Curve) of data credit, proposes an analysis of the credit risk of RMSEs which is targeted at rural micro-enterprises. Then, this study uses the logistic regression method to find out the credit risk control factors affecting RMSEs, so as to build a control model. Finally, this study proposes an adjusted decision-making plan for the control factors from the appropriate perspective (Kotarba, 2016).

2. Materials and Methods

Through the analysis of all kinds of related literature, it was found that the use of classical game theory and its proposed assumptions relative to the evolution of game theory, in the "complete" logic, which does not show a good equilibrium dynamic game, can't be more rationalized to highlight the changes in the form of the social market economy, therefore, to better evolve the law of change. The evolutionary dynamic mechanism of differential equations was proposed by Taylor and Jonker in 1978. This paper constructs an evolutionary game model, which is based on a set of differential equations, among RMSEs, third-party investors, and government regulators. This paper mainly explores that RMSEs can be third-party investor participation and government regulation of RMSEs. Three-party investors mainly for RMSEs through capital financing, borrowing, loans, etc. for RMSEs to provide paid capital transactions, such as banks, investors, and other borrowers. Government regulators can mainly realize the regulation of RMSEs and third-party investor regulators.

Compared with previous research scholars, this paper focuses on as following. Firstly, in order to make a discussion of the three-party in the evolutionary game theory, this study analyzes the strategy of the stability of the game point. This paper first introduced the government regulation as well as the profile of the third-party investor and the credit risk of RMSEs and the third-party investor between the existence of the investment behavior. Secondly, Lyapunov The first method analyzes the stability of the assumptions, pure strategy replication dynamic system, and equilibrium point of the mixed strategy, to obtain the conclusion of the evolution of the stable strategy combination under different conditions. Thirdly, this study uses Python to analyze the control model for the different initial conditions, and conclusions verification. Finally, this study gives corresponding recommendations.

The production capacity and risk-bearing capacity of RMSEs play a decisive role in the credit risk of RMSEs. This paper constructs an evolutionary game model among RMSEs, third-party investors, and government regulators, as shown in Figure 1.

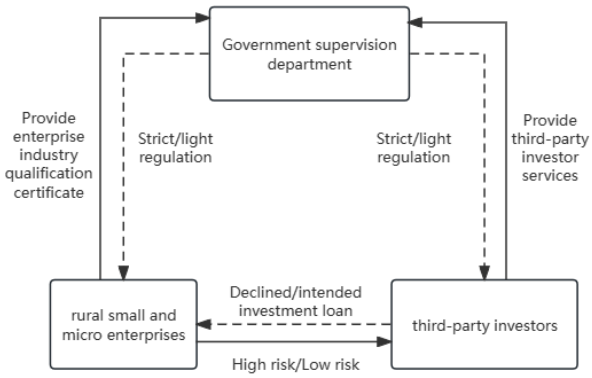

Figure 1. A three-party credit risk progression diagram using game theory in rural small and micro companies.

2.1. Basic Assumptions

Based on the online questionnaire data, it is discovered that in order to construct the tripartite evolutionary game model, care must be taken to guarantee that the parties' decisions are stable, and that the equilibrium point reaches stability in the face of a changing decision-making environment. The ensuing presumptions are made in light of each factor.

(1) Hypothesis 1

The evolutionary game model includes three subjects, such as RMSEs, third-party investors (banks, investors, other investors), and government regulators, naming three subjects as participants

1, 2, and 3, respectively. The optimal strategy stability points in the three evolved strategies evolve over time.

(2) Hypothesis 2

Low credit risk for MSMEs represents a high repayment capacity and low-risk index in green credits, in contrast to high credit risk for MSMEs, which represents a weak repayment capacity and a high-risk index. The strategic space of RMSEs $\alpha = (\alpha_1, \alpha_2)$ = (low credit risk, high credit risk), and is selected with probability x α_1, (1-x) choose with probability α_2, $x \in [0,1]$; The strategy space of the third-party investor is $\beta = (\beta_1, \beta_2)$ = (rejection of investment, intention to invest), its selection β_1 probability is y, and the selection β_2 probability is (1-y) , $y \in [0,1]$; The strategy space of the government regulatory department $\gamma = (\gamma 1, \gamma 2)$ = (strict regulation, lax regulation), and is selected with probability z γ_1, (1-z) selected with probability γ_2, $z \in [0,1]$.

(3) Hypothesis 3

The income of small and micro enterprises in rural areas is R_p, the cost of rural microenterprises with high credit risk is C_{ph}, and the cost of rural microenterprises with low credit risk is C_{pl}, $C_{ph} > C_{pl}$. When RMSEs produce products, government departments regulate them, and the products are tested and qualified. When RMSEs have high credit risk, they will seek investment from third-party investors to obtain more funds, and the cost of seeking investment is B, $B < C_{ph} - C_{pl}$. The speculative costs incurred will be for the speculative behavior of the products produced by RMSEs, where the main business management costs are falsification of production records and false and illegal publicity, etc., and let the speculative costs of RMSEs be C_p.

(4) Hypothesis 4

RMSEs can have more liquidity through the funding of third-party investors, and the third-party investor will also receive a return on the investment return of V_t. When the credit risk of RMSEs is high, if the third-party investor has an intention to "refuse to invest", the financing will fail. If the investor "intends to invest", the two-party will engage in investment behavior. Investors can help RMSEs with low credit risk to access capital, and then RMSEs are successful in financing. The speculative cost of a third-party investor's intended investment is C_t, which includes the cost of advancing rural MSME funding gaps and enhancing information security.

(5) Hypothesis 5

When the pressure of government regulation is very high, if RMSEs are at high credit risk, they will be fined F_p by the government regulator, and third-party investors who have taken the intention to invest in rural microenterprises will be fined F_t accordingly. RMSEs are rewarded M_p if they are at low credit risk and M_t is given to third-party investors who refuse to invest. If the government regulator, loosens or deregulation, because there is no decision-making data for both rural microenterprises and investors, for this reason, the government regulator is unable to judge and exercise the responsibility of rewards and punishments, set C_g be the cost of strict government regulation.

(6) Hypothesis 6

In rural areas, small and micro enterprises with low credit risk are conducive to economic development and social stability and will have a corresponding social benefit value A_g to society and government. When RMSEs are at high credit risk and have reached an agreement with a third-party investor to invest, high credit risk RMSEs financing enters the market, which affects employment stability and economic development, and costs the government the cost of maintaining social stability and regulating RMSEs D_g. Government regulators adopt a lax regulatory strategy, resulting in inadequate supervision, and high credit risk. RMSEs financing into the market situation, the higher-level regulators will be the lower level of the exercise of responsibility of the government regulators on the corresponding punishment, set T_g is the amount of administrative penalties of the higher level, $T_g > C_g$.

2.2. Model Parameter Setting

Based on the above assumptions, the mixed strategy game matrix among rural small and micro enterprises, third-party investors, and government regulators is shown in Table 1.

Table 1. Three-way mixed-strategy game matrix.

investor			Regulatory authorities	
			z keep under strict supervision	1 − z Lax regulation
RMSEs	Low credit risk x	refuse to invest y	$R_p - C_{ph} + M_P, V_t + M_t, -C_g - M_P - M_t + A_g$	$R_p - C_{ph}, V_t, A_g$
		Intentional investment 1 − y	$R_p - C_{ph} + M_P, V_t - C_t - F_t, -C_g - M_P + F_t + A_g$	$R_p - C_{ph}, V_t - C_t, A_g$
	High credit risk1 − x	refuse to invest y	$-C_{ph} - C_p - F_P, V_t + M_t, -C_g + F_P - M_t$	$-C_{ph} - C_p, V_t, 0$
		Intentional investment 1 − y	$R_p - C_{ph} - C_p - B_t - F_P, V_t - C_t + B_t - F_t, -C_g + F_P + F_t - D_g$	$R_p - C_{ph} - C_p - B_t, V_t - C_t + B_t, -D_g - T_g$

2.3. Model Analysis

(1) Analysis of the stability of rural small and micro enterprise strategies

(E_{11}, E_{12}, $\overline{E_1}$) represents the expected return for RMSEs with high credit risk, the expected return with low credit risk, and the average expected return, respectively, relative to:

$$\begin{cases} E_{11} = yz[R_p - C_{ph} + M_p] + y(1-z)[R_p - C_{ph}] + (1-y)z[R_p - C_{ph} + M_p] + (1-y)(1-z)[R_p - C_{ph}] \\ E_{12} = z[(1-y)(R_p - B_t) - C_{pl} - C_p - F_p] + (1-z)[(1-y)(R_p - B_t) - C_{ph} + C_p] \\ \overline{E_1} = xE_{11} + (1-x)E_{12} \end{cases} \tag{1}$$

Replicating dynamic equations:

$$\begin{aligned} F(x) &= dx/dt \\ &= x(xE_{11} - \overline{E_1}) \\ &= x(x-1)[C_{ph} - C_{pl} - C_p - B_t - y(R_p - B_t) - z(F_p + M_p)] \end{aligned} \tag{2}$$

The first-order derivatives of X and the set G(y) are respectively:

$$\frac{d\left(F(x)\right)}{dx} = (2x-1)C_{ph} - C_{pl} - C_P - B_t - y\left(R_P - B_t\right) - z(F_p + M_p) \tag{3}$$

$$G\left(y\right) = C_{ph} - C_{pl} - C_P - B_t - y\left(\left(R_P - B_t\right) - z\left(F_p + M_p\right)\right) \tag{4}$$

According to the law of stability of differential equations, rural MSMEs are in a steady state for low credit risk must satisfy: $F(x) = 0$ and $dF((x))/dx < 0$. Since $\partial G(y) / \partial y < 0$, G(y) is a decreasing function with respect to y. Therefore: at that time, $y = [C_{ph} - C_{pl} - C_p - B_t - z(F_p + M_p)] / (R_p - B_t) = y^*G(y) = 0$, $dF((x))/dx = 0$, this is an uncertain strategy; at that time, $y < y^*G(y) > 0$, at this time $dF((x)) / dx|_{x=0} < 0$, $x = 0$ is the evolutionary stable strategy of (ESS) RMSEs; conversely, $x = 1$ is ESS. The strategy evolution phase of RMSEs Figure, as shown in Figure 2.

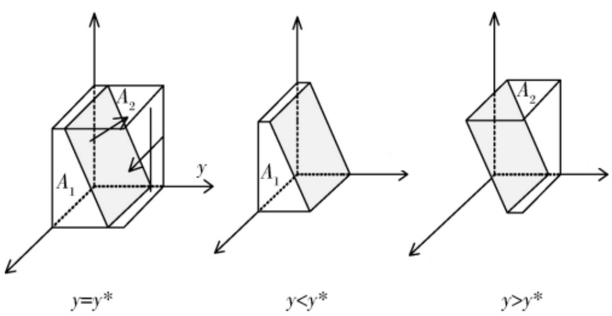

Figure 2. Phase diagram of strategic evolution of RMSEs.

The above figure shows that the probability of a RMSEs being at a stable low credit risk is calculated as the volume A_1 of V_{A1}, the probability of being at a stable low credit risk is calculated as the volume A_2 of V_{A2}:

$$V_{A1}\int_0^1\int_0^1 \frac{C_{ph}-C_{pl}-C_P-B_t-z\left(F_p+M_p\right)}{\left(R_P-B_t\right)}dzdx = \frac{2\left(C_{ph}-C_{pl}-C_P-B_t\right)-\left(F_p+M_p\right)}{2\left(R_P-B_t\right)} \qquad (5)$$

$$V_{A2}=1-V_{A1}$$

Corollary 1: The probability of a RMSEs being in a low credit risk state is positively related to the RMSEs' production and marketing revenues, investment costs, speculative costs, and government incentives and penalties, and is negatively related to the costs saved by the RMSEs' high credit risk.

Proof: Based on the expression for the probability of a RMSEs being a low credit risk, V_{A2}, the first-order partial derivatives of each element are obtained as: find the first-order partial derivatives of each factor, we get: $\partial V_{A2}/\partial R_p > 0$, $\partial V_{A2}/\partial(F_p+M_p) > 0$, $\partial V_{A2}/\partial C_p > 0$, $\partial V_{A2}/\partial(C_{ph} - C_{pl}) < 0$, therefore, an increase in R_p、B_t、$(F_p + M_p)$ or a decrease in $C_{ph} - C_{pl}$ will increase the probability of a RMSEs being at low credit risk.

Corollary 1 shows that safeguarding the income from production and sales of RMSEs can prevent them from being exposed to high credit risk. The government can improve the strength of rewards and penalties in the exercise of supervision, which will effectively reduce the probability of high credit risk for small and micro enterprises in rural areas and can also use high-tech means to increase the speculative costs of RMSEs with the help of external forces, which will be conducive to the reduction of credit risk for rural microenterprises.

Corollary 2: The probability of low credit risk for rural microenterprises increases as the probability that the game generates investor "refusals" and strict regulation increases.

Proof: In the analysis of the decision-making of RMSEs, $z < [C_{ph} - C_{pl} - C_p - B_t - y(R_p - B_t)] / (F_p + M_p)$, $y < y^*$ when, $\overline{G}(y) > 0, \overline{d(\overline{F}(x))/d}x|_{x=0} < 0$, then x=0 is an evolutionary strategy; conversely, x=1 is an evolutionary strategy. Thus, as y, z gradually increase, the stabilisation strategy for RMSEs increases from x = 0 (Low credit risk) to x = 1 (high credit risk).

Corollary 2 indicates that increasing the likelihood of refusal to invest generated by third party investors will contribute to the reduction of credit risk in RMSEs, making it low credit risk as an accurate decision. Increasing the probability of strict supervision by government regulators can effectively ensure the credit risk of rural microenterprises. Or ensuring the rigor of third-party investors, such as the third-party investor's own sense of responsibility, social responsibility, external assistance, etc. can effectively ensure that the rural microenterprise's credit supervision, to achieve the credit risk of rural microenterprises, the social management of the atmosphere of the co-management.

(2) Strategic stability analysis of third-party investors

The expected return E_{21}, E_{22}, $\overline{E_2}$ of the third-party investor who chooses to decline to invest and intends to invest is the average expectation:

$$E_{21}=x\left[z\left(V_t+M_P\right)+\left(1-z\right)V_t\right]+\left(1-x\right)\left[z\left(V_t+M_t\right)+\left(1-z\right)V_t\right]$$

$$E_{21}=x[z\left(V_t-C_t-F_t\right)+\left(1-z\right)\left(V_t-C_t\right)]+(1-x)[V_t-C_t+B_t-zF_t] \qquad (6)$$

$$\overline{E_2}=yE_{21}+\left(1-y\right)E_{22}$$

Replicating the dynamic equations and the corresponding first-order derivatives from (6):

$$F(y)=dy/dt=y(xE_{21}-\overline{E_2})=y(y-1)[(1-x)(B_t-M_t)-z(F_p+M_t)-C_t \qquad (7)$$

$$\frac{d\left(F\left(y\right)\right)}{dy}=\left(2y-1\right)\left[\left(1-xB_t-z\left(F_p+M_t\right)\right)-C_t\right] \qquad (8)$$

$$\text{Set } J\left(z\right)=(1-x)B_t-z\left(F_p+M_t\right)-C_t] \qquad (9)$$

Based on the stability of the differential equation, it is known that to stabilize the probability of a third-party investor rejecting an investor, it is necessary to achieve: F(y)=0 and dF((y))/dy<0.

Since J (z) is negatively correlated. Therefore: at that time, $z = (1-x)B_t - \frac{C_t}{(F_t+M_t)} = z^* J(z) = 0$, $dF((y)) / dy = 0$, $F(y) = 0$, the third-party investor cannot determine the stable strategy; at that time, $z < z^* J(z) > 0$, $dF((y)) / dy|_{y=0} < 0$, it is y=0ESS; at that time , $z > z^* y = 1$ it is ESS. The evolution phase diagram of third-party investor strategies is shown in Figure 3.

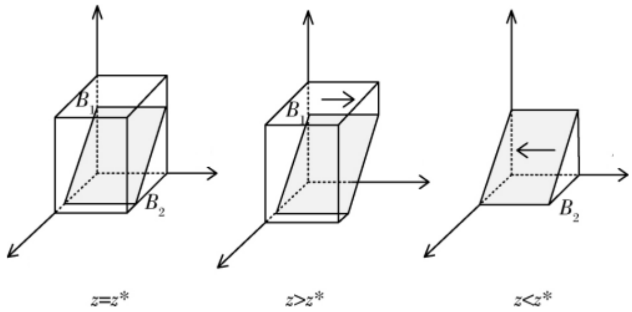

Figure 3. Third-party investor strategy evolution phase diagram.

From Figure 3, the volume C_1 of V_{C_1} represents the probability of strict regulation by the government regulator, and the volume C_2 of V_{C_2} represents the probability of lax regulation. As follows:

$$V_{C_1} = \int_0^1\int_0^1 \frac{F_P + F_t + T_g - C_g - x\left(M_p + F_P + T_g\right)}{\left(F_t + M_t + T_g - xT_g\right)} dxdy$$
$$= \frac{M_p + F_P + T_g}{T_g} - \left[\frac{M_p + F_P + C_g}{T_g} + \frac{\left(M_p + F_P\right)\left(M_t + F_t\right)}{T_g^2}\right] \ln\left(1 + \frac{T_g}{M_t + F_t}\right) \quad (10)$$
$$V_{C_2} = \left[\frac{M_p + M_t + C_g}{T_g} + \frac{\left(M_p + F_P\right)\left(M_t + F_t\right)}{T_g^2}\right] \ln\left(1 + \frac{T_g}{Mt + Ft}\right) - \frac{M_p + F_P}{T_g}$$

Corollary 3: Fines for rural MSEs and administrative fines for lower-level regulators will be an additive function of strict government regulation, while fines for third-party investors and rural MSEs will be a subtractive function of strict regulation, and fines for third-party investors will be a function of a large number of factors that cannot be determined.

Proof: The first-order partial derivatives of each of the elements are obtained separately for $\partial V_{B_1} / \partial B_t < 0$, $\partial V_{B_1} / \partial M_t > 0$, $\partial V_{B_1} / \partial F_t > 0$, $\partial V_{B_1} / \partial C_t > 0$. Thus, a decrease in B_t and an increase in M_t, F_t and C_t increase the probability that a third-party investor will refuse to invest.

Corollary 3 suggests that when third-party investors earn a large return on their investments, the government should strengthen strict regulation of third-party investors. In addition, by improving the professionalism of investors and expanding the media's disclosure efforts, the speculative costs of third-party investors' investments can be increased, and their speculative behaviors can be reduced in the interest of the third-party investors. Severe penalties can effectively protect the capital recovery of third-party investors, as well as the credit risk of RMSEs, and can also take incentives to help their financing.

Corollary 4: During the game, as the probability of strict government regulation increases, it increases the probability of speculative behavior by third-party investors who refuse to invest.

Proof: on the basis of the stability of third-party investors' decisions, y = 0 is ESS when $z < z^*$， $x < B_t - M_t - C_t - z(F_t + M_t) / (B_t - M_t) = x^*$, $y = 0$; $z > z^*$, $x > x^*$; y = 1 is ESS when $z > z^*$, $x > x^*$. Therefore, when x、z becomes bigger and bigger and y = 0 appears when the third party investor refuses to invest up to y = 1, then x, z, and y are positively correlated.

Corollary 4 suggests that the decision-making behavior of third-party investors will be influenced by rural MSMEs and government regulators. The government to increase strict supervision, RMSEs to reduce credit risk for low credit risk probability can promote third-party investors to refuse to invest as a stable strategy. For this reason, the strict supervision of government regulators, in favor of rural small and micro-enterprise industry economic development, to protect the interests of third parties, to protect the normal operation of RMSEs, incentives for RMSEs in the mode of production and operation, the introduction of corresponding policies and other measures.

(3) Analysis of the stability of government regulators' strategies E_{31}, E_{32}, $\overline{E_3}$, are the expected returns to strict regulation, the expected returns to lax regulation, and the expected returns to average regulation by government regulators, respectively:

$$\begin{cases} E_{31} = -C_g + xA_g - xM_P - yM_t + (1-x)F_P + (1-y)F_t - (1-x)(1-y)D_g \\ E_{32} = xA_g - (1-x)[0 + (1-y)(D_g - T_g)] \\ \overline{E_3} = zE_{31} + (1-z)E_{32} \end{cases} \quad (11)$$

(9) is the replicated dynamic equation for the regulator, (12) is the first order derivative, and (13) is the hypothetical H(y):

$$F(z) = dz/dt = z(z-1)[C_g - F_P - F_t - T_g + x(M_P + F_P + T_g) + y(M_t + F_t + T_g) - xyT_g] \quad (12)$$

$$d(F(z))/dz = (2z-1)\left[C_g - F_P - F_t - T_g + x(M_P + F_P + T_g) + y(M_t + F_t + T_g) - xyT_g\right] \quad (13)$$

$$H(y) = C_g - F_P - F_t - T_g + x(M_P + F_P + T_g) + y(M_t + F_t + T_g) - xyT_g \quad (14)$$

When government regulation is entirely strict: $F(z) = 0$ and $dF((z))/dz < 0$. Because of $\frac{\partial H(y)}{\partial y} > 0$ that H(y) It is positively correlated with y. Therefore: when $y = F_p + F_t + T_g - C_g - \frac{x(M_P + F_P + T_P)}{(M_t + F_t + T_g - xT_g)} = y^{**}$, $H(y) = 0$, $dF((z))/dz = 0$, the stable strategy cannot be determined; when $y < y^{**}$, $H(y) < 0$, $dF((z))/dz|_{z=0} < 0$, $z = 1$, is ESS, on the other hand $z = 0$ is ESS Government regulatory department phase diagram, as shown in Figure 4.

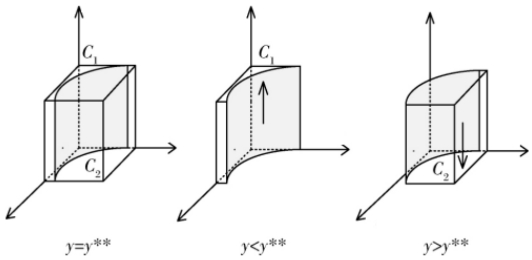

Figure 4. Phase diagram of the strategic evolution of government regulatory agencies.

From Figure 4, the probability of strict regulation by the government regulator is the same as the volume V_{C_1} of C_1. The volume V_{C_2} of C_2 is the same as the probability of lax regulation by the government regulator.

$$\begin{aligned} V_{C_1} &= \int_0^1\int_0^1 \frac{F_P + F_t + T_g - C_g - x(M_p + F_P + T_g)}{(F_t + M_t + T_g - xT_g)} dxdy \\ &= \frac{M_p + F_P + T_g}{T_g} - [\frac{M_p + F_P + C_g}{T_g} + \frac{(M_p + F_P)(M_t + F_t)}{T_g^2}] ln(1 + \frac{M_t + F_t}{T_g}) \end{aligned} \quad (15)$$

$$V_{C_2} = \left[\frac{M_p + M_t + C_g}{T_g} + \frac{(M_p + F_P)(M_t + F_t)}{T_g^2}\right] \ln\left(1 + \frac{T_g}{M_t + F_t}\right) - \frac{M_p + F_P}{T_g} \quad (16)$$

Corollary 5: The probability of tough measures by government regulators is related to many factors. Among them, government fines for RMSEs and administrative penalties for ineffective government regulation will increase the probability of tough regulation. Conversely, government regulators' incentives for drug manufacturers and third-party investors reduce the likelihood of tough measures. Moreover, the relationship between the amount of government fines imposed on third-party investors and the probability of strict regulation is complicated by a number of factors.

Proof: According to V_{C_1}, find the first-order partial derivatives of each element respectively. Since $1 - M_t + F_t + C_g < \ln(1 + T_g / M_t + F_t) < T_g/M_t + F_t$, we get $\partial V_{C_1} / \partial F_t > 0$(st $(M_p + M_t + C_g) - (M_t + F_t + C_g) > 0$), $\partial V_{C_1} / \partial M_p < 0$, $\partial V_{C_1} / \partial M_t < 0$, $\partial V_{C_1} / \partial T_g > 0$, so $(M_g + M_t + C_g) - (M_t + F_t + C_g) > 0$ when, F_t increases, can V_{C_1} increase. In addition, F_t、T_g increasing or M_p、M_t decreasing can increase the regulatory stringency rate of government regulatory authorities.

Corollary 5 suggests that there are a number of factors that contribute to strict regulation by government regulators. On the one hand, the higher the fine set by the government regulator, the stricter the government regulation; on the contrary, the higher the amount of reward, the lower the rate of strict government regulation. On the other hand, higher administrative penalties imposed on regulators by higher levels of government may motivate regulators to strictly fulfill their regulatory duties. In addition, increasingly strict government regulation may cause third-party investors to refuse to invest, thus reducing the high credit risk of RMSEs in the market and improving the operational stability of social RMSEs.

Corollary 6: In the evolutionary process, the rate of strict regulation by government regulators decreases as the rate of low credit risk or refusal to invest by third-party investors in RMSEs increases. Proof: Through the analysis of the evolutionary stability of the strategic choices of government regulatory agencies, it can be concluded that when $y < y^{**}$, immediately, $x < [(1 - y)(F_t + T_g) + (F_p - C_g - yM_t)] / (M_p + F_p + T_g - yT_g)$ $z = 1$ it is an evolutionary stable strategy; as y and x increase, the probability of strict government supervision decreases from $z = 1$ As small as $z = 0$, so z decreases as y and x increase.

Corollary 6 shows that the strict supervision rate of government regulatory authorities is affected by the strategic choices of RMSEs and third-party investors. When the credit risk of RMSEs is low or the probability of third-party investors refusing to invest is high, government regulatory authorities may reduce strict supervision, resulting in a lack of supervision. Therefore, government regulatory authorities should strengthen the supervision of RMSEs and third-party investors to ensure the rigor and stability of supervision, thereby maintaining market order and protecting consumer interests.

(4) Stability analysis of the equilibrium point of the three-party evolutionary game system

From $F(x) = 0$, $F(y) = 0$, $F(z) = 0$ the system equilibrium point can be obtained:

$$E_6(1,\ 0,\ 1), E_7(0,\ 1,\ 1), E_8(1,\ 1,\ 1), E_9\left(0,\ \frac{F_p + F_t + T_g - C_g}{M_t + F_t + T_g},\ (B_t - C_t)(F_t + M_t)\right),$$

$$E_{10}\left((F_p + F_t + T_g - C_g)/F_p + M_P\right), E_{11}\left((F_p - M_t - C_g)/F_p + M_P),\ 1,\ (C_{ph} - C_{pl} - C_p - R_p)/(?F_p + M_P)\right),$$

$$E_{12}\left((B_t - C_t)/B_t,\ (C_{ph} - C_{pl} - C_p - R_t)/(R_p - B_t)\right),$$

$$E_{13}\left((B_t - M_t - F_t - C_t)/B_t\ \ (C_{ph} - C_{pl} - C_p - B_t - F_p - M_p)/(R_p - B_t),\ 1\right)$$

Because of x，y，z ∈ [0,1], then

$E_9 \sim E_{13}$ under certain conditions, existence is meaningful, and because of $(C_{ph} - C_{pl} - C_p - R_p) < 0$, it is E_{11} meaningless. The Jacobian matrix of the third-party evolutionary the game system is:

$$J = \begin{bmatrix} J_1 & J_2 & J_3 \\ J_4 & J_5 & J_6 \\ J_7 & J_8 & J_9 \end{bmatrix} = \begin{bmatrix} \frac{\partial F(x)}{\partial x} & \frac{\partial F(x)}{\partial y} & \frac{\partial F(x)}{\partial z} \\ \frac{\partial F(y)}{\partial x} & \frac{\partial F(y)}{\partial y} & \frac{\partial F(y)}{\partial z} \\ \frac{\partial F(z)}{\partial x} & \frac{\partial F(z)}{\partial y} & \frac{\partial F(z)}{\partial z} \end{bmatrix} \tag{17}$$

$$= y(y-1)[-F_t - M_t]z(z-1)[F_p + M_P + T_g - yT_g]$$

$$= \begin{bmatrix} (2x-1)[-C_{pl} - C_p - B_t - y(R_p - B_t) - z(?F_p + M_P) & x(x-1)[B_t - R_p] & x(x-1)(-F_p - M_P) \\ y(y-1)[-B_t] & (2y-1)[(1-x) - B_t - z(F_t + M_t) - C_t] & y(y-1) \end{bmatrix}$$

According to Liapunov’s first rule, the equilibrium point of a dynamical system is asymptotically stable when the real part of all eigenvalues of the Jacobi matrix is negative (Matt et al., 2015). The equilibrium point is unstable if the real part of at least one eigenvalue of the Jacobi matrix is positive. If the real part of the Jacobi matrix is negative except for the real part of the eigenvalues, which is zero (Altaf & Shah, 2018; Ma & Ma, 2020; Vives, 2019), the equilibrium point is in a critical state and its stability cannot be determined by the sign of the eigenvalues (Deloof & Rocca, 2015; Huang et al., 2019). Therefore, the stability of the equilibrium point of the system can be determined by analyzing the eigenvalues of the Jacobi matrix. As shown in Table 2.

Table 2. Equilibrium point stability analysis.

equilibrium point	Jacobian matrix eigenvalues $\lambda_1, \lambda_2, \lambda_3$	Stability conclusion real part sign	condition	
$\mathbf{E_1 = (0,0,0)}$	$C_{pl} - C_{ph} + C_p + B_t + C_t, F_p + T_g + F_t - C_g$	(−，−，+)	~	\
$\mathbf{E_2 = (1,0,0)}$	$C_{ph} - C_{pl} - C_p - B_t, F_t - C_g - M_P$	(+，+，×)	~	\
$\mathbf{E_3(0，1，0)}$	$C_{pl} - C_{ph} + C_p - R_p, F_p - M_t - C_g$	(+，+，×)	~	\
$\mathbf{E_4(0，0，1)}$	$C_{pl} - C_{ph} + C_p + B_t + C_t + M_P, M_t + F_t + C_t - B_t, C_g - F_p - F_t - T_g$	(−，−，−)	ESS	①
$\mathbf{E_5(1，1，0)}$	$C_{ph} - C_{pl} - C_p - R_p, -C_g - M_P - M_t,$	(−，−，−)	ESS	\
$\mathbf{E_6(1，0，1)}$	$C_{ph} - C_{pl} - C_p - B_t - F_p - M_P, F_t + M_t + C_t, C_g + M_P - F_t,$	(×，+，×)	~	\
$\mathbf{E_7(0，1，1)}$	$C_{pl} - C_{ph} + C_p + R_p + F_p + M_P, B_t - M_t + F_t - C_t, C_g + M_t - F_p$	(+，×，×)	~	\
$\mathbf{E_8(1，1，1)}$	$C_{ph} - C_{pl} - C_p - R_p - F_p - M_P, -F_t - M_t - C_t, C_g + M_t + M_P$	(−，−，+)	~	\
$\mathbf{E_9(0, y_1，z_1)}$	$a_1, \lambda_1 = \lambda_3 = \sqrt{y_1(1-y_1)(F_t + M_t)z_1(1-z_1)(M_t + F_t + T_g)}$	(−，0，0)	~	②
$\mathbf{E_{10}(x_1, 0，z_2)}$	$a_2, \lambda_2 = \lambda_3 = \sqrt{x_1(1-x_1)(F_p + M_P)z_1(1-z_1)(M_P + F_p + T_g)}$	(−，0，0)	~	③
$\mathbf{E_{11}(x_2, y_2，0)}$	$a_3, \lambda_2 = -\lambda_3 = \sqrt{x_2(1-x_2)(R_p + B_t)y_2(1-y_2)B_t}$	(×，+，−)	~	④
$\mathbf{E_{12}(x_3, y_3，1)}$	$a_4, \lambda_2 = -\lambda_3 = \sqrt{x_3(1-x_3)(R_p + B_t)y_3(1-y_3)B_t}$	(×，+，−)	~	⑤

Note: x means uncertainty and means instability, x_1, x_2, x_3, y_1, y_2, y_3, z_1, z_2 are the coordinates of the corresponding equilibrium point respectively. If the conditions corresponding to the equilibrium point are not met, the equilibrium point is unstable or meaningless. ①$C_{pl} - C_{ph} + C_p + B_t + C_t + M_p < 0$ ②$a_1 < 0$, $F_p - C_g < M_t$, $B_t - M_t - F_t - C_t < 0$ ③$a_2 < 0$, $F_t - C_g < M_p$, $C_{ph} - C_{pl} - C_p - B_t - F_p - M_p < 0$ ④$B_t - C_t > 0$, $C_{ph} - C_{pl} - C_p - B_t > 0$ ⑤$B_t - M_t - F_t - C_t > 0$, $C_{ph} - C_{pl} - C_p - B_t > 0$

Corollary 7: When $C_{pl} - C_{ph} + C_p + B_t + C_t + M_p < 0$, $B_t + M_t + F_t + C_t < 0$, there are two stable points in a replicated dynamic system $E_4(0, 0, 1)$, $E_5(1, 1, 0)$.

Proof: According to Table 2, the conditions are met at this time ①, so $E_4(0, 0, 1)$ and $E_5(1, 1, 0)$ are the asymptotic stable points of the system. If the conditions ②③do not meet the situation, the equilibrium point $E_9(0, y_1, z_1)$ is $E_{10}(x_1, 0, z_2)$ worthless. If all conditions ④⑤apply, the equilibrium point $E_{11}(x_2, y_2, 0)$, $E_{12}(x_3, y_3, 1)$ is an unstable point.

Corollary 7 suggests that when government penalties and incentives are not sufficient to influence the strategic choices of RMSEs and third-party investors, or when rural MSEs have high credit risk and high returns to speculation, and when third-party investors have high returns to rent-seeking, the initial point of choice for tripartite investors should be determined (high credit risk, willingness to rent-seeking, low credit risk, no rent-seeking, light regulation). At this point, government regulation is ineffective in restraining the behavior of RMSEs and third-party investors, and RMSEs with high credit risk jeopardize the stability of the social enterprise market. In order to avoid a combination of stabilization strategies (i.e., the high credit risk of RMSEs, strong rent-seeking intentions of third-party investors, and a low rate of strict regulation by the government regulator), the regulator needs to set fines or incentives sufficiently large to make the incentive and penalty mechanisms effective. This can influence the strategic choices of rural MSMEs and third-party investors, thereby increasing the rate of strict supervision by government regulators and avoiding the emergence of regulatory deficiencies.

Corollary 8: When $F_p + M_p > C_{ph} - C_{pl} - C_p - B_t > 0$, $M_t + F_t > B_t - C_t > 0$ When, the system has at least one stable point $E_5(1, 1, 0)$, and $F_p - M_t > C_g$, $F_t - M_p > C_g$ when it is satisfied, the replica dynamic system has and has only one stable point $E_5(1, 1, 0)$.

Proof: When $F_p + M_p > C_{ph} - C_{pl} - C_p - B_t > 0$, $M_t + F_t > B_t - C_t > 0$ When, according to Table 2, does not meet the conditions ①, ⑤, it is an unstable point and is $E_4(0, 0, 1)$ $E_{12}(x_3, y_3, 1)$ meaningless; in this case, if it meets the conditions ④, it $E_{12}(x_3, y_3, 1)$ is an unstable point; conditions ②, ③they require more factors to judge. When we add another condition $F_p - M_t > C_g$, $F_t - M_p > C_g$, the condition ②, ③is not satisfied, and at this time $E_9(0, y_1, z_1)$, $E_{10}(x_1, 0, z_2)$ It makes no sense that there is only one stable point in a replicated dynamic system $E_5(1, 1, 0)$.

Corollary 8 suggests that the amount of rewards and penalties limited to government regulators should be higher than the amount of respective behavioral returns of RMSEs and investors, so as to ensure the emergence of behavioral combinations in the game among the three (low credit risk of RMSEs, investors' willingness to seek rent and strict supervision by the government). And, RMSEs cost income, cost of regulation, and government regulators in the exercise of the process of ineffective, government regulators will also suffer the amount of administrative penalties, the amount of change in the evolution of the game for the results of the impact. Furthermore, the government will be in accordance with the RMSEs under the set reasonable requirements, set the corresponding rewards and penalties rules, and effectively reduce the number of times the equilibrium point of the mixed strategy occurs. For example, the cost of the government regulatory department is less than the difference between the amount of fines for RMSEs and the amount of incentives for investors. It can be seen that the reasonable design of the government regulatory mechanism rules can effectively protect the social market credit stability of small and micro enterprises in rural areas and promote the steady development of all types of enterprises.

3. Results

Using Python tools, assignments are made in conjunction with the questionnaire values to verify the stability of the conclusions obtained from the evolutionary game, and the strategy model is analyzed. Obtain array 1, which satisfies the conditions in Corollary 8 above: $R_p = 150$, $C_{ph} - C_{pl} = 85$, $C_p = 10$, $B_t = 40$, $F_p = 40$, $M_p = 20$, $F_t = 20$, $M_t = 15$, $C_t = 10$, $C_g = 15$, $T_g = 40$. Based on the above array 1 R_p、B_t、F_t、M_t、M_p、T_g, Analyze the impact on evolutionary game processes and outcomes.

First, R_p as an analysis of the changes that will have an impact on the game process and results, $R_p$three numerical values are assigned. as follows $R_p = 100, 150, 200$, running through Python, you can get the data model after the game evolves 50 times, as shown in Figure 5 below.

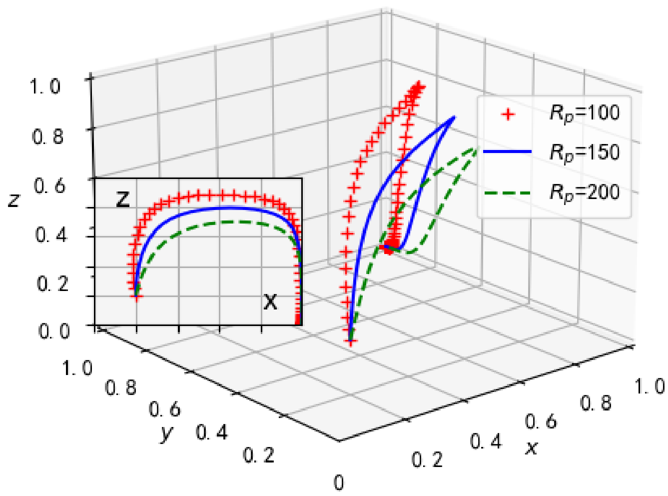

Figure 5. Income Impact Chart of RMSEs.

As can be seen from the above figure, the overall result tends to a stable point in the process, when the increase in the overall benefits received by RMSEs ensures a stable rate of evolution of credit risk in RMSEs. As R_p increases, the probability of low credit risk of RMSEs increases, then the probability of strict regulation will reduce. Therefore, when the government regulators supervise RMSEs, they should do strict supervision of the credit risk of RMSEs, which focuses on the control of some remote areas and rural areas with relatively difficult operation and relatively low returns and can moderately relax the control of the operating status of rural microenterprises to ensure the credit risk of rural microenterprises.

When B_t analyzing the changes in the evolutionary game, yes B_t assignment, $B_t = 20, 40, 60$, the running results are shown in Figure 6.

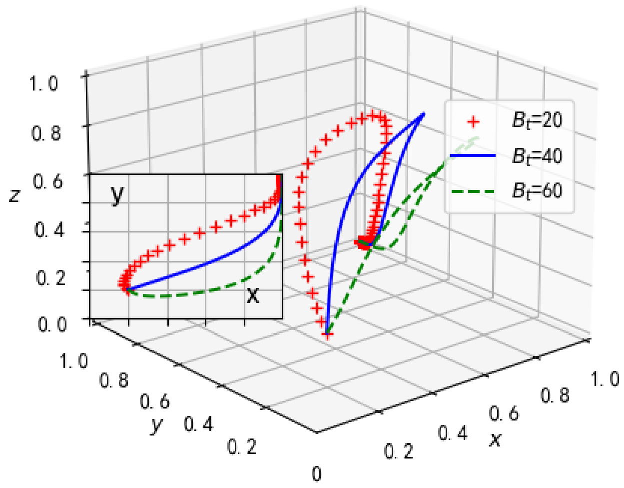

Figure 6. Investment cost impact diagram.

The investment cost impact diagram shows that as B_t the credit risk of RMSEs rises, the probability of low credit risk is gradually increasing, and the probability of third-party investors' investment behavior of "rejecting investment" is also decreasing. In order to ensure that the credit risk stability of RMSEs plays a role in the market, government regulatory authorities can use the ability of social media disclosure to enhance the impact of the credit risk reputation of RMSEs and increase investment in RMSEs where credit risks arise. costs, increasing the probability of producing low credit risk.

Next, assigned respectively $F_t = 0, 20, 40$, and the analysis model results are shown in Figure 7.

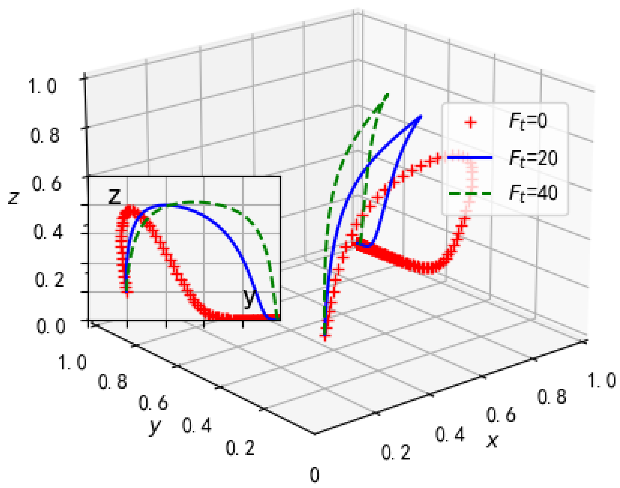

Figure 7. Government's influence on third-party investors.

Figure 7 shows that before the credit risk of RMSEs is low and the credit risk is stable, increasing, the probability of government regulatory authorities implementing strict supervision increases. When the credit risk of RMSEs is low, the credit risk probability tends to be stable. F_t After 1, the probability of strict government regulation gradually decreases and stabilizes at 0, and F_t an increase will increase the probability of third-party investors' "rejection of investment" behavior.

Assigned respectively $M_t = 0, 15, 30$, the analysis model results are shown in Figure 8.

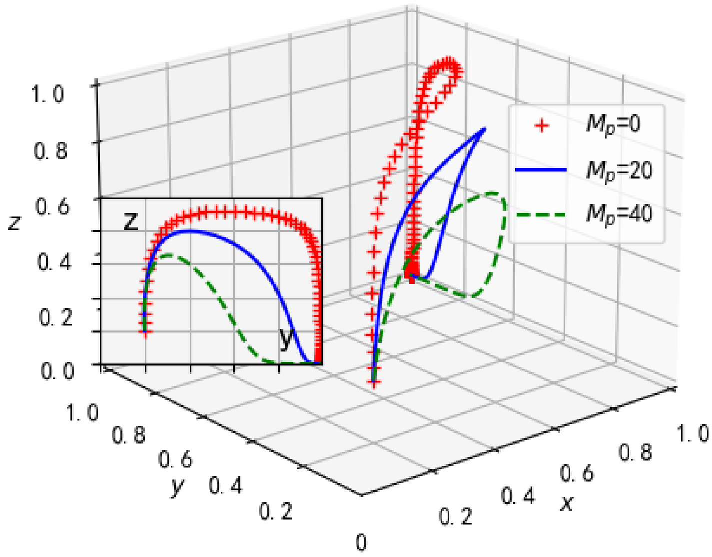

Figure 8. Government's influence on RMSEs.

As the impact of government regulatory departments on RMSEs M_t increases, the rate of strict supervision by government regulatory departments will decrease during the implementation process. In order to prevent fixed payments, government regulatory authorities should adopt reasonable reward and punishment measures and convert payments to third-party investors into rewards. This can encourage third-party investors to assume the responsibility of protecting the social enterprise economy and promote economic stability.

Then assigning M_p values to respectively. M_p=0, 20, 40. The model generated after running the results 50 times is shown in Figure 9.

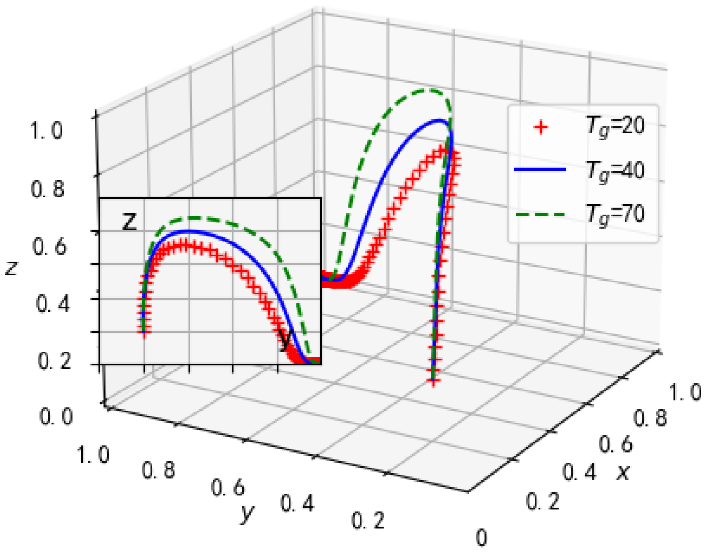

Figure 9. The impact of weak government supervision.

The graph of government supervision Figure 9 shows that when the game tends to a stable value, as M_p the increase in, the rate of strict government supervision will decrease, and the rate of third-party investors taking "rejection of investment" behavior will increase.

For T_g assignment, T_g=20, 40, 70, the running model diagram is shown in Figure 10.

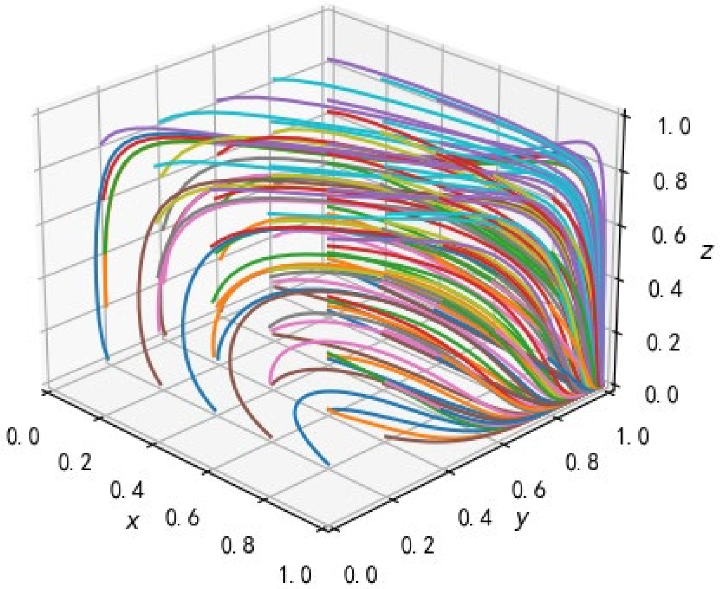

Figure 10. The result of array evolution 50 times.

Figure 10 shows that the credit risk of RMSEs is low. After the credit risk stabilizes at 1, T_g it rises, and the probability of strict government supervision increases. It can be seen that although the government's regulatory reward and punishment mechanism can ensure the stability of the credit risk of RMSEs, it does not facilitate the government regulatory authorities to supervise themselves during the supervision process. Administrative rewards and punishments implemented by higher-level governments can enable regulatory authorities to increase the rate of strict supervision and further improve the robustness of credit risks of RMSEs.

Array 1 can provide the basis required in Corollary 6. Assign array 2: $R_p = 150$, $C_{ph} - C_{pl} = 105$, $C_p = 10$, $B_t = 50$, $F_p = 25$, $M_p = 15$, $F_t = 18$, $M_t = 12$, $C_t = 10$, $C_g = 15$ which meets the requirements in Corollary 5. The values change according to time and evolve 50 times. The running results are shown $T_g = 40$ in Figure 11.

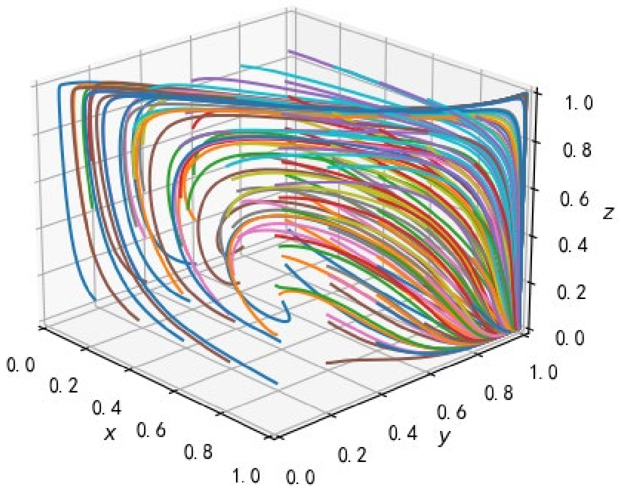

Figure 11. Array 2 evolution 50 times results.

50 evolutions of array 2 shows in the figure that $F_{10}(x_1, 0, z_2)$ it is an unstable point in the equilibrium point. It can be concluded that the behavior value of the state Gy combination point at this point is (low credit risk, refusal to invest, and loose supervision), which is consistent with the results of Corollary 6, under the condition ①, there are two stable points in the operating data: (0, 0, 1) and (1, 1, 0), the corresponding stable strategic behavior combinations are (high credit risk, intention to invest, strict supervision) and (low credit risk, refusal to invest, loose supervision). Therefore, government regulatory authorities must establish a complete information network to

help understand the interests of RMSEs and third-party investors, promptly adopt rewards and punishments for both, and promptly avoid the harm of excessive credit risks of RMSEs. The phenomenon of economic stability of small and micro enterprises in rural areas. It can be seen that the control model analysis and stability analysis of various strategies are the same and highly efficient, which has practical guiding significance for credit risk management of RMSEs.

4. Discussion and Implications

Given the status of small and micro enterprises in rural growth, the following research is conducted in this paper. ①Investigate the process of correlation between the influencing factors, pinpoint the primary factors impacting the credit risk of rural small and micro businesses, and establish a foundation for the ensuing game assumptions. Examine the primary elements influencing the credit risk of small and micro businesses in rural locations, taking into account the information team's reputation, moral hazard, the enterprise’s own environmental impact, the external environment, and credit reward and punishment mechanisms; ②Through the method of evolutionary game theory, combined with the collected relevant data, Combining theory with practice, establish relevant game analysis models, make basic assumptions, and conduct detailed analysis of the participants, information, probabilities, and strategies in the assumptions, taking the retail industry enterprises in RMSEs and various subjects of credit risk issues as examples The main research object is to use game analysis to build a decision tree, analyze the relationship between various subjects, achieve game equilibrium, and obtain relevant information from the results of game analysis to provide relevant basis for proposing relevant and effective countermeasures on how to control the credit risk of RMSEs; ③Analyze the final conclusion, build a control model, and propose relevant and effective control strategies for the credit risk of RMSEs.

Considering the possibility of credit risk investment behavior of RMSEs and third-party investors, this paper builds an evolutionary game theory by using the evolutionary game theory on the credit risk of RMSEs and their decision-making role of the three “RMSEs, third-party investors and government regulators”, discusses the stability of decision-making among the three, and then verifies the validity of the conclusions obtained by participating in the control model. In evolutionary game theory, the stability of the six combinations, as well as the relationship between the interaction of the various elements, and then the conclusions obtained, participation in the control model to verify the validity of the conclusions, to give the credit risk of RMSEs and the third-party investment behavior resulting in the stability of the portfolio of strategies to meet the corresponding conditions, and the influence of the relationship between the various factors and the stability of the requirements of the rural microenterprises on the issue of credit risk to put forward the relevant strategies. The strategy is proposed to the credit risk of small and micro enterprises in rural areas.

The main conclusions are as follows: government regulators, by increasing the strength of incentives and penalties will be conducive to the stabilization of the credit risk of rural microenterprises, but on the contrary, to increase the strength of incentives and penalties will have a negative impact on the exercise of government responsibilities. In order to maintain the overall market environment, where the credit risk of rural microenterprises tends to stabilize the state, the relevant government departments should be consistent in their adjustments to the incentives and penalties mechanism, allowing them to gain less than the incentives and penalties. An important means to increase the stability of the credit risk of RMSEs is the accountability of the higher level of leadership of the government to the supervisory authorities for their own lack of responsibility. In addition, the growth of RMSEs’ own industry revenue is also an effective means to avoid the occurrence of high credit risk in RMSEs.

5. Conclusions

The issue of how to address small and microbusiness financing challenges in rural areas is one that requires consideration during the development process. To solve this dilemma, we must first focus on solving its root cause. The credit risks faced by rural microenterprises must be taken seriously. No matter which method RMSEs adopt to finance, credit risk plays a crucial role. Therefore, the analysis of credit risks of RMSEs is crucial. Explore the factors that influence the development of credit risks in RMSEs, analyze pertinent factors, use games, and compare the ideas and characteristics of these businesses with traditional credit risks from various perspectives and scenarios. The analytical method is to conduct a targeted analysis of the key causes of credit risks in RMSEs, and thereby propose targeted control strategies and build a control model for research.

During the research process, this article only considered the credit risks of RMSEs in their own operations and the credit risk supervision issues caused by investors under the conditions of information asymmetry and limited rationality. It ignored the part that small, and micro businesses play in the market in rural areas. In the face of different market turbulences, the robustness of credit risks caused by unexpected phenomena has declined, and the impact of the game order of each subject during the game has not been taken into account. Therefore, it is possible to appropriately involve influencing factors such as feedback from objects participating in the consumption behavior of rural microenterprises, improve the evolutionary game model under the participation of consumers involved in rural small microenterprises, and study the operation of rural microenterprises in the face of the market environment. The changes in the existing credit risk can provide innovative thinking and suggestions for the follow-up research to explore and analyze the credit risk game of rural microenterprises.

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Reference

Abdel-Basset, M., Mohamed, R., Sallam, K., & Elhoseny, M. (2020). A novel decision-making model for sustainable supply chain finance under uncertainty environment. *Journal of Cleaner Production*, *269*. https://doi.org/10.1016/j.jclepro.2020.122324

Altaf, N., & Shah, F. A. (2018). Investment and financial constraints in Indian firms: Does working capital smoothen fixed investment? *Decision*, *45*, 43−58.https://doi.org/10.1007/s40622-018-0178-8

Blanco-Oliver, A., Reguera-Alvarado, N., & Veronesi, G. (2021). Credit risk in the microfinance industry: The role of gender affinity. *Journal of Small Business Management*, *59*(2), 280−311. https://doi.org/10.1080/00472778.2020.1844487

Boushnak, E., Rageb, M. A., Ragab, A. A., & Sakr, A. M. (2018). Factors influencing credit decision for lending SMEs: A case study on National Bank of Egypt. *Open Access Library Journal*, *5*(11), 1−17, Article e4996. https://doi.org/10.4236/oalib.1104996

Breeden, J. L. (2021). A survey of machine learning in credit risk. *Journal of Credit Risk*, *17*(3), 1−62. https://doi.org/10.21314/JCR.2021.008

Deloof, M., & La Rocca, M. (2015). Local financial development and the trade credit policy of Italian SMEs. *Small Business Economics*, *44*(4), 905−924. https://doi.org/10.1007/s11187-014-9617-x

Fang, F. (2022). Credit Risk Evaluation Model of Small-Micro Enterprises for Rural Commercial Bank Based on XGBoost and Random Forest. In *Proceedings of the 2022 International Conference on E-business and Mobile Commerce* (pp. 125–131). https://doi.org/10.1145/3543106.3543127

Gray, J., & Rumpe, B. (2017). Models for the digital transformation. *Software & Systems Modeling*, *16*, 307−308. https://doi.org/10.1007/s10270-017-0596-7

He. M., & Hu, W. (2018). The research about the credit risk assessment of small and medium-sized enterprises from the perspective of Supply Chain Finance—The comparative study based on the Logistic regression model & the BP Neural Network Model. *Finance*, *8*, 128−136.

Huang, L., Ying, Q., Yang, S., & Hassan, H. (2019). Trade credit financing and sustainable growth of firms: Empirical evidence from China. *Sustainability*, *11*(4), 1032. https://doi.org/10.3390/su11041032

Jones, S., Johnstone, D., & Wilson, R. (2015). An empirical evaluation of the performance of binary classifiers in the prediction of credit ratings changes. *Journal of Banking & Finance*, *56*, 72−85. https://doi.org/10.1016/j.jbankfin.2015.02.006

Kotarba, M. (2016). New factors inducing changes in the retail banking customer relationship management (CRM) and their exploration by the FinTech industry. *Foundations of management*, *8*(1), 69−78. https://doi.org/10.1515/fman-2016-0006

Kuang, H., Du, H., & Feng, H. (2020). Construction of the credit risk indicator evaluation system of small and medium-sized enterprises under supply chain finance. *Science Research Management*, *41*(4), 209. https://www.kygl.net.cn/EN/abstract/abstract22090.shtml

Li, L., Su, F., Zhang, W., & Mao, J. Y. (2018). Digital transformation by SME entrepreneurs: A capability perspective. *Information Systems Journal*, *28*(6), 1129–1157. https://doi.org/10.1111/isj.12153

Lu, P. (2018). Research on the amplification effect of financial moral hazard in agricultural supply chain. *Financial Research*, *4*, 88−103. https://kns.cnki.net/kcms2/article/abstract?v=MTbc36RhFpQnwB5G58Mj7sAMHbxOoXD_cS8Z0v6PERevaL_Jh2gchOsChe-ym5727IiOm2VWZaxhZfSixTiTN0L30rNchb_yrdG59MV1D6X4oDvXhlWlZW5YiA-FFdrRwV_oP6p0L3A=&uniplat-form=NZKPT&language=gb

Ma, L., & Ma, S. (2020). Trade credit use and bank loan access: An agency theory perspective. *Accounting & Finance*, *60*(2), 1835−1865. https://doi.org/10.1111/acfi.12517

Matt, C., Hess, T., & Benlian, A. (2015). Digital transformation strategies. *Business & information systems engineering*, *57*, 339−343. https://doi.org/10.1007/s12599-015-0401-5

Meng, B., & Chi, G. (2015). New combined weighting model based on maximizing the difference in evaluation results and its application. *Mathematical Problems in Engineering*, *2015*. https://doi.org/10.1155/2015/239634

Mhlanga, D. (2021). Financial inclusion in emerging economies: The application of machine learning and artificial intelligence in credit risk assessment. *International Journal of Financial Studies*, *9*(3), 39. https://doi.org/10.3390/ijfs9030039

Nufus, E. H., Zuhroh, I., & Suliswanto, M. S. W. (2021). Analysis of COVID-19 impact on micro, small, and medium enterprises (MSMEs) credit distribution in East Java Banks. *Journal of Accounting and Investment*, *22*(2), 342−360. https://doi.org/10.18196/jai.v22i2.10701

Pratama, M., Lu, J., Lughofer, E., Zhang, G., & Er, M. J. (2016). An incremental learning of concept drifts using evolving type-2 recurrent fuzzy neural networks. *IEEE Transactions on Fuzzy Systems*, *25*(5), 1175−1192. https://doi.org/10.1109/TFUZZ.2016.2599855

Serrano-Cinca, C., Gutiérrez-Nieto, B., & Reyes, N. M. (2016). A social and environmental approach to microfinance credit scoring. *Journal of Cleaner Production*, *112*, 3504−3513. https://doi.org/10.1016/j.jclepro.2015.09.103

Shi, B., Zhao, J., & Wang, J. (2016). A credit rating attribute reduction approach based on pearson correlation analysis and fuzzy-rough sets. *ICIC Express Letters*, *10*(2), 519−525.
Shi. B., Zhao, X., Wu, B., & Dong, Y. (2019). Credit rating and microfinance lending decisions based on loss given default (LGD). *Finance Research Letters*, *30*, 124−129. https://doi.org/10.1016/j.frl.2019.03.033
Singh, A., & Hess, T. (2020). Strategic Information Management. In R. D. Galliers, D. E. Leidner (Eds.), *How chief digital officers promote the digital transformation of their companies* (pp. 202−220). Routledge. https://doi.org/10.4324/9781315880884
Tan, X., Zhang, H. (2018). Research on supply chain financial decision-making based on buyback under information asymmetry. *Nankai Economic Research*, 1, 104−123. https://link.cnki.net/doi/10.14116/j.nkes.2018.01.007
Vives, X. (2019). Digital disruption in banking. *Annual Review of Financial Economics*, *11*, 243−272. https://doi.org/10.1146/annurev-financial-100719-120854
Wang, S., Qi, Y., Fu, B., & Liu, H. (2016). Credit risk evaluation based on text analysis. *International Journal of Cognitive Informatics and Natural Intelligence (IJCINI)*, *10*(1), 1−11. https://doi.org/10.4018/IJCINI.2016010101
Yang, Y., Chu, X., Pang, R., Liu, F., & Yang, P. (2021). Identifying and predicting the credit risk of small and medium-sized enterprises in sustainable supply chain finance: Evidence from China. *Sustainability*, *13*(10), 5714. https://doi.org/10.3390/su13105714
Zhu, Y., Zhou, L., Xie, C., Wang, G. J., & Nguyen, T. V. (2019). Forecasting SMEs' credit risk in supply chain finance with an enhanced hybrid ensemble machine learning approach. *International Journal of Production Economics*, *211*, 22−33. https://doi.org/10.1016/j.ijpe.2019.01.032