Collaborative governance analysis of new rural credit system ba sed on evolutionary game

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Abstract: Based on the logical framework of collaborative rural credit governance, this paper uses evolutionary game analysis to construct a tripartite evolutionary game model of collaborative governance in which grassroots government organizations lead, financial institutions collaborate, and farmers participate, analyzes the strategy choices of the three subjects in rural credit governance, and analyzes and studies the influencing factors of each subject's strategy choices.

1. Introduction

Rural credit governance is an important part of building a closed loop of China's social credit governance system[1], an endogenous driving force to boost rural revitalization[2], enhance the government's rural governance effectiveness and build an efficient rural governance system[3].China's rural governance is still in its initial stage, the new rural credit rating system has not yet been popularized, and there is still much room to improve the participation behavior of the main bodies involved in rural credit construction. Therefore, this paper analyzes the game between farmers, grassroots government organizations and financial institutions, and studies how to realize the healthy and smooth operation of the rural credit system in more efficiently.

In the analysis of rural credit management, Liu Tao (2017) takes the credit risk of Bank of China Fudeng Village Bank as the entry point, uses game theory to theoretically analyze the moral credit risk it faces and proposes policy recommendations in response to the game results [4]. Ni Xu (2018) explored the mechanism of credit risk generation of new agricultural business entities by using game theory analysis [5]. Rao Siyuan, Li Zejian, Wang Jiawei (2019) based on the static game model of incomplete information, take the linkage development of inclusive finance and credit system construction in Lankao County as an example,and consider the new path of rural credit system construction under the perspective of inclusive finance[6]. The dynamic game analysis is less.

2. Game model construction

2.1 Evolutionary game

2.1.1. Evolutionary game

A tot Evolutionary Game Theory (EGT) basically assumes that all players are finitely rational, incorporates the factors affecting the behavior of players into the analysis framework, and describes how players make strategy choices through continuous learning and imitation in the game process from a dynamic perspective.

2.1.2. Selection of the game subject

The new rural credit system game model includes three subjects: farmers, grassroots government organizations and financial institutions.

Table 1 Tripartite interest needs and behaviors of farmers, grassroots government organizations and financial institutions in the construction of new rural credit system

Participating Subjects	Needs of interest	Behavior
Financial Institutions	Maximize benefits	Support rural credit construction
Grassroots government organizations	Improving the effectiveness of rural governance	Active and passive governance
Farmers	Access to loans and self-fulfillment	Participate in rural credit building

2.1.3Basic assumptions and game payoff matrix

Hypothesis 1: With x denoting the probability of positive

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regulation by grassroots government organizations, y denoting the probability of financial institutions choosing cooperation, and z denoting the probability of farmers choosing participation strategies, "1- x", "1-y", and "1-z " denote the probability of negative regulation, non-cooperation, and non-participation, respectively, and x,y,z ∈ [0,1].

Hypothesis 2: The behavioral strategies of each evolving game subject are as follows: the behavioral strategy set of grassroots government organization G={G1 active governance, G2 negative governance}, "active governance" means that the grassroots government organization actively collects farmers' credit information for rating, and builds a platform of farmers' credit information data. "Passive governance" means that grassroots government organizations do not take active actions, but only passively reward farmers who actively participate in rural credit construction and subsidize financial institutions that support rural credit construction.

Financial institutions' behavior strategy set F={F1 cooperation, F2 non-cooperation}, financial institutions "cooperation" refers to financial institutions actively cooperate with grassroots government organizations, invest certain human and material resources, etc. to jointly build the credit information data platform of farmers, and maintain the update and smooth operation of the credit information platform. Financial institutions "non-cooperation" means that they do not participate in the construction of rural credit information data platform, and directly interface with farmers for credit level evaluation and independent credit issuance.

Farmers' behavior strategy set A={A1 Participate, A2 Do not participate}, farmers "participate" refers to actively participate in rural governance and credit governance practices, the process of participation requires a certain amount of time and energy and other costs, participate in the credit index points evaluation, to obtain a good credit rating. Non-participation" means that farmers do not participate in rural credit governance practices, which does not contribute to the improvement of rural governance effectiveness and credit governance effectiveness, and cannot obtain credit points and government rewards.

Hypothesis 3: The assumptions of relevant parameters and their implications in the game model of the evolution of new rural credit system construction.

Table 2 Main parameters and their meanings

Parameters	Meaning
P_1	Gains from active government governance
P_2	Benefits to farmers when financial institutions are actively involved
P_3	Potential social benefits when financial institutions are actively involved
P_4	Benefits from cooperation with financial institutions when farmers are actively involved
P_5	Self-growth benefits when farmers are actively involved
C_1	Costs to the government when actively governing
C_2	Costs such as human and financial resources when financial institutions actively cooperate
C_3	Additional costs when financial institutions are actively involved and the government is no
C_4	Costs such as time and effort when farmers actively participate
T_1	Incentives from grassroots government organizations for farmers who actively participate
T_2	Grants from grassroots government organizations to financial institutions that actively cooperate
L	Losses caused by farmers' participation when financial institutions do not cooperate in participation

Based on the above assumptions and the parameter settings in Table 2, the payoff matrix of the game between grassroots government organizations, financial institutions and farmers is constructed as shown in Table 3.

Table 3 Benefit matrix of the three-way game under the participation strategy adopted by the farmers

Strategy Portfolio	Grassroots Government Organization Benefits	Financial institution earnings	Farmers' income
(G_1, F_1, A_1)	$P_1-C_1-T_1-T_2$	$P_2+T_2+P_3-C_2$	$P_4+P_5+T_1-C_4$
(G_1, F_1, A_2)	$P_1-C_1-T_2$	$T_2+P_3-C_2$	0
(G_1, F_2, A_1)	$P_1-C_1-T_1$	-L	$P_5+T_1-C_4$
(G_1, F_2, A_2)	P_1-C_1	0	0
(G_2, F_1, A_1)	$-T_1-T_2$	$T_2+P_2+P_3-C_2-C_3$	$P_4+P_5+T_1-C_4$
(G_2, F_1, A_2)	$-T_2$	$T_2+P_3-C_2$	0
(G_2, F_2, A_1)	$-T_1$	-L	$P_5+T_1-C_4$
(G_2, F_2, A_2)	0	0	0

Let Eg , Ef , and Ea denote the average expected returns of grassroots government organizations, financial institutions, and farmers under the mixed strategy, respectively, and t denotes the time of behavioral strategy evolution. Then we have. (1) The average benefit to a grassroots government organization is:Eg=Eg1x+Eg2 (1-x). Among them, the expected benefits of choosing active regulation by grassroots government organizations. Eg1=(P1-C1-T1-T2)zy+(P1-C1-T1)z(1-y)+(P1-C1-T2)y(1-z)+(P1-C1)(1-y)(1-z).Expected benefits of choosing negative regulation by grassroots government organizations. Eg2=(-T1-T2)zy+(-T1)z(1-y)+(-T2)y(1-z).Thus, the dynamic replication equation for the choice of active regulation by grassroots government organizations is Ug(x)=dx/dt=(Eg1-Eg)x=x(1-x)(Eg1-Eg2)= x(C1-P1)(x-1).

(2) The average return for a financial institution is: Ef = Ef1y+ Ef2(1-y). Expected benefits for financial institutions choosing to cooperate. Ef1=(P2+T2+P3-C2)xz+(T2+P2+P3-C2-C3)z(1-x)+(T2+P3-C2)x(1-z)+(T2+P3-C2)(1-x)(1-z).Expected benefits for financial institutions choosing not to cooperate. Ef2=(-L)xz+(-L)z(1-x).The dynamic replication equation for the financial institution's choice of non-cooperative strategy is. Uf(y)=dy/dt=(Ef1-Ef)y=y(1-y)(Ef1-Ef2)=y(1-y)(P3-C2+T2+Lz-C3z+P2z+C3xz).

(3) The expected return of the farmer is Ea=Ea1z+Ea2(1-z). Expected benefits for farmers choosing to participate. Ea1=(P4+P5+T1-C4)xy+(P5+T1-C4)x(1-y)+(P4+P5+T1-C4)y(1-x)+(P5+T1-C4)(1-x)(1-y)Expected benefits for farmers who choose not to participate. Ea2=0.The dynamic replication equation for the farmers' participation strategy is. Ua(z)=dz/dt=(Ea1-Ea)z=z(1-z) (Ea1-Ea2)=z(1-z) (P5-C4T1+P4Y).

2.2 Game stability analysis

2.2.1. Evolutionary game equilibrium point solution a nd Jacobi matrix

The replicated dynamic equation of each game subject describes the dynamic adjustment process of the strategy choice of grassroots government organizations, financial institutions and farmers, and the three parties will weigh their respective interests and finally reach Nash equilibrium through mutual learning and adjustment, i.e., the complete system composed of the three parties reaches the stable state of the game. Therefore, let. Ug (x)=0, Uf (y)=0 and Ua (z)=0, when the rate of change of the system policy choice is 0, we can obtain 10 equilibria of this system, which are D1 = (0,0,0), D2 =(1,0,0), D3 =(0,1,0), D4 =(0,0,1), D5 =(1,1,0), D6 =(1,0,1), D7 =(0, 1,1), D8 =(1,1 ,1), D9 =[1,-(p5-c4+t1)/p4,-(p3-c2+t2)/(L1+p2)], D10 =[0,-(p5-c4+t1)/ p4,-(p3-c2+t2)/(L1-c3+p2)] where the first 8 equilibria form the boundaries of the equilibrium solution domain {(x,y,z)|0≤x≤1, 0≤y≤1, 0≤ z≤1|}. In this re plicated dynamic system composed of grassroots government organizations, fina ncial institutions, and farmers, the last two points, D9= [1,-(P5 -C4+T1)/P4 ,-(P3-C2+T2)/(L+P2)] and D10=[0,-(P5 -C4+T1)/P4 ,-(P3-C2+T2)/(L-C3+P2)] are non-asymptotically stable, so only the stability of the first eight points ne ed to be discussed. The Jacobi matrix of the replication dynamics system for the construction of the new rural credit system is as follows.

$$J=\begin{bmatrix} x(C1-P1)+(C1-P1)(x-1) & 0 & 0 \\ y(1-y)zC3 & J* & y(1-y)(L-C3+P2+C3x) \\ 0 & z(1-z)P4 & J** \end{bmatrix}$$

where J*=(1-y)(P3-C2+T2+Lz-C3z+P2z+C3xz)-y(P3-C2+T2+Lz-C3z+P2z+C3xz), J**=(1-z)(P5-C4+T1+P4y)-z(P5-C4+T1+P4y). According to evolutionary game theory, the equilibrium point that satisfies the Jacobi matrix when all eigenvalues of the matrix are negative is the evolutionary stability point of this dynamic system, ESS.

2.2.2. Stability analysis of evolutionary games

Bringing the equilibrium point D1 = (0,0,0) into the Jacobi matrix, we can obtain.

$$J1=\begin{bmatrix} P1-C1 & 0 & 0 \\ 0 & P3-C2+T2 & 0 \\ 0 & 0 & P5-C4+T1 \end{bmatrix}$$

This shows that the eigenvalues at the equilibrium point D1 = (0,0,0) are λ = P11 - C1 , λ2 = P3 -C2 +T2, λ3 = P5 -C4 +T1 , and the remaining seven points are all brought into the Jacobi matrix and the eigenvalues obtained are shown in the table below.

Table 3 Eigenvalues of the Jacobi matrix corresponding to each equilibrium poin

Balancing point	Eigenvalue λ1	Eigenvalue λ2	Eigenvalue λ3
(0,0,0)	P_1-C_1	P_3-C_2+T_2	P_5-C_4+T_1
(1,0,0)	C_1-P_1	P_3-C_2+T_2	P_5-C_4+T_1
(0,1,0)	P_1-C_1	C_2-P_3-T_2	P_4-C_4+P_5+T_1
(0,0,1)	P_1-C_1	C_4-P_5-T_1	L-C_2-C_3+P_2+P_3+T_2
(1,1,0)	C_1-P_1	C_2-P_3-T_2	P_4-C_4+P_5+T_1
(1,0,1)	C_1-P_1	C_4-P_5-T_1	L-C_2+P_2+P_3+T_2
(0,1,1)	P_1-C_1	C_4-P_4-P_5-T_1	C_2-L+C_3-P_2-P_3-T_2
(1,1,1)	C_1-P_1	C_4-P_4-P_5-T_1	C_2-L-P_2-P_3-T_2

The analysis reveals that A1(0,0,0), A3(0,1,0), A4(0,0,1) and A7(0,1,1) can only be source or saddle points because the government will eventually choose to adopt a negative governance strategy if P1-C1<0, if the benefits obtained by the government when adopting an active governance strategy are not enough to cover its costs. A2(1,0,0) could be a sink because C1-P1< 0 holds, if P3-C2+T2 < 0 and P5-C4+T1<0 holds, then A2(1,0,0) is ESS; A5(1,1,0) can only be a source or saddle point, because if P4-C4+P5+T1<0, the benefits obtained when farmers actively participate are not enough to pay the cost of active participation, farmers will eventually choose to adopt a non-participation strategy; A6 (1,0,1) can only be

the source or saddle point, because if L-C2+P2+P3+T2<0, the financial institutions will choose to adopt a negative participation strategy if the benefits obtained from the participation of financial institutions are not enough to pay for the cost of active participation; A8(1,1,1), C1-P1 < 0, C4-P4-P5-T1< 0, C2-L-P2-P3-T2 < 0, When the equilibrium point A8 of the dynamic replication system is a sink, a stable point, otherwise it is a source or saddle point.

3. Conclusion

The above analysis illustrates that the exact behavioral strategy adopted by each actor in this dynamic system depends critically on the magnitude of the costs involved in choosing that behavior. First of all, from the perspective of the financial institutions, the strategy that affects whether they adopt cooperation to participate in the new rural credit cooperative governance is the cost that they pay when they cooperate. If the benefits of the financial institution's cooperative strategy are greater than the costs, the financial institution is willing to cooperate, the interests of the three game subjects are maximized, and the system evolves to a stable and ideal state; secondly, from the perspective of the grassroots government organization, whether the government actively governs depends on the cost of collecting farmers' credit information and building a credit information sharing platform. Finally, from the farmers' perspective, whether farmers participate or not depends on the size of the rewards and costs of participation by the grassroots government organizations, and farmers will only participate if the rewards they receive are greater than the costs of their time and effort.

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