The evolution game analysis of crowdfunding market financing supervision

Guoshun Ma, Yongfei Li

Abstract— **The rapid development of Internet crowdfunding market financing has brought great convenience to consumer investment. However, due to the information asymmetry between the initiator and the investee, there is a great risk of investment behavior. Based on the theory of evolutionary game, through the establishment of replicated dynamic equations, the dynamic evolution process of crowdfunding platform and sponsors' strategic choices is analyzed, and the evolutionary stability strategies of both sides of the game are obtained. The conclusion shows that the punishment of deception, the success rate of supervision on crowdfunding platforms, and the awareness of investing in rights protection are key factors affecting the crowdfunding market.**

Index Terms— **crowdfunding market; evolutionary game; replicated dynamic equation; evolutionary stability strategy.**

I. INTRODUCTION

With the rapid development of Internet finance, the crowdfunding as a new financing mode has made great achievements. Crowdfunding [1] means that the sponsors show a project or idea through the Internet platform, and raise funds for the public investors in some form of repayment. This financing model provides unlimited possibilities for more small and micro enterprises or creative individuals. The characteristics of its low threshold and diversity are loved by the sponsors, making crowdfunding become one of the most important ways of modern financing. Because the domestic supervision and management of the crowdfunding industry is not sufficient, the participants of crowdfunding are also taking on greater additional risks while obtaining their own interests. For the majority of the investors, it is not only to face the risks caused by the
incomplete disclosure of information from the project sponsors and the loss caused by the failure of the project, but also to face the risk of being deceived from the improper supervision and audit of the platform. As a financing intermediary, the main source of crowdfunding platform is the commission charges of successful financing. It has the responsibility to guarantee the investment of the investors and audit and supervise the sponsors of the project, but it will cost a lot of cost. At the same time, the platform is a limited rational decision maker, its strategy choice have active supervision and passive supervision, But people's awareness of rights is weak at present, which leads to few people who will be reported to the relevant departments and platforms because of the loss of their personal interests. For the purpose of maximizing benefits, the platform will tend to choose passive supervision, thus reducing the cost of supervision and increasing the income. At this time, the platform rarely attracts high quality projects, and the interests of investors are not guaranteed. In addition, the current platform supervision system and methods are not perfect, the implementation of supervision may not guarantee success, resulting in the unsteady development of crowdfunding market in China. Under such a realistic situation, how to achieve multi-win among all platforms, sponsors and investors has become an important issue of research.

At present, many scholars have discussed the above game problems. Li Jing [2] made an evolutionary game analysis on the crowdfunding platform and the supervision department, and proposed that the sound laws and regulations and the complete credit collection system are the key factors for the healthy development of the crowdfunding industry. Wang Shuqiang [3] studied the supervision of crowdfunding market by using the complete information static game model, and pointed out that big data, cloud computing and other technologies should be used to reduce the regulatory cost of the platform. Wang Fei [4] discussed the influence of the incentive regulation of crowdfunding platform on the strategy of sponsors, and believed that the incentive of commission charges can effectively reduce the capital risks. Deng Biteng [5] analyzed the evolutionary game of the incentive platform and the sponsor, and put forward that the financing demand, the service efficiency of the platform and the degree of government supervision are the important factors that affect the operation mode of the crowdfunding platform. Wang Xianjia [6] used the large group repeated game model to study the dynamic of the consumer crowdfunding strategy under the two situations of fair contribution and altruism, and concluded the favorable factors for the success of the crowdfunding evolution under different mechanisms. He Qilong [7] analyzed the supervision strategy of the Internet crowdfunding platform by using the evolutionary game model, and put forward that effective supervision and different degree of punishment strategies can reduce the deception of the sponsors and improve the enthusiasm of investors to participate in crowdfunding. Meanwhile, Belleflamme believes that the crowdfunding platform is more effective than investors in dealing with the problems caused by asymmetric information [8]. Miao Wenlong believes that platform regulation is an effective way to reduce the risk of fraud and project failure [9].

The above literature focuses on the incentive and supervision of the crowdfunding market, the role of the platform in crowdfunding and the study of the game between the platform and the investors. However, with the country's further supervision and management of the crowdfunding market and people’s awareness of their rights protection continues to increase, the assumptions in the literature have some irrationalities. First, the strategy selection of the crowdfunding platform should be changed from supervision

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and non-supervision into active supervision and passive supervision. Second, the supervision ability of the platform is too idealized, which means that there is a possibility that the platform supervision will not succeed in reality. Therefore, on the basis of the above research, based on the evolutionary game theory [10-11], we set up the game model [12] of the crowdfunding platform and the sponsor, and analyze the evolutionary stability strategy (ESS) and the main factors that influence the strategy selection, so as to provide the theoretical basis for the promotion of the better development of the crowdfunding market.

II. MODEL

2.1 The basic assumptions of the model

According to the reality, the strategy choices of the crowdfunding platform and sponsors in game directly affect whether the investor participates in crowdfunding. We assume that there are two types of participants in the model, one is the crowdfunding platform, and the alternative strategy is active supervision and passive supervision, respectively denoted as P_1 and P_2; the other is the sponsors, the optional strategy are integrity and deception, respectively denoted as S_1 and S_2, both sides of game is limited rational decision makers, and are all under the condition of complete information, through continuous imitation learning to improve their own strategies.

Active supervision means that the crowdfunding platform supervises the sponsors through establishing rules, reputation surveys, and project evaluation. We assume that the cost is C_{P1}, However, due to the limited technical level and imperfect supervision system, the active supervision may not be successful, Therefore, assume that α is the success rate of active supervision $(0 < \alpha < 1)$; The passive supervision is that the platform will be supervised when the project sponsor is notified by the investor. We assume that the cost is C_{P2}, and the probability of the sponsor's deception being reported to the platform is $\lambda(0 < \lambda < 1)$, and β is the success rate of passive supervision $(0 < \beta < 1)$.

Let π_s is the benefit of the sponsor's integrity transaction, and π_d is the benefit of the sponsor's deceptive behavior, and π_p is the commission charge that the sponsor pays to the platform$(\pi_p > 0)$, which is the revenue of the crowdfunding platform. At the same time, the cost required for the sponsor to complete the project is C_h, the cost for coordinating supervision is C_E, and the penalty for fraud is P.

2.2 Establishment of model

It is assumed that in the crowdfunding platform groups, there is a x proportion of the crowdfunding platforms choose the active supervision strategy, then the proportion of the passive supervision strategy is $1-\mathrm{x}$; in the sponsor groups, there are y proportions of sponsors who choose Integrity strategies, then the proportion of deceive strategies is $1-\mathrm{y}$, we get the revenue matrix of both sides of the game, as shown in Table 1.

Table 1 game revenue matrix

Sponsors	Crowdfunding platform	
	Active supervision $(\mathrm{P_1})$	Passive supervision $(\mathrm{P_2})$
Integrity $(\mathrm{S_1})$	$\pi_S-\pi_p-C_h-C_E,\pi_p-C_{p_1}$	$\pi_S-\pi_p-C_h-\lambda C_E,\pi_p-\lambda C_{p_2}$
	$(1-\alpha)\pi_d-\pi_p-C_E-\alpha P,$	$(1-\lambda\beta)\pi_d-\pi_p-\lambda C_E-\lambda\beta P,$
Deceive $(\mathrm{S_2})$	$\pi_p-C_{p_1}+\alpha P$	$\pi_p-\lambda C_{p_2}+\lambda\beta P$

The expected profits of active supervision and passive supervision for crowdfunding platforms and the average profit of population are U_{P1}, U_{P2} and $\bar{U}_P$ respectively:

$$U_{P1} = y(\pi_p - C_{p_1}) + (1-y)(\pi_p - C_{p_1} + \alpha P) = \pi_p - C_{P1} + (1-y)\alpha P$$

$$U_{P2} = y(\pi_p - \lambda C_{p_2}) + (1-y)(\pi_p - \lambda C_{p_2} + \lambda\beta P) = \pi_p - \lambda C_{P2} + (1-y)\lambda\beta P$$

$$\bar{U}_P = xU_{P1} + (1-x)U_{P2}$$

The replicated dynamic equation of crowdfunding platforms choose the active supervision is

$$F(x) = \frac{dx}{dt} = x(U_{P1} - \bar{U}_P) = x(1-x)[(\alpha-\lambda\beta)(1-y)P - C_{p_1} + \lambda C_{p_2}] \quad (1)$$

Let $F(x)=0$, we get $x=0, x=1$, $y^* = 1 - \frac{C_{P1}-\lambda C_{P2}}{(\alpha-\lambda\beta)P}$;

The expected profits of integrity crowdfunding and deceive crowdfunding for sponsors and the average profit of population are U_{S1}, U_{S2} and $\bar{U}_S$ respectively:

$$U_{S1} = x(\pi_S - \pi_p - C_h - C_E) + (1-x)(\pi_S - \pi_p - C_h - \lambda C_E) = \pi_S - \pi_p - C_h - \lambda C_E + (\lambda-1)xC_E$$

$$U_{S2} = x[(1-\alpha)\pi_d - \pi_p - C_E - \alpha P] + (1-x)[(1-\lambda\beta)\pi_d - \pi_p - \lambda C_E - \lambda\beta P]$$

$$\bar{U}_S = yU_{S1} + (1-y)U_{S2}$$

The replicated dynamic equation of sponsors choose the integrity crowdfunding is

$$U_{S2} = x[(1-\alpha)\pi_d - \pi_p - C_E - \alpha P] + (1-x)[(1-\lambda\beta)\pi_d - \pi_p - \lambda C_E - \lambda\beta P]$$

Let $G(y)=0$, we get $y=0, y=1$, $x^* = \frac{\pi_S - C_h - \pi_d + \lambda\beta(\pi_d+P)}{(\lambda\beta-\alpha)(\pi_d+P)}$. The dynamic system $(1)-(2)$ exists 5 equilibrium points $(0,0)$、$(0,1)$、$(1,0)$、$(1,1)$ and $\left(x^* = \frac{\pi_S - C_h - \pi_d + \lambda\beta(\pi_d+P)}{(\lambda\beta-\alpha)(\pi_d+P)}, y^* = 1 - \frac{C_{P1}-\lambda C_{P2}}{(\alpha-\lambda\beta)P}\right)$. Below we analyze the stability of equilibrium points in different situations.

2.3 The analysis of model

Let $\delta = (\alpha P - C_{P1}) - (\lambda\beta P - \lambda C_{P2})$, and $\delta < 0$. We call δ as the maximum profit difference for the platform, which means that the current government's supervision and

management policies on the crowdfunding market are incomplete and public awareness of rights protection is also weak. Under the goal of maximizing profits, sponsors have the incentive to choose to deceive crowdfunding. At the same time, crowdfunding platforms will tend to choose passive supervision strategies with higher returns. Let $\gamma = (\pi_S - C_h) - [\pi_d - \lambda\beta(\pi_d + P)]$, and $\gamma < 0$, say γ is the sponsor's maximum profit difference, indicating that under the same reality, the crowdfunding platform has the initiative to choose to passive supervision, while the sponsors will tend to choose a more profitable strategy of deceive crowdfunding.

According to the hypothesis, we have $0 < y^* < 1$, because of $\delta < 0$, so $(\alpha - \lambda\beta)P < (\alpha - \lambda\beta)P - C_{p_1} + \lambda C_{p_2} < 0$, that is $C_{p_1} < \lambda C_{p_2}$.

When $y = y^*$, $F'(x) \equiv 0$, then all $0 \le x \le 1$ points are ESS.

When $y > y^*$, we have $F'(1) < 0, F'(0) > 0$, at this time, $x = 1$ is an evolutionary stable state, in this case, active supervision is the optimal strategy for the crowdfunding platform; when $y < y^*$, we have $F'(0) < 0, F'(1) > 0$, then, $x = 0$ is the stable state of evolution, in this case, passive supervision is the optimal strategy of the crowdfunding platform, The dynamic phase diagrams of this two cases are shown in Figure 1.

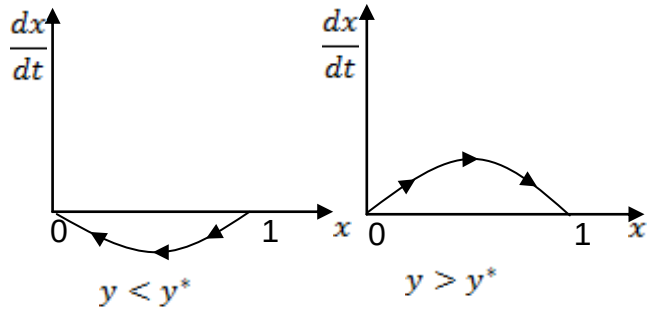


Figure 1 $\delta < 0$ dynamic phase diagram

According to the hypothesis, we have $0 < x^* < 1$, because of $\gamma < 0$, so $(\lambda\beta - \alpha)(\pi_d + P) < \pi_S - C_h - \pi_d + \lambda\beta(\pi_d + P) < 0$, that is, $\pi_S - C_h > (1 - \alpha)\pi_d - \alpha P$.

When $x = x^*$, $G'(y) \equiv 0$, then all $0 \le y \le 1$ points are ESS.

When $x > x^*$, we have $G'(1) < 0, G'(0) > 0$, at this time, $y = 1$ is an evolutionary stable state, that is, in this case, integrity crowdfunding is the optimal strategy of the sponsor; when $x < x^*$, there is $G'(0) < 0, G'(1) > 0$, then, $y = 0$ is the stable state of evolution, in that case, deceive crowdfunding is the optimal strategy of the sponsor, The dynamic phase diagrams of this two cases are shown in Figure

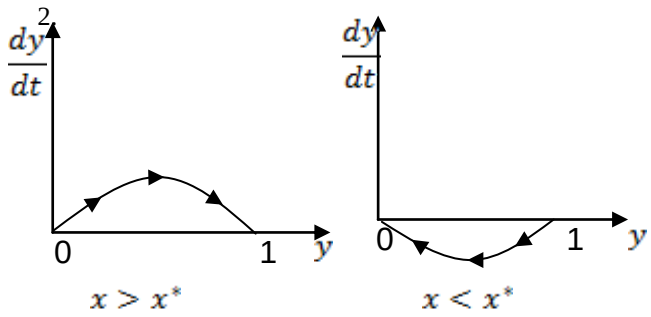


Figure 2 $\gamma < 0$ dynamic phase diagram

2.4 Evolutionary stable strategy analysis

From (1) and (2) we get the Jacobian matrix of the system

$$J = \begin{pmatrix} (1-2x)\begin{bmatrix}(\alpha-\lambda\beta)(1-y)P \\ -C_{p_1} + \lambda C_{p_2}\end{bmatrix} & x(1-x)(\lambda\beta-\alpha)P \\ y(1-y)(\alpha-\lambda\beta)(\pi_d+P) & (1-2y)\begin{bmatrix}\lambda\beta(\pi_d+P)+\pi_S-C_h \\ -\pi_d + x(\alpha-\lambda\beta)(\pi_d+P)\end{bmatrix} \end{pmatrix}$$

According to the stability theorem of Jacobian matrix, we obtain the stability results of 5 equilibrium points as shown in Table 2.

Table 2 Stability analysis of equilibrium points

Equilibrium point	DetJ	TrJ	Result
$x = 1, y = 0$	+	+	Unstable Point
$x = 0, y = 1$	+	+	Unstable Point
$x = 0, y = 0$	+	−	ESS
$x = 1, y = 1$	+	−	ESS
$x = x^*, y = y^*$		0	Saddle Point

Based on the above analysis results, we get the evolution phase diagram of $\delta < 0, \gamma < 0$, as shown in Figure 3.

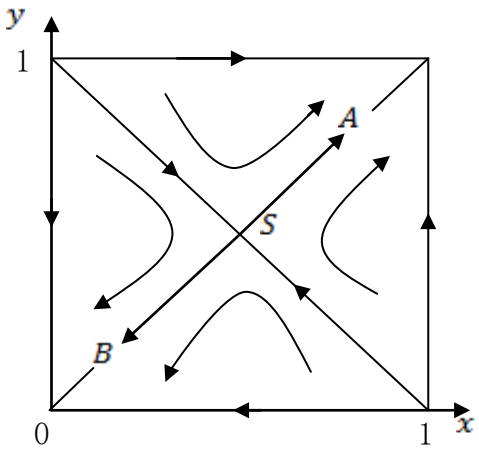
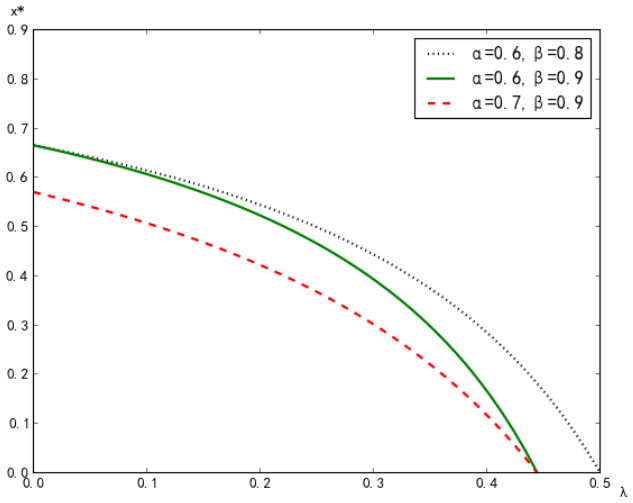


Figure 3 evolutionary phase diagram

For the analysis of evolutionary phase diagram, we can see that points $(0,0)$ and $(1,1)$ are stable points, and points $(1,0)$ and $(0,1)$ are unstable points, and point $S(x^*, y^*)$ is saddle point. When the initial state is in the region A (the upper right of the line connecting point $(1,0)$ and $(0,1)$ and point S), the system will converges to the point $(1,1)$. That is, all the crowdfunding platform groups choose the active supervision, at the same time, the sponsor groups adopt the integrity crowdfunding strategy. This situation is the ideal state of the game, and the crowdfunding market is developing towards the expected direction. When the initial state is in the region B(the lower left area connecting points $(1,0)$ and $(0,1)$ and point S), the system will converge to the point $(0,0)$, that is, all the crowdfunding platform groups choose the passive supervision, and at the same time sponsor groups adopt the deceive crowdfunding. Under such circumstances, the development of crowdfunding market is seriously out of balance. It can be seen that the evolutionary process of the game depends on the initial state of the system and the relative position of the saddle point. In order to achieve the expected ESS of the crowdfunding market, the area of the A region should be increased and the system should be able to evolve to the point $(1,1)$ with the maximum possibility.

III. NUMERICAL SIMULATION ANALYSIS

Due to the current imperfect supervision and management policies of the relevant government departments on crowdfunding market and the weak public awareness of rights protection, the ideal strategy set of the game (active supervision, integrity crowdfunding) is difficult to achieve. On the basis of the above conclusions, we use MATLAB software to conduct numerical simulation analysis and study the impact of important parameters such as the success rate of supervision and the rate of reporting on the strategy choices of both parties. Here we let $\mu = \frac{\pi_d - (\pi_s - c_h)}{\pi_d + p}$, and called as the risk tolerance, which indicates the ratio of the sponsor's extra profit of deception successful and the loss of the failure. Considering the reality, we set $\mu = 0.4$, the relationship among the parameters under different supervision success rate shown in Figure 4, Comparison and analysis can be obtained, When α and β are determined, the larger λ is, the smaller x^* is. Under the same value of α, x^* decreases with increasing β. Under the same value of β, x^* also decreases with increasing α. That is, x^* is negatively correlated with α and β, and the larger the α and β, the lower the curve. Therefore, it is very important to choose integrity crowdfunding for the sponsors that raising investor's awareness of rights protection. At the same time, the higher supervision success rate of the platform can also prompt sponsors to choose integrity crowdfunding.



Graph 4 parameter diagram

IV. CONCLUSIONS AND RECOMMENDATIONS

This article combines the reality, establishes the asymmetric game model between the crowdfunding platform and the project sponsors, analyzes the situation under different strategies of the two sides of the game by using the evolutionary game theory, and obtains the optimal strategy for the healthy and stable development of the crowdfunding market. Through the analysis, we find that the strategic choice between the platform and the sponsor is interdependent, and the evolutionary stability strategy of game has many influence factors. The results of the analysis in this paper have certain guiding significance for the development of the crowdfunding market.

Combined with the analysis results, we make the following suggestions: first, improve the credit system and strictly review the standards. The crowdfunding platforms should work together with relevant departments to establish and improve the credit information system, and strictly evaluate the project and review standards. Second, increase penalties to reduce cheating. The platform should establish a reasonable punishment mechanism, and punish the sponsor' malicious deception through various means. Third, implement the supervision system and improve the quality of supervision. The government should use effective incentives to promote the platform's strict formulation and implementation of the regulatory system, and strengthen the supervision level with the help of modern technology. Fourth, encourage public supervision and enhance awareness of rights protection. Through propaganda and other means to enhance investors' awareness of reporting, and using physical rewards and other means to mobilize the enthusiasm of reporting with investors.

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