Evolutionary Game Analysis of Technology Finance Model in Underdeveloped Areas Based on Blockchain

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Abstract. The traditional model of technology finance, especially in underdeveloped areas, the model of technology finance has some limitations, such as high risk, imperfect system and lack of government intervention. This paper proposes blockchain technology to solve this problem and verify its effectiveness. Firstly, with the help of evolutionary game method, we construct a tripartite game model of credit among the demanders, the suppliers and intermediary institutions in technology finance, and study the influence of various factors on technology and finance model by numerical simulation with Matlab software, including, application degree of blockchain technology, punishment intensity and reward mechanism. The results show that the blockchain technology has a positive trend of maintaining credit business and achieving system stability, increasing supervision efficiency and reducing system risk.

Keywords: technology finance; evolutionary game; blockchain; numerical simulation

1 Introduction

Since the "technology finance" was formally put forward at the first science and technology promotion meeting in China in 1993, technology finance has been an important starting point for promoting strategic emerging industries and realizing high-quality economic development. However, there are still many problems in China's underdeveloped areas, such as imperfect policies, imperfect market system, and shortage of talents in technology finance, which lead to insufficient financial support and low conversion rate of scientific and technological achievements and restricts the innovation and development of enterprises for small and medium-sized innovative enterprises.

The research on the relationship between scientific and technological innovation and financial development can be traced back to the beginning of last century. As early as 1912, some scholars began to demonstrate the influence of financial related variables such as credit funds and interest rates on innovation activities and economic growth. Zhao is the first to put forward the definition of technology finance[1]. Later, You defines the connotation of technology finance service platform, and constructed and analyzed the structural model[2]. Allen[3] and Peter[4] began to put forward the conceptual framework and model of financing for small and medium-sized innovative enterprises. In recent years, scholars' research on science and technology finance mainly focuses on three parts.. The first is the evaluation of technology finance's construction level. An studies the dynamic evolution path of financial supervision and financial innovation[5], and Wang evaluates the combined efficiency of

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technology finance by using DEA-Malmquist index[6]. The second is the studies of the influencing factors. Antonio deals with the interdependence to explore the influence of technology on financing[7]. Yuan draws lessons from public policy theory to build a model of influencing factors of technology finance's policy implementation[8]. Liu[9] and Wen[10] use evolutionary game model to verify the influencing factors of scientific and technological innovation. This kind of research mainly studies the influence of technology finance's influencing factors by qualitative and quantitative methods to find the development direction of technology finance. The Thirdly is to study the optimization path of technology finance system. Nazir[11] and Ritesh[12] both propose that blockchain platform will replace intermediary institutions as virtual intermediaries. Han put forward the direction of blockchain to solve the risk supervision in technology finance[13] This kind of research mainly discusses emerging technologies or new mechanisms to optimize the development direction of technology finance.

However, technology finance is still not perfect in underdeveloped areas. Even if some scholars put forward a new model, they do not verify and analyze it and fail to analyze the advantages brought by this model. Therefore, this paper intends to use blockchain technology to explore the mechanism of technology finance in underdeveloped areas, and verify the impact of blockchain technology by using evolutionary game model.

2 Analysis of technology finance in underdeveloped areas

2.1 Analysis of the current situation of the application in underdeveloped areas

Technology finance is a financial activity to promote technological innovation and the development of science and technology enterprises. For further analysis and research, this paper takes Hebei Province as an example. There are seven parties in technology financial system of Hebei Province, which are government management departments, science and technology funds, financial institutions, universities and research institutions, innovative enterprises, incubators and information platform. The mechanism of their participation in technology finance is shown in Figure 1. They mainly serve for technological innovation.

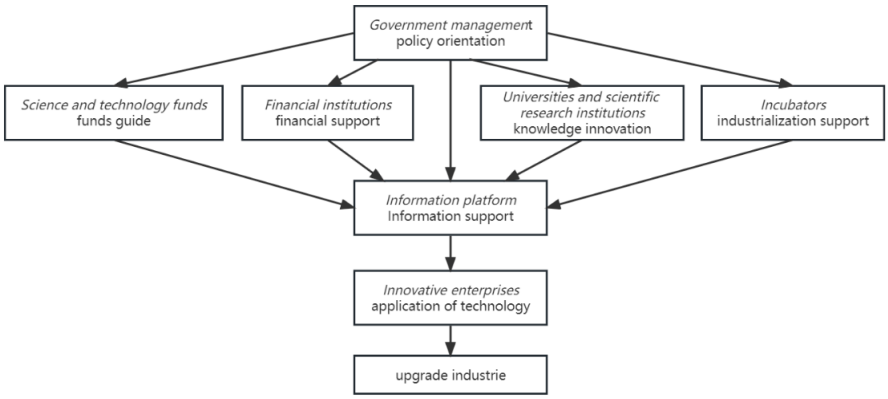

Figure 1 The mechanism of their participation in technology finance

According to the participation roles of the parties of Hebei Province, they can be divided into four categories in technology finance: the demanders, the suppliers, the intermediary institutions and the government, as shown in Table 1.

Table 1 Types and roles of parties

category	subject	Main functions
Technology finance demanders	Universities, research institutions and innovative enterprises	It uses loan funds to carry out scientific and technological innovation
Technology finance suppliers	Financial institutions and science and technology funds	It provides funds and products for scientific and technological innovation.
Intermediary institutions	Incubators and information platform	It is responsible for credit evaluation and information support
Government	Government management departments	It is responsible for market regulation and political intervention

2.2 Technology finance model in underdeveloped areas based on blockchain technology

The traditional transaction process is shown in Figure 2. There are credit risks and operational risks here. there is no guarantee that the demanders can compliant operation in technology finance. At the same time, there is the risk that the demanders and guarantee institutions jointly defraud loans. It is mainly caused by information asymmetry. Operational risk is mainly caused by human operation and data inconsistency in business links.

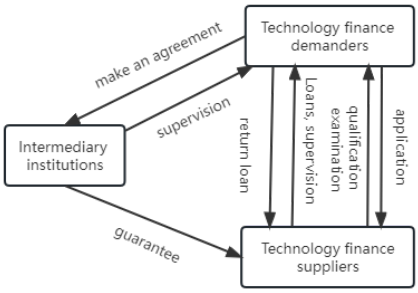

Figure 2 Technology finance in traditional mode

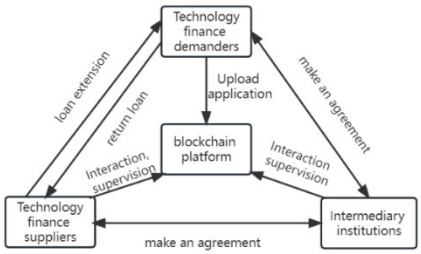

Figure 3 Technology finance based on blockchain

When the blockchain technology is introduced, the whole process of financing will be recorded on the blockchain, as shown in Figure 3. Thus it can reduce credit risk and operational risk. First of all, because the hash can prevent data tampering and privacy information disclosure. Secondly, it can reduce the cost and mistakes of manual processing and supervision process. In general, blockchain can reduce transaction risks, increase willingness to participate, and reduce costs and human errors.

3 Analysis of evolutionary game between technology finance parties

3.1 Description of the game

The parties of the technology finance model studied in this paper are mainly technology finance demanders, technology finance suppliers, intermediary institutions and governments. Among them, demanders, suppliers and intermediary institutions are directly involved in the process of credit transactions. The government mainly intervenes and regulates through interest discounts, penalties, rewards and other measures. Therefore, the next model studies the direct parties of the business, whish are technology finance demanders, technology finance suppliers and intermediary institutions.

3.2 The basic assumptions

Table 2 Description of game model parameters

Parties	Parameter meaning	Parameter symbol
technology finance demanders	The probability of choosing compliance innovation	x
	The cost of Compliance innovation	C_1
	The cost of Illegal innovation	C_2
	The income of Compliance innovation	R_1
	The Extra income from illegal innovation	R_2
	Application degree of blockchain	α
	the reduced cost of blockchain	t_1
	The reward of Blockchain	V_1
	Blockchain punishment for violation	P_1
	Income from investment	ΔR
Intermediary institutions	Guarantee fee	i
	The probability of choosing guarantee	y
	the cost of Guarantee to pay	C_3
	the reduced cost of blockchain	T_2
	The reward of Blockchain	V_2
	Blockchain punishment for guarantee error	P_2
Technology finance suppliers	The probability of choosing loan	z
	The cost of Loan payment	C_4
	the reduced cost of blockchain	T_3
	The reward of Blockchain	V_3
	loan fund	B
	interest rate	r
	Blockchain punishment for violation	P_3

Assumption 1. There are three kinds of parties in the game system: technology finance demanders, technology finance suppliers and intermediary institutions, all of which are bounded rationality. Technology finance demanders have two possible strategies: (compliance innovation, illegal innovation), intermediary institutions have two possible strategies: (guarantee, no guarantee), and technology finance suppliers have two possible strategies: (loan, no loan), among which "compliance innovation", "guarantee" and "loan" strategies are active credit strategies.

Assumption 2. Blockchain can reduce transaction costs, including the cost of applying for loans by the demanders in technology finance, and the cost of evaluation by guarantee institutions and supervision by the suppliers in technology finance.

Assumption 3. It is assumed that the recognizable probability is 1 when the blockchain technology is fully applied. its value is affected by the application degree of blockchain technology.

Assumption 4. The blockchain will reward parties When all three parties have a positive strategy. On the contrary, when demander violates the rules of innovation, it will punish them. The specific parameters of the game model are shown in Table 2.

3.3 Model construction

The payoff matrix between the three parties of technology finance is shown in Table 3.

Table 3 Payoff matrix between the three parties of technology finance

		Intermediary institutions	Technology finance suppliers	
			Loan z	No loan 1-z
Technology finance demanders	Compliance innovation x	Guarantee y	$R_1+\Delta R-C_1-rB-i+\alpha t_1+V_1$; $i-C_3+\alpha t_2+V_2$; $rB-C_4+\alpha t_3+V_3$	$R_1-C_1-i+\alpha t_1$; $i-C_3+\alpha t_2$; 0
		No guarantee 1-y	$R_1+\Delta R-C_1-rB+\alpha t_1$; 0; $rB-C_4+\alpha t_3$	$R_1-C_1+\alpha t_1$; 0; 0
	Illegal innovation 1-x	guarantee y	$R_1+R_2+\Delta R-C_2-rB-i-\alpha P_1$; $i-C_3-\alpha P_2+\alpha t_2$; $rB-C_4-\alpha P_3+\alpha t_3$	$R_1+R_2-C_2-i-\alpha P_1$; $i-C_3-\alpha P_2+\alpha t_2$; 0
		No guarantee 1-y	$R_1+R_2+\Delta R-C_2-rB-\alpha P_1$; 0; $rB-C_4-\alpha P_3+\alpha t_3$	$R_1+R_2-C_2-\alpha P_1$; 0; 0

3.4 Stability analysis of the evolutionary game

Among the payment matrix, when the technology finance demanders choose "compliance innovation", the replication dynamic equation can be expressed by Eq. (1).Among them, when the intermediary institutions choose "guarantee", the replication dynamic equation can be expressed by Eq. (2). Among them, when the technology finance suppliers choose "loan", the replication dynamic equation can be expressed by Eq. (3).

$$F_x=x(1-x)(C_2- C_1+\alpha P_1 +yzV_1+\alpha t_1-R_{2)} \quad (1)$$

$$F_y=y(1-y)[\alpha t_2+ xzV_2+i-_{C3} -(1-x)\alpha P_2] \quad (2)$$

$$F_z=z(1-z)[\alpha t_3+ xyV_3+rB-C_4-(1-x)\alpha P_3] \quad (3)$$

From Eqs. (1), (2)and (3), nine local equilibrium points are obtained: $E_1(0,0,0)$, $E_2(1,0,0)$, $E_3(0,1,0)$, $E_4(0,0,1)$, $E_5(0,1,1)$, $E_6(1,0,1)$, $E_7(1,1,0)$, $E_8(1,1,1)$ and $E_9(x^*,y^*,z^*)$. Where (x^*,y^*,z^*) is solution of Eqs. (1), (2) and (3).

According to the replication dynamic equations F_x, F_y and F_z, the Jacobian matrix J of the replication dynamic system of technology finance system can be obtained by taking partial differentiation of F_x, F_y and F_z in turn. It can be expressed by Eq. (4). When all eigenvalues of Jacobian matrix are negative, the equilibrium point is an evolutionary stable point (ESS).

$$J = \begin{bmatrix} F_{xx} & F_{xy} & F_{xz} \\ F_{yx} & F_{yy} & F_{yz} \\ F_{zx} & F_{zy} & F_{zz} \end{bmatrix} \tag{4}$$

Because the stable solution of multi-agent game system is a strict Nash equilibrium solution, E_9 is not a strict Nash equilibrium solution, so it only needs to consider E_1-E_8. In the study of evolutionary game, the local stability of Jacobian matrix can judge the stability of the equilibrium point of the system. The judgment results are shown in Table 4.

The existing five equilibrium points E_1, E_3, E_4, E_5 and E_8 may be stable points. Now we will discuss the application degree of different blockchains.

For F_{xx}, there are three situations: a. when $0<\alpha<R_2+C_1-C_2-V_1/(P_1+t_1)$, E_1, E_3 ,E_4 and E_5 are negative, and E_2, E_6, E_7 and E_8 are positive. b. when $R_2+C_1-C_2-V_1/(P_1+t_1)<\alpha<R_2+C_1-C_2/(P_1+t_1)$, E_3, E_4 and E_8 are negative, and the rest are positive. c. when $R_2+C_1-C_2/(P_1+t_1)<\alpha<1$, E_2, E_6, E_7 and E_8,are negative, and the rest are positive.

For F_{yy}, d. when $0<\alpha<i-C_3/(P_2-t_2)$, E_3, E_5, E_7 and E_8 are negative, and the rest are positive. e. when $i-C_3/(P_2-t_2)<\alpha<1$, E_1, E_4, E_7 and E_8 are negative, and the rest are positive.

For F_{zz}, f. when $0<\alpha<rB-C_4/(P_3-t_3)$, E_4, E_5, E_6 and E_8 are negative and the rest are positive. g. when $rB-C_4/(P_3-t_3)0<\alpha<1$, E_1, E_3, E_6 and E_8 are negative. The equilibrium point analysis of blockchain application degree under different conditions is shown in Table 5.

Table 4 8 Determination of local stability of equilibrium points

Equilibrium point	(F_{xx},F_{yy},F_{zz})	Mark	Stability judgment
$E_1(0,0,0)$	$(C_2-C_1+\alpha P_1+\alpha t_1-R_2,\alpha t_2+i-C_3-\alpha P_2,$ $\alpha t_3+rB-C_4-\alpha P_3)$	Indefinite, indefinite, indefinite	Ess or unstable point or saddle point
$E_2(1,0,0)$	$(-C_2+C_1-\alpha P_1-\alpha t_1+R_2,\alpha t_2+i-C_3,$ $\alpha t_3+rB-C_4)$	Indefinite, positive, positive	Instability point or saddle point
$E_3(0,1,0)$	$(C_2-C_1+\alpha P_1+\alpha t_1-R_2,-\alpha t_2-i+C_3+\alpha P_2,$ $\alpha t_3+rB-C_4-\alpha P_3)$	Indefinite, indefinite, indefinite	Ess or unstable point or saddle point
$E_4(0,0,1)$	$(C_2-C_1+\alpha P_1+\alpha t_1-R_2,\alpha t_2+i-C_3-\alpha P_2,$ $-\alpha t_3-rB+C_4+\alpha P_3)$	Indefinite, indefinite, indefinite	Ess or unstable point or saddle point
$E_5(0,1,1)$	$(C_2-C_1+\alpha P_1+\alpha t_1-R_2+V_1,-\alpha t_2-i+C_3+\alpha$ $P_2,-\alpha t_3-rB+C_4+\alpha P_3)$	Indefinite, indefinite, indefinite	Ess or unstable point or saddle point

$E_6(1,0,1)$	$(-C_2+C_1-\alpha P_1-\alpha t_1+R_2, \alpha t_2+i-C_3+V_2, -\alpha t_3-rB+C_4)$	Indefinite, positive, negative	Instability point or saddle point
$E_7(1,1,0)$	$(-C_2+C_1-\alpha P_1-\alpha t_1+R_2, -\alpha t_2-i+C_3, \alpha t_3+rB-C_4+V_3)$	Indefinite, negative, positive	Instability point or saddle point
$E_8(1,1,1)$	$(-C_2+C_1-\alpha P_1-\alpha t_1+R_2-v_1, -\alpha t_2-i+C_3-V_2, -\alpha t_3-rB+C_4-V_3)$	Indefinite, negative, negative	Ess or saddle point

Table 5 Local stability judgment of 8 equilibrium points under different blockchain applications

equilibrium point	adf	adg	aef	aeg	bdf	bdg	bef	beg	cdf	cdg	cef	ceg
$E_1(0,0,0)$	-++	-+-	--+	---	+++	++-	+-+	+--	+++	++-	+-+	+--
$E_2(1,0,0)$	+++	+++	+++	+++	+++	+++	+++	+++	-++	-++	-++	-++
$E_3(0,1,0)$	--+	---	-++	-+-	--+	---	-++	-+-	+-+	+--	+++	++-
$E_4(0,0,1)$	-+-	-++	---	--+	-+-	-++	---	--+	++-	+++	+--	+-+
$E_5(0,1,1)$	---	--+	-+-	-++	+--	+-+	++-	+++	+--	+-+	++-	+++
$E_6(1,0,1)$	++-	++-	++-	++-	++-	++-	++-	++-	-+-	-+-	-+-	-+-
$E_7(1,1,0)$	+-+	+-+	+-+	+-+	+-+	+-+	+-+	+-+	--+	--+	--+	--+
$E_8(1,1,1)$	+--	+--	+--	+--	---	---	---	---	---	---	---	---

It can be seen that the application degree of blockchain has a certain influence on the system. When the application degree of blockchain increases gradually, the financial system will gradually tend to the positive direction of credit. Therefore, the application degree of blockchain greatly affect the stability of the system. When the application of blockchain technology matures the system will be stable towards the positive strategy.

4 Numerical simulation

Based on the above analysis, the dynamic game process of each subject in technology finance is numerically analyzed by using Matlab software to verify the influence of related factors of blockchain. Assuming that the demanders loan cycle in technology finance is 10 years, the interest rate of demanders loan in technology finance is 5% and the loan amount is 6, the initial value is defined accordingly. The parameters are as follows: R_1=5, R_2=3.5, C_1=2, C_2=3,α=0.6, P_1=3, P_2=2, r=0.5, B=8, C_4=3, P_3=3, i=2, C_2=0.5, P_2=2, t_1=1, t_2=0.5, t_3=1, V_1=1, V_2=0.5, V_3=1,ΔR=6.

4.1 Influence of the degree of technology application

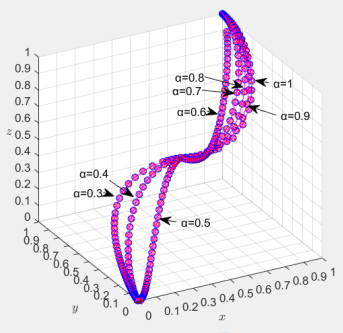

Figure 4 Influence of technology application

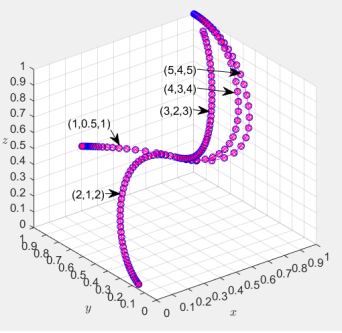

Figure 5 Influence of blockchain punishment

With the application of blockchain technology, the probability of illegal innovation of technology finance demanders will be higher. Blockchain technology is conducive to improving the transparency of transactions and increasing the probability of violations being discovered. The influence of the application degree of blockchain technology on system evolution is shown in Figure 4. The system has two equilibrium and stability strategies (0,0,0) and (1,1,1), and the evolution result depends on the application degree of blockchain technology, which helps the system to converge to the optimal state.

4.2 Influence of the degree of blockchain punishment

As shown in Figure 5, the influence of the punishment degree of the three parties on the system, when the punishment of the three parties is also particularly loose, the suppliers will tend to the loan strategy, but the technology finance demanders and intermediary institutions will continue to evolve towards the negative strategy, and the suppliers in technology finance will also choose the negative strategy, thus the system will evolve into a (0,0,0). With the increasing degree of punishment, the three parties are constantly evolving towards a positive strategy, and the higher the punishment, the better the system.

4.3 Influence of the degree of cost reduction

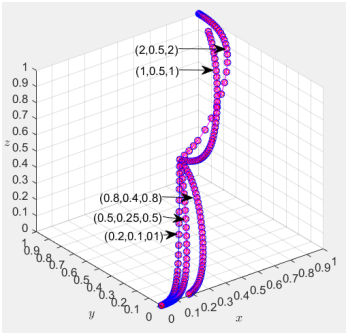

Figure 6 Influence of the degree of cost reduction

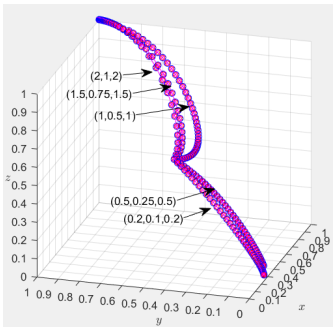

Figure 7 Influence of the degree of reward

As can be seen from Figure 6, there are two equilibrium stability strategies (0,0,0) and (1,1,1) in the system, and the final evolution result depends on the participation cost of the players. Obviously, the higher the cost of blockchain reduction, the greater the probability that the system will converge to the stable equilibrium point (1,1,1). When the cost of blockchain reduction reaches a certain level, the system will develop in a stable direction.

4.4 Influence of the degree of reward

As can be seen from Figure 7, there are two equilibrium stability strategies (0,0,0) and (1,1,1) in the system. And the final evolution result depends on the incentive mechanism of the blockchain. Obviously, the more rewards given by the incentive mechanism, the higher the probability that the system converges to (1,1,1). From the above results, the incentive mechanism of blockchain is conducive to the system tending to evolve to the optimal state.

5. Conclusions

In this paper, we establish and three-parties analyze evolution game model and study the analysis of the evolution game of the technology finance model involving the demanders, the intermediary institutions and the suppliers in technology finance. We discuss the stability of the equilibrium points in different situations and carry out the numerical simulation analysis by using Matlab software. The conclusions as the following:

(1) Blockchain technology has a significant impact on the evolution of the three parties. The higher the application level of blockchain technology and the reduce of the cost, the more stable the system will be in the optimal direction, and the speed of development will accelerate.

(2) The penalty mechanism in the blockchain has a significant impact on the stability of the system. The stricter the penalty, the more stable the system will be in the optimal direction.

(3) The incentive mechanism in the blockchain promotes the stability of the system. When the incentive mechanism is higher, it will stimulate the active participation of parties.

From the results, the application of blockchain is beneficial to the stability of technology finance model and the benign development of trading environment. Its transparency, non-tampering, decentralization and other characteristics can effectively solve the problems of asymmetry information, opaque transactions, insufficient participation of all parties and high transaction risk in the current situation of technology finance in underdeveloped areas. Blockchain technology can effectively improve the willingness of parties to participate, help supervision and regulation. Therefore, it can promote the improvement of financial level.

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