Available online at www.sciencedirect.com

SciVerse ScienceDirect

Procedia Computer Science 17 (2013) 930 – 938

Procedia Computer Science

Information Technology and Quantitative Management (ITQM2013)

The Evolutionary Game Analysis of Credit Behavior of SME in Guaranteed Loans Organization

Xu Chao[a], Zhou Zongfang[a,]*

[a]School of Economics and Management, UESTC, ChenDu,610054,China

Abstract

The guaranteed loans mode was proposed to solve the small and medium enterprises' financing difficulties, but it did not achieve the desired results. The credit risk of organization would cause a chain reaction and result in huge losses. In this paper, we studied the credit behavior of companies by evolutionary game theory. First, we analyzed the situation when the organization composed by two companies and found out the conditions that ensure the sustained and stable development. Further, we researched the organization of a number of enterprises. The result shown that implement reasonable entry and exit mechanisms could effectively manage and control credit risk.

Selection and peer-review under responsibility of the organizers of the 2013 International Conference on Information Technology and Quantitative Management

Keywords: Guaranteed Loans, Small and Medium Enterprises, Credit Risk, Evolutionary Game

1. Introduction

At present, the number of small and medium enterprises accounts for 99% of the total number of Chinese enterprises, with a contribution of more than 60 percent to GDP, more than 50% to tax, and providing more than 75 percent of urban jobs. The rapid development of small and medium enterprises not only lays a solid foundation for the economic prosperity, but also has made a significant contribution to social harmony and stability. Therefore, the development of small and medium enterprises plays a pivotal role in the process of sustainable development in China. However, small and medium enterprises in the development process are faced with many difficulties, particularly in financing. As is shown in Figure 1, from the various types of corporate credit balance statistics of 2009 to the end of 2010 in China we can see: in recent years, China's support for the enterprises' credit increase, but compared with the growth rate of more than 18% of large and medium-sized enterprises' credit loans, the growth rate of small enterprises' is only 8.1%. And what's more, the total of the credit support for small and medium-sized enterprises is less than 50% of the large enterprises'. The main reasons that the lending policies of the financial institutions are biased in favor of large enterprises

* Xu Chao. Tel.: +086-138-8054-7877
E-mail address: xcwdl@126.com.

Selection and peer-review under responsibility of the organizers of the 2013 International Conference on Information Technology and Quantitative Management
doi:10.1016/j.procs.2013.05.118

are as follows: first, the financial system of small and medium-sized enterprises is not perfect, while the risk management and control capability is not mature enough as well; second, small and medium-sized enterprises are small-scale, so they often do not have enough collateral to guarantee; third, the set up time of small and medium-sized enterprises usually is short, so that the level of their credit risk is hard for financial institutions to identify accurately. In that way, though small and medium-sized enterprises have a strong demand for the financing, the financial institutions pay less attention to them in order to control the rate of bad debts and credit risk. The needs of small and medium-sized enterprises can not be met because of been ignored, resulting in impeding the development of small and medium-sized enterprises. And so forth, it causes further vicious cycle.

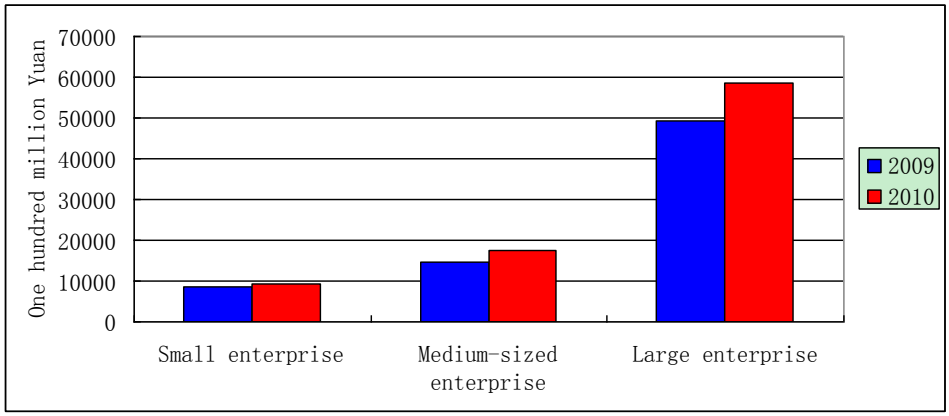

Fig. 1 The credit balance of the loan of China's medium and small enterprises from 2009-2010

Preventing against adverse selection and moral hazard caused by information asymmetry, thus reducing the loss caused by default, is the key to solve the small and medium-sized enterprises financing difficulties. Followed the farmers guaranteed loans mode ,which has achieved a great success in Grameen Bank in Bangladesh, the People's Bank of China Bazhou Branch first proposed a similar mode in 2003. The mode is that two or more than two small and medium enterprises, which are familiar with each other, form a voluntary group to apply for loans, sharing the responsibility of jointly guaranteed load. Subsequently, China's major banks continue to carry out the business of small and medium-sized enterprises guaranteed loans. Guaranteed loads mode on one hand makes up for the small and medium-sized enterprises' difficulty in guarantee, lacking in collateral; on the other hand, it provides an opportunity for the banks to expand their business. Guaranteed loans mode for small and medium enterprises has constantly achieved great success, however, events of load default are also not uncommon. The events like" default event of Wenzhou guaranteed loans "and" event of Zhejiang Economic Development Group "not only caused the enterprises related with the guaranteed loans into a serious crisis, but caused a great deal of impact for the local economic development and social stability as well. Therefore, more and more experts and scholars questioned the mode of guaranteed loans.

Whether guaranteed loans mode has its superiority or not? Why does guaranteed loans mode change from "insurance lock" of the risk prevention and control into the "fuse" of the contagion of credit risk? How can guaranteed loans mode manage credit risk effectively? All these problems are important practical problem urgent to be solved in the financing problems of small and medium-sized enterprises in China, and it is also the significance that this study lies in.

2. Review of the Literature

Guaranteed loans mode is originally proposed to solve the financing problems of the farmers and guard

against credit risk with the condition of inadequate collateral to guarantee. Therefore, the initial object that the mode researched on is the farmers guaranteed loans problem. Many scholars first in-depth analyze on whether the guaranteed loans mode can solve the financing difficulties, Timothy Besley and Stephen Coate (1995) verified the actual effects of the operation of the farmers guaranteed loans in Bangladeshi, they thought the guaranteed loans mode did not only solve the farmers' loans demand, but also reduced the credit risk. [1] Gregorio Impavido (1998) pointed out that the guaranteed loans organizations existed "social punishment" within its internal, even in the absence of physical collateral, guaranteed loans mode could still effectively solved the problem of credit rationing. [2] However, the effect of the implementation of the guaranteed loans modes in different regions is very different, through empirical research of Heilongjiang region in China, Liu Feng, et al (2006) found that due to deficiencies in the system of guaranteed loans, the guaranteed loans behavior was distorted. [3] Therefore, the scholars gradually focused on exploring the main factors affecting the result of guaranteed loans mode. Klaus Abbink and Bernd Irlenbusch (2006) found that the size of the group and the tightness of the social relations were the key factors that made impact on the default of the guaranteed loans. [4] While Christian Ahlin and Rober M. Townsend (2007) considered rationalized joint responsibility had a great impact on the loan repayment rate, and through four types of joint responsibility model, they tested the actual effects. [5] Chinese scholars Zhao Yanqing He Guangwen (2007) analyzed the reasons that farmers guaranteed loans did not go well, based on game analysis of debit, credit, guarantees. They thought enhancing network, trust factors, improving incentives and increasing the defaulting cost were important factors to ensure the effective implementation of guaranteed loans mode. [6] James Barham and Clarence Chitemi (2009) considered that the maturity of internal structure was also very important in addition to the tightness of the internal structure of the guaranteed loans group. [7] Bharat Bhole and Sean Ogden (2010) compared the default strategy of guaranteed loans with small loans for farmers, even in the absence of social punishment, guaranteed loans was more reasonable. [8] Zhang Zhengping and Xiao Xiong (2012) analyzed the conditions for the development of the guaranteed loans of our farmers based on the evolutionary game theory, the study found the farmers with similar risk were easier to form a guaranteed loans group. And the guaranteed loans group members, gaining more social benefits for assuming responsibility for defaulting members, were more inclined to join the group. [9]

Guaranteed loans mode for small and medium enterprises draws from the farmers guaranteed loans mode. However, compared with farmers, the enterprises' operations and decision-making mechanisms are more complex. Therefore, guaranteed loans mode for small and medium enterprises has its own characteristics. Many scholars have conducted extensive research on the guaranteed loans for small and medium enterprises according to the situations in China: macro analysis of the effectiveness of the guaranteed loans mode for small and medium enterprises. Li Rirong (2011) compared guaranteed loans mode for farmers with guaranteed loans mode for small and medium enterprises, he found that the social capital of trust, reputation and long-term cooperative relationship with the bank was more valuable to small and medium enterprises. Therefore, it takes more advantage to carry out guaranteed loans among small and medium enterprises with close economic ties than farmers. [10] Li Zhichen (2012) thought that we should consider guaranteed loans group as a loan subject, in order to study the overall credit risk, the industry systemic risk, regional risk and the associated enterprise risk. [11] There are also many other scholars analyze the system of guaranteed loans from different angles. Xie Shiqing, and Li Siguang (2011) put the reputation as the starting point to analyze, they thought that the effective cost of reputation was the institutional basis to carry out the guaranteed loans for small and medium enterprises. And Bank excitation conditions endogenously determined the boundary of the market risk of the guaranteed loans. [12] Zhou Haifeng and Li Rirong (2011) thought that the size of the members of the guaranteed loans group could not be over-expansion. They also suggested developing more guaranteed loans groups within the enterprise cluster to solve the financing problem. [13] Hu Guang and Zhao Hua (2012) analyzed the perfect information dynamic game model of guaranteed loans for small and medium enterprises within the enterprise cluster from both single-stage and repeated games, and proposed that the banks' keeping

the corporate reputation cost stable at a given value would effectively avoid the default of the guaranteed loans enterprises. [14]

The current study still mainly focuses on the qualitative analysis of the main factors of the guaranteed loans mode for small and medium enterprises, while it is lacking in in-depth analysis of the mechanism that various factors affect guaranteed loans credit behavior. In fact, the decision-making behavior of defaults within guaranteed loans group is not determined by one event, but by constantly modifying their own decision-making behavior through learning and imitating the better strategy. Therefore, this paper adopts evolutionary game theory and methods, and dynamically analyzes the trend of the credit behavior of enterprises within guaranteed loans group. First of all, this paper studies the most simple and basic group composed by the two enterprises within guaranteed loans group, in order to reveal general theory and conclusion of the sustainable and stable development of guaranteed loans group; Secondly, further to study whether the former conclusions are also applicable to N enterprises of guaranteed loans group. In fact, in reality the default punishment incentives and the size of the group are closely related to the default rate within the guaranteed loans group, so this article will put those factors into the guaranteed loans credit behavior evolution game model, thus making the model closer to reality; Finally, some proposals and measures of controlling credit risk will be concluded for enterprises and banks.

3. The evolutionary game model of the credit behavior of small and medium-sized enterprises in guaranteed loans organization

3.1 The basic concept of the evolutionary game theory

The evolutionary game theory is the combination of game theory and dynamic evolution. [15-16] It differs from game theory to focus on the static equilibrium and comparative static equilibrium, but to emphasize the dynamic equilibrium. Currently, evolutionary game theory has been widely applied in cooperative behavior[17-19] and strategy selection problem[20-21] The core content of the evolutionary game model is the evolutionary stable strategy(ESS), it characterizes the dynamic convergence process to the steady state. The replicator dynamic equations describe the steady state of the evolutionary game. [22] The dynamic pace of change is expressed as $dx(t)/dt = x(U_s - \overline{U})$, x is the proportion of the individuals who choose the policy s, Us is the expected revenue of the individuals who choose the policy s, $\overline{U}$ is the average benefit of all policy strategy for the individual, $dx(t)/dt$ shows the change of ratio that select the policy s over time.

In order to simplify the problem, the following basic assumptions had been made:

(1) The probability of success of the project is P and the revenue rate is R. If the project was successful, each company gained *L*R*. Otherwise, gained 0. So the expected revenue of the project I was (*L*R*)**P*. Assuming that the loan interest rate was *i*, each company had to repay the bank financing costs before the deadline and financing costs is $L(1+i_1)$.

(2) Every enterprise in the guaranteed loans organization only had two strategies: repay the loans or choose to default.

3.2 Evolutionary game analysis of the credit behavior of simplified case

Consider the guaranteed loans organization is only composed by two companies, denoted as company 1 and company 2. If company 1 chose to repay the loans, company 2 faced with two decisions. (a)When company 2 chose repay the loans too, both of the two companies gained the same income $\pi_1 = I - c$; (b)When company 2 chose to default, company 2 gained $\pi_2 = I - S$ and company 1 gained

$\pi_3 = I - 2c + S$. S expressed the penalties and incentives of the organization. If company 1 chose to default, company 2 faced with two decisions. (c)When company 2 chose to repay, company 1 gained $\pi_2 = I - S$ and company 2 gained $\pi_3 = I - 2c + S$. (d)When company 2 chose to default, both of the two companies would punished by bank and gained $\pi_4 = I - K$.The above game can be described by an symmetric payoff matrix as table 1：

Table 1 The payoff matrix of the organization composed by two companies

		Company 2	
		Repay	Default
Company 1	Repay	π_1, π_1	π_3, π_2
	Default	π_2, π_3	π_4, π_4

If the tendency that company 1 chose to repay is α, we could get the expected revenue that the company chosen different strategies:

$$U_{repay} = \alpha\pi_1 + (1-\alpha)\pi_3 \quad (1)$$

$$U_{default} = \alpha\pi_2 + (1-\alpha)\pi_4 \quad (2)$$

So the average expected revenue is

$$U_{average} = \alpha U_{repay} + (1-\alpha)U_{default} \quad (3)$$

Futher, we could get the replicator dynamics equation of company to choose repay:

$$\begin{aligned} \frac{d\alpha}{dt} &= \alpha(U_{repay} - U_{average}) = \alpha(1-\alpha)(U_{repay} - U_{default}) \\ &= \alpha(1-\alpha)\left[\alpha(c-K) + (K+S-2c)\right] \end{aligned} \quad (4)$$

When $U_{repay} - U_{default} > 0$, the number of enterprises which chose to repay would increase, on the contrary, the enterprises would change to default. We discussed the nature of the following function.

$$f(\alpha) = \alpha(c-K) + (K+S-2c) = (c-K)\left[\alpha - \frac{K+S-2c}{K-c}\right] \quad (5)$$

When $f(\alpha) = 0$, we can gain the other stable point $\alpha = \frac{K+S-2c}{K-c} = 1 + \frac{S-c}{K-c}$.

In fact, in order to make sure that the companies would chose to repay, the punishment given by the bank should be higher than financing costs, $K>c$. So the nature of the stable point depends primarily on S and c.

(1)If $S \geq c$, then $\alpha \geq 1$, we know $\frac{d\alpha}{dt} = \alpha(1-\alpha)\left[\alpha(c-K) + (K+S-2c)\right] \geq 0$. The compliance strategy will eventually become a stable point.

(2)If $K + S \leq 2c$, then $\alpha \leq 0$ and $\frac{d\alpha}{dt} = \alpha(1-\alpha)\left[\alpha(c-K) + (K+S-2c)\right] \leq 0$. Breach of policy will eventually become a stable point.

(3)If $0 \leq S < c$ and $K + S > 2c$, then $0 < \alpha < 1$. When the initial compliance proportion higher than α, the compliance strategy will eventually become a stable point. Otherwise, breach of policy will eventually become a stable point. As shown in figure 2.

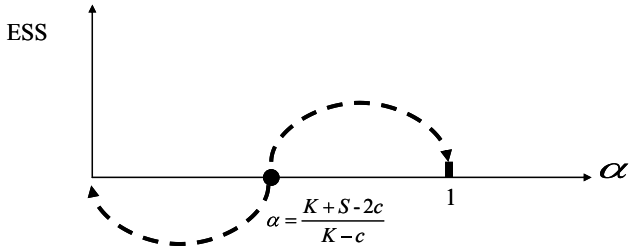

Fig. 2 The stable process of ESS when $0 < \alpha < 1$

From the above analysis, we know that $K + S > 2c$ is the prerequisite for sustainable development of the guaranteed loans organization. Improve the bank punishment *K* would promote compliance strategies become the ultimate evolutionary stable strategy. But excessive punishment would make the formation process of organization become difficult. So how to guide the organization find the reasonable punishment and incentive become the key to control credit risk.

3.3 Evolutionary game analysis of the credit behavior of complex situations

Game situation would become complicated when organizations composed by a number of companies. The joint costs borne by each enterprise and the incentive inside the organization were impacted by the scale and the initial breach proportion. The enterprises were divided into two groups, denoted as group 1 and group 2. If the tendency that group 1 chose to repay is β, similar to the discussion in 3.2. We gained the payoff matrix of the organization composed by two groups as shown in table 2.

Table 2 The payoff matrix of the organization composed by a number of companies

		Group 2	
		Repay	Default
Group 1	Repay	$\pi_1^{'}$, $\pi_1^{'}$	$\pi_3^{'}$, $\pi_2^{'}$
	Default	$\pi_2^{'}$, $\pi_3^{'}$	$\pi_4^{'}$, $\pi_4^{'}$

$$\pi_1^{'} = I - c;\ \pi_2^{'} = I - n \times \frac{1-\beta}{\beta} S;\ \pi_3^{'} = I - \frac{c}{\beta} + n \times \frac{1-\beta}{\beta} S;\ \pi_4^{'} = I - K$$

We could get the expected revenue that the company chosen different strategies:

$$U_{repay}^{'} = \beta \pi_1^{'} + (1 - \beta)\pi_3^{'} \tag{6}$$

$$U_{default}^{'} = \beta \pi_2^{'} + (1 - \beta)\pi_4^{'} \tag{7}$$

So the average expected revenue is

$$U_{average}^{'} = \beta U_{repay}^{'} + (1 - \beta)U_{default}^{'} \tag{8}$$

Similarly, we cloud get strategy dynamic equation

$$\frac{d\beta}{dt} = \beta(U'_{repay} - U'_{average}) = \beta(1-\beta)(U'_{repay} - U'_{default})$$
$$= \beta(1-\beta)\left[\frac{-(K+c)\beta^2 + (K+c-ns)\beta + (ns-c)}{\beta}\right] \quad (9)$$

Let $f(\beta) = -(K+c)\beta^2 + (K+c-ns)\beta + (ns-c) = 0$, we got two solutions:

$$\beta_1 = \frac{(K+c-ns) - \sqrt{(K+c-ns)^2 + 4(K+c)(ns-c)}}{2(K+c)} \quad (10)$$

$$\beta_2 = \frac{(K+c-ns) + \sqrt{(K+c-ns)^2 + 4(K+c)(ns-c)}}{2(K+c)} \quad (11)$$

Because $K+c>0$, the image of the function

(1) If $ns-c>0$, then $\beta_1 < 0$ and $\beta_2 > 0$.

Because $\beta_2 = \frac{(K+c-ns) + \sqrt{(K+c-ns)^2 + 4(K+c)(ns-c)}}{2(K+c)} < 1$, the copy function graphics and the stability process of ESS shown as figure 3.

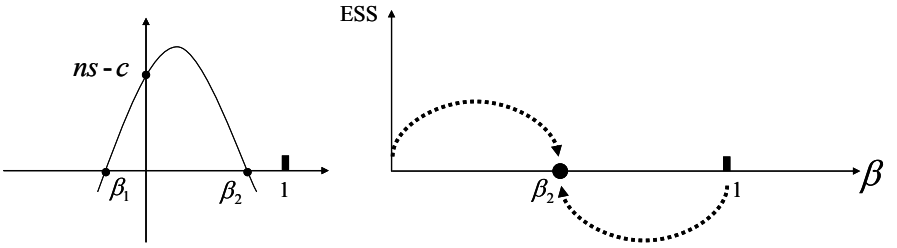

Fig.3 The stable process of ESS when $ns-c>0$

(2)If $ns-c=0$, then $\beta_1 = 0$ and $\beta_2 = \frac{K}{K+c}$, the specific case shown in figure 4.

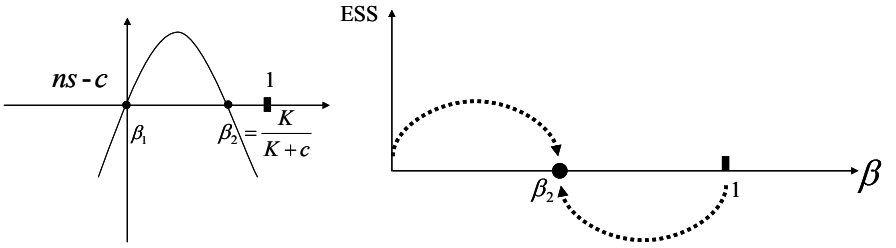

Fig. 4 The stable process of ESS when $ns-c=0$

(3)If $ns-c<0$, then divided into the following two situations:

(a)If $K+c-ns<0$, then $\beta_1 < 0$ and $\beta_2 < 0$. Breach of policy will eventually become a stable

point as shown in figure 5.

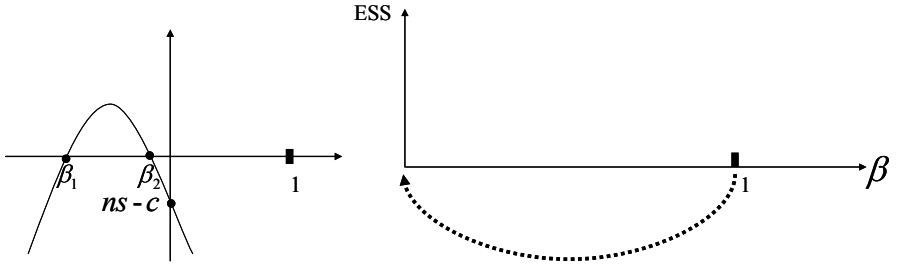

Fig. 5 The stable process of ESS when $ns-c<0$ and $K+c-ns<0$

(b)If $K+c-ns>0$, then $0<\beta_1<\beta_2<1$, the ESS process was shown as figure 6.

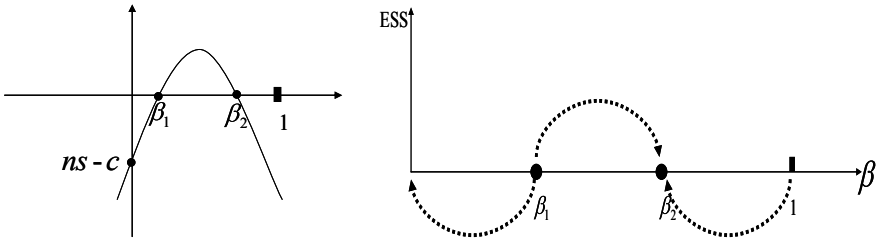

Fig. 6 The stable process of ESS when $ns-c<0$ and $K+c-ns>0$

From the above analysis, different from 3.2 we know that when consider the scale of the organization and the initial breach proportion, the ultimate evolutionary stable proportion is between 0 and 1. It means that companies would choose to default if there is no exit mechanism. The formation of the elimination mechanism could fundamentally control credit risk.

4. Summary

In this paper, we analyzed credit behavior of members in organization based on evolutionary game theory. Through the research on organization which composed by two companies, we found out that improve the bank punishment *K* would promote compliance strategies become the ultimate evolutionary stable strategy. And guide the organization find the reasonable punishment and incentive become the key to control credit risk. Then we consider the situation that the organization had a number of companies, we found out that the ultimate evolutionary stable proportion is between 0 and 1. The formation of the elimination mechanism could fundamentally control credit risk.

We assumed that the enterprises are homogeneous and ignore the difference between them. In fact, the status of each company in organization is not consistent. We would characterize heterogeneous enterprise and organizational structure to make the model closer to reality in future studies.

Acknowledgements

This research has been supported by National Natural Science Foundation of China (70971015, 71271043), the Special Research Foundation of PhD Program of China（20110185110021）

References

[1] Timothy Besley, Stephen Coate. Group lending, repayment incentives and social collateral[J]. Journal of Development Economics, 1995, 46(1): 1-18.

[2] Gregorio Impavido. Credit Rationing, Group Lending and Optimal Group Size[J]. Annals of Public & Cooperative Economics, 1998, 69(2): 243-260.

[3] Liu Feng, Xu Yonghui, He Tian. The Institutional Defect and Behavior Distortion of Fanner's Coguarantee Loans: the Case of Heilongjiang Province[J]. Journal of Financial Research, 2006, (9): 171-178.

[4] Klaus Abbink. Bernd Irlenbusch. Elke Renner. Group size and social ties in microfinance institutions[J]. Economic Inquiry, 2006, 44(4): 614-628.

[5] Christian Ahlin, Rober M. Townsend. Using repayment data to test across models of joint liability lending[J]. The Economic Journal, 2007,117(517): F11-F51.

[6] Zhao Yanqing, He Guangwen. On the Validity of Farm Household Group Lending[J]. Journal of Financial Research, 2007, (7): 61-77.

[7] James Barham, Clarence Chitemi. Collective action initiatives to improve marketing performance: Lessons from farmer groups in Tanzania[J]. Food Policy, 2009, 34(1):53-59.

[8] Bharat Bhole, Sean Ogden. Group lending and individual lending with strategic default[J]. Journal of Development Economics, 2010, 91(2): 348-363.

[9] Zhang Zhengping, Xiao Xiong. The conditions for the development of the guaranteed loans of our farmers: Based on the analysis of evolutionary game theory[J]. Journal of Agrotechnical Economics, 2012, (5): 60-69.

[10] Li Rirong. The advantage analysis of guaranteed loans for SMEs form Social Capital Perspective - based on the comparison of the guaranteed loans with farmers[J]. South China Finance, 2011, (9): 26-30.

[11] Li Zhichen. The analysis and preventive measures of the risk of guaranteed loans for SMEs[J]. Finance and Economy, 2011, (9): 26-30.

[12] Zhou Huaifeng, Li Rirong. The constraint mechanism of Guaranteed loans for SMEs and the determination of its size[J]. Journal of Zhongnan University of Economics and Low, 2011, (6):113-120.

[13] Xie Shiqing, Li Siguang. A Game Analysis on the SMEs' Group Lending Reputation Model[J]. Economic Research Journal, 2011, (1): 97-111.

[14] Hu Guang, Zhao Hua. Dynamic Game Analysis of Enterprise Clusters guaranteed loans for SMEs[J]. China Economic & Trade Herald, 2012, (17): 51-54.

[15] Maynard S J. The theory of Games and the evolution of animal conflicts[J]. Journal of Theoretical biology, 1974, 47(1):209－221.

[16] Selten R. Evolutionary stability in extensive two person Games correction and further development[J]. Mathematical Social Sciences, 1988, 16(3):223－266.

[17] Jiang Guoyin, Hu Bin, Qian Ren. Evolutionary Game Theoretic Perspective on Analysis of Cooperative Performance Among Mobile Service Providers[J]. Operations Research and Management Science, 2010, 19(5): 90-94.

[18] Zhou Min. Research on Cooperative Innovation in Industrial Clusters Based on Evolutionary Game Theory[J]. Science and Technology Management Research, 2012, 15(2): 71-82.

[19] Luo Jianfeng. The Default Punishment Mechanism of Cooperation among Enterprises Based on Evolutionary Game Theory[J]. Systems Engineering, 2012, 30(1): 27-31.

[20] Tan Jiayin, Li Bo. Study of Manufacturer's Channel Selection Strategy under Both Channel and Brand Competiton[J]. Management Review, 2012, 24(6): 74-82.

[21] Zhang Junjun, Han Xiao, Zou Zuxu, Fan Wentao. Analysis on venture capitalists' strategies in IPO Market based on evolutionary game[J]. 2012, 15(2): 71-82.

[22] Hofbauer J, Sigmund K. Evolutionary Games and population dynamics[M]. Cambridge: Cambridge University Press, 1998.