Research on the Competitive Strategy of China's Online Lending Industry

Xiaoji Wan[1, 2*], Liping Zhang[1], Zhiguo Zhu[3]

[1] College of Business Adminstration, Huaqiao University, Quanzhou 362021, Fujian, China.
[2] Oriental Enterprise Management Research Center, Huaqiao University, Quanzhou 362021, Fujian, China.
[3] School of Management Science and Engineering, Dongbei University of Finance and Economics, Dalian 116023, Liaoning, China.

* Corresponding author. Tel.: +86-18120648016; email: wanxiaoji@hqu.edu.cn
Manuscript submitted October 10, 2017; accepted January 25, 2018.
doi: 10.17706/ijeeee.2019.9.2.67-80

Abstract: With the flood of traditional banks, state-owned assets, quoted companies and venture capitals into China's online lending marketplace, the competition among China's P2P platforms becomes more serious than before. To ensure survival and development, a large number of small and medium-sized P2P platforms in China are seeking to coordinate with other P2P platforms and external institutions (such as traditional banks, insurance companies, etc). However, in reality, it is difficult for certain inexperienced P2P platforms to accurately maintain the cooperation strength. To this end, this paper proposes a nonlinear growth dynamics model for China's P2P platforms, and studies quantitatively the relationship between cooperation strength and growth trend of P2P platforms by using the Lyapunov's first method in stability theory. The results show that the powerful P2P platforms may occupy the whole online lending market in the future. In addition, the small and medium-sized P2P platforms also can gradually narrow the gap with the powerful P2P platforms by adjusting the cooperation strength properly, and even it is possible for them to enjoy the same customer rate at some point in the future. The numerical simulation demonstrates the effectiveness and feasibility of obtained model, and some development proposals are further put forward for China's P2P platforms. The findings in this study give insights on how China's P2P operators coordinate reasonably the cooperation and competition.

Key words: P2P platforms, cooperation strength, mutual benefit and win-win, winner-take-all.

1. Introduction

Owing to low-threshold and huge market demand, China's online lending industry achieves a vigorous development since PPdai.com was launched firstly in 2007. The monitoring data from "Annual Report of China's Online Lending Industry in 2016" indicates that there are 2,448 P2P platforms by December 2016. And the loan has risen from 982.3 billion yuan in 2015 to 2063.9 billion yuan in 2016.

However, in recent years, because of supervision absence, business boundary indistinct, and operating rules imperfection, numerous risks have been exposed in the high speed development of China's online lending industry. The number of closed and problem platforms achieves 1741 in 2016 from the report issued by "Yingcan Consulting", which seriously hurts the confidence of China online lending participants and industry's reputation. To promote the healthy development of China online lending industry, several important regulatory documents such as ``Guiding opinions on promoting the healthy development of

Internet Banking'' and ``Interim measures for the management of business activities of Internet lending information intermediary institutions'' have been promulgated recently. With clearer regulation and oversight, some non-compliance P2P platforms are banned or forced to close. Meanwhile, as traditional banks, state-owned assets, quoted companies, and venture capitals pour into China's online lending marketplace, the competition in this industry is also becoming more and more fierce. Obviously, it is more difficult for large numbers of small and medium-sized P2P platforms to survive than before. In reality, to ensure survival and development, many small and medium-sized P2P platforms are seeking to cooperate with other platforms or external institutions. For example, renrendai.com reinforces the cooperation with zdcredit.com and anshengcredit.com in business; ppdai.com coordinates with Sunshine Insurance in the areas of transaction fund security and anti-money laundering; jimu.com and renrendai.com coordinate with Minsheng Bank in Capital Depository.

Nevertheless, in reality, it is difficult for certain inexperienced P2P platforms to coordinate the relationship between competition and cooperation. To this end, we propose a coopetition model based on the current situation of China's online lending industry, and mainly focus on discussing the relationship between the cooperative strength and P2P platform's growth tendency by using the Lyapunov's first method in stability theory.

This paper offers both academic and practical insights. On the one hand, our study deepens the cross and penetration between dynamic system and internet financial theory by introducing stability theory into P2P lending industry. On the other hand, our study also provides China's P2P operators with suggestions and references on how to balance the relationship between cooperation and competition.

The rest of paper is organized as follows. In Section 2, the literature related to online lending is reviewed. In Section 3, a coopetition model for China's online lending marketplace is presented. In Section 4, certain detailed analysis for this coopetition model is conducted from nonlinear dynamics. The final Section reviews the conclusions and offers development suggestions.

2. Literature Reviews

Recent years have witnessed the prosperous development of China's online lending industry. Additionally, much attention has been paid to the research on the online lending too.

From the view of borrowers, the previous studies mainly focused on assisting borrowers to make decisions and exploring the key factors of successfully securing a loan. For example, Puro [1] developed an aid decision-making system for borrowers based on a logistic regression model and a data driven query method, which displays the relationship between starting interest rate, loan amount and final interest rate. Moreover, Wu [2] designed a decision support system for borrowers based on the intelligent agent in P2P online lending. By providing borrowers with individual risk evaluation, lending portfolio, and loan recommendation, the loan demand of borrowers will be effectively guaranteed. Regarding the auction-related determinants of funding success, Herzenstein [3] found that the race and the gender of borrowers affect the likelihood of the auction funding success, but the effects are small in comparison with those borrowers financial strength and effort when listing and publicizing the auction. In addition, Ryan [4] noted that both the individual/society information (e.g. guarantees, lists, resumes) and financial information (e.g. credit rating, bank account, debt to income ratio, housing ownership) are key factors in securing a loan successfully.

From the perspective of investors, the current research mainly concentrated on the lender's bidding behavior, investment strategy, and decision-making. As to lender's bidding behavior, Garman [5] studied the investment behavior of lenders by establishing an optimal selection model and explained the market interest rate curve by introducing the concept of search premium. For the conformity in the process of investment, Ceyan [6], Lee [7], Krumme and Herrero [8], Herzenstein [9] and Wang [10] conducted detailed research. In particular, Wang [10] found that the herd behavior in the process of online lending results in unfair risk-return, low investment return and the waste of investment opportunities, et al. In terms of the investment strategy, Puro [11] defined and recognized nine different bidding strategies by analyzing the loan data from Prosper.com, and found three common strategies: valuator strategy, late bidding strategy, and multi-times strategy. To effectively improve investment performances, Guo [12] proposed a data-driven investment decision-making framework for P2P lending marketplaces and formulated the investment decision in P2P lending as a portfolio optimization problem with boundary constraints. Moreover, Luo [13] also presented three quantitative credit assessment and investment decision models relating to the lender composition, borrower credit risk and multiple sources of information.

From the point view of P2P platforms, existing research mainly focused on analyzing the loan data from online lending platforms. For example, Lee [7] confirmed the herd behavior by analyzing the trade data from Pobfunding.com, the largest online lending platform in South Korea. By analyzing the loan data from Prosper.com, Puro[1], [11] constructed an aid decision support system for borrowers, and Berkovich [14] found that the loan with lower ex-post return contains higher deviation between price and ex-post return. Even if the risk is illustrated and evaded, high priced loans can still obtain the excess return. As to the information question in online lending marketplace, Freedman and Jin [15], [16] extracted the loan data of prosper.com from June, 2006 through July, 2008. In addition, by analyzing a large number of loan listings from Prosper.com, Lin [17] found that friendships can increase the probability of successful funding and decrease the final interest rates on funded loans and ex-post default rates.

All above studies offer the online lending participants certain valuable guides, but few research focuses on the development situation of P2P platforms. Actually, with the introduction of several online lending regulatory documents, a growing number of China P2P investors choose to sit on their cash or invest in some larger P2P platforms with high-profile. Due to the difficulty in capturing customers, the survival environment of small and medium-sized P2P platforms gets more worse than before. To integrate the assets, technology and talent advantage, many China's small and medium-sized P2P platforms are considering to coordinate with commercial banks, insurance companies or other P2P platforms, et al. However, in reality, it is difficult for certain inexperienced P2P platforms to coordinate the cooperation and competition strength reasonably. How to coordinate this relationship is just this paper purpose.

3. Coopetition Model for China's Online Lending Industry

To describe the growth characteristics of website, Maurer and Huberman [18] firstly established the following competition model based on the Lotka-Volterra competitive equations

$$dx_i/dt = \alpha_i x_i\left(\beta_i - x_i\right) - \sum_{j\neq i,\, j=1}^{n} \gamma_{ij} x_i x_j,\ i = 1, 2, \ldots, n, \tag{1}$$

where x_i is the proportion of customers visiting website i, α_i is the growth rate of individual website without any competition, β_i denotes their saturation capacity to service customers, γ_{ij} is the competition strength between websites i and j. The parameter values are such that x_i, α_i, $\gamma_{ij} > 0$, $0 < \beta_i \le 1$, $j = 1, 2, \ldots, n$.

After that, López and Sanjuán [19] defined the weak competition relationship between websites i and j ($\gamma_{ij} < \alpha_i$) in model (1) as cooperation, and further discussed the growth tendency of three websites in completely collaborative markets, completely competitive markets and mixed markets. Lastly, they obtained a series of winning strategies. Based on these, Wang and Wu [20] extended the model in [19] to the cooperation and competition, and discussed the coopetition of two weak and one strong commercial websites. The winning strategies for two mutual cooperative weak websites were given. They presented this model as follows

$$
\begin{aligned}
dx_1/dt &= x_1\left(b_1 - b_1c_1x_1 + a_{12}x_2 - a_{13}x_3\right),\\
dx_2/dt &= x_2\left(b_2 - b_2c_2x_2 + a_{21}x_1 - a_{23}x_3\right),\\
dx_3/dt &= x_3\left(b_3 - b_3c_3x_3 - a_{31}x_1 - a_{32}x_2\right),
\end{aligned}
\tag{2}
$$

where x_i is the fraction of customers that visit website i, b_i is the intrinsic growth rate of website i, $1/c_i\left(c_i > 0\right)$ is the maximum fraction of customers that website i can afford at the same time, a_{12} is the cooperation rate between websites 1 and 2, which measures the fraction of customers that website 1 obtains because of website 2. a_{21} has a similar meaning as a_{12}. a_{13} is the competition rate between websites 1 and 3, which measures the fraction of customers that website 1 loses because of website 3. a_{23}, a_{31}, a_{32} are nonnegative and have a similar meaning as a_{13}.

Due to the strict hypothesis in model (2), such as $b_i = b, 1/c_i = 100\%, a_{ij} = a_{ji}, i \neq j, i, j = 1,2,3,$ the achieved results may not be perfect. To make up the defects, Jiang and Cheng [21] discussed the general case of model (2), and obtained some interesting strategies; for instance, weak websites with cooperation will win and strong websites will be closed.

In fact, as a new type of commercial websites, P2P platforms are often affected by user preferences. Generally speaking, the clients in online lending marketplace prefer borrowing and investing in a larger P2P platform. Obviously, this type of platforms has greater advantages. This phenomenon exactly mirrors the "rich gets richer" characteristics of commercial sites. To study the effect of "rich gets richer" on commercial websites, Li and Zhu [22-[24] proposed this model as follows

$$
dx_i/dt = \alpha_i x_i\left(\beta_i - x_i\right) - \sum_{j\neq i, j=1}^{n} \gamma_{ij}\left(1+\omega_{ij}\left(x_j - x_i\right)\right)x_i x_j, i = 1,2,\ldots,n, \tag{3}
$$

where x_i is the fraction of customers visiting website i, $\omega_{ij}\left(x_j - x_i\right)$ is the influence of user preferences, ω_{ij} is the effect intension, α_i, β_i and γ_{ij} have the same definition as in model (1). $x_i, \alpha_i, \gamma_{ij} > 0$, $0 < \beta_i \leq 1$, $0 < \omega_{ij} < \min\{1, \gamma_{ij}\}, j = 1,2,\ldots,n.$

On this basis, to the best of our knowledge, Wan and Deng [25] first proposed a growth dynamics model of P2P platforms. That is,

$$
dx_i/dt = \alpha_i x_i\left(\beta_i - x_i\right) - \sum_{j\neq i, j=1}^{n} \gamma_{ij}\left(1+\omega_{ij}\left(x_j - x_i\right)\right)x_i x_j + \sum_{j\neq i, j=1}^{n} k_{ij} x_i x_j, i = 1,2,\ldots,n. \tag{4}
$$

Although model (4) can partly coordinate the relationship between competition and cooperation of P2P platforms, it can not completely describe the cooperation status of China's online lending marketplace. In reality, many small and medium-sized P2P platforms in China not only cooperate with other P2P platforms, but also work with traditional banks, insurance companies, third party payment institutions, et al. To better describe the coopetition situation of China's Online lending marketplace, we present the following model

$$dx_i/dt = \alpha_i x_i\left(\beta_i - x_i\right) - \sum_{j\neq i,\, j=1}^{n} \gamma_{ij}\left(1+\omega_{ij}\left(x_j - x_i\right)\right)x_i x_j + \sum_{j\neq i,\, j=1}^{n} k_{ij} x_i x_j + s_i x_i^2, i = 1,2,\ldots,n. \quad (5)$$

In our model, x_i is the fraction of clients that visit P2P platform i. α_i is the intrinsic growth rate of P2P platform i without any competition, which measures the quality of contents and services of P2P platform. β_i is the maximum growth rate of P2P platform i. If there exists competition, $x_i x_j$ is the fraction of clients that visit P2P platforms i and j. $\gamma_{ij} x_i x_j$ is the fraction of clients that give up visiting P2P platform i and visit P2P platform j because of j, γ_{ij} is the competitive strength between P2P platforms i and j. k_{ij} is the cooperation strength between P2P platforms i and j, which measures the fraction of clients that P2P platform i obtains because of P2P platform j, namely implies the complement of P2P platforms. s_i denotes the cooperation strength between P2P platforms and other external agencies such as traditional banks, insurance companies, the third party payment institutions. Due to the characteristic of "rich gets richer", the clients of P2P platforms prefer to visit the stronger platforms, here $\omega_{ij}\left(x_j - x_i\right)$ denotes the effect of preferential choice, ω_{ij} is the influence degree. α_i, $\gamma_{ij} > 0$, $k_{ij} \geq 0, s_i \geq 0, 0 < \beta_i \leq 1, 0 < \omega_{ij} < \min\{1, \gamma_{ij}\}, j = 1,2,\ldots,n.$

4. Model Solving and Analysis

Before solving and analyzing system (5), we need to introduce two definitions [25] as follows.

Definition 1. In system (5), we regard a website as powerful if it has bigger fraction of customers at the initial time than other websites which are called small websites. Specially, we regard a website as monopoly, if it occupies the whole market and other websites tend to extinction.

Definition 2. In system (5), two websites are nip and tuck if they have the same natural growth rate, saturated growth rate, user preference, competitive and cooperative strength.

Adjust system (5) to the following form

$$dx_i/dt = x_i[\alpha_i\left(\beta_i - x_i\right) - \sum_{j\neq i,\, j=1}^{n} \gamma_{ij}\left(1+\omega_{ij}\left(x_j - x_i\right)\right)x_j + \sum_{j\neq i,\, j=1}^{n} k_{ij} x_j + s_i x_i] = x_i f_i\left(x\right), i = 1,2,\ldots,n. \quad (6)$$

Obviously, system (6) has isoclinic curved surfaces $x_i = 0$ and $f_i\left(x\right) = 0$. Because the singular point of system (6) are intersection points of isoclinic curved surfaces, the singular point in m dimension subspace of system(6) can be figured out from the equations $f_{i_r}\left(x\right) = 0, r = 1,2,\ldots,m$ and $x_{i_l} = 0$, $l = m+1, m+2,\ldots,n$. Below, we analyze these singular points.

1) If $m = 0$, then the coordinate origin is the singular point of system (6).

2) If $m \neq 0$, then

$$f_{i_r}\left(x\right) = \alpha_{i_r}\left(\beta_{i_r} - x_{i_r}\right) - \sum_{j\neq i_r,\, j=1}^{n} \gamma_{i_r j}\left(1+\omega_{i_r j}\left(x_j - x_{i_r}\right)\right)x_j + \sum_{j\neq i_r,\, j=1}^{n} k_{i_r j} x_j + s_{i_r} x_{i_r} = 0, r = 1,2,\ldots,m. \quad (7)$$

Owing to the complexity of equations (7), it is extremely difficult to solve their solutions. Without loss of generality, we only discuss the nip and tuck case in this paper. According to Definition 2, the corresponding parameters in equations (7) are equal. Assume

$$\alpha=\alpha_{i_r},\beta=\beta_{i_r},\omega=\omega_{i_r j},\gamma=\gamma_{i_r j},k=k_{i_r j},s=s_{i_r}, \tag{8}$$

$$\alpha^*=\alpha_{i_r}/\gamma_{i_r j},k^*=k_{i_r j}/\gamma_{i_r j},s^*=s_{i_r}/\gamma_{i_r j},r=1,\ldots,m. \tag{9}$$

where $\alpha^*>1$ reflects the weak competition between P2P platforms, and $0<\alpha^*<1$ strong competition. $k^*>1$ implies that the cooperation between P2P platforms holds dominant, and $0<k^*<1$ competition. $s^*>1$ shows that the cooperation strength between P2P platforms and traditional banks, insurance companies and so on is stronger than the competition strength between P2P platforms, and $0<s^*<1$ is the opposite case.

After alternation of (8) and (9), equations (7) can be converted into

$$\gamma\left[\alpha^*\beta-\left(\alpha^*-1+k^*-s^*\right)x_{i_r}+\left(\omega x_{i_r}-1+k^*\right)\sum_{j=1}^{n}x_j-\omega\sum_{j=1}^{n}x_j^2\right]=0,r=1,2,\ldots,m. \tag{10}$$

Because of $\sum_{j=1}^{n}x_j=\sum_{r=1}^{m}x_{i_r},\sum_{j=1}^{n}x_j^2=\sum_{r=1}^{m}x_{i_r}^2$, summing two ends of (10), we have

$$m\alpha^*\beta+\left[m\left(k^*-1\right)-\alpha^*-k^*+s^*+1\right]\sum_{r=1}^{m}x_{i_r}+\omega\left(\sum_{r=1}^{m}x_{i_r}\right)^2-m\omega\sum_{r=1}^{m}x_{i_r}^2=0, \tag{11}$$

That is,

$$\sum_{r=1}^{m}x_{i_r}^2=\left\{m\alpha^*\beta+\left[m\left(k^*-1\right)-\alpha^*-k^*+s^*+1\right]\sum_{r=1}^{m}x_{i_r}+\omega\left(\sum_{r=1}^{m}x_{i_r}\right)^2\right\}\Big/m\omega. \tag{12}$$

Substituting (12) into (10), we have

.

$$\left(\omega\sum_{r=1}^{m}x_{i_r}+1-\alpha^*-k^*+s^*\right)\left(x_{i_r}-\sum_{r=1}^{m}x_{i_r}\Big/m\right)=0. \tag{13}$$

Combine both (12) and (13), the solutions of equations (10) will satisfy

$$\begin{cases}\sum_{r=1}^{m}x_{i_r}=mx_{i_r}, \\ \sum_{r=1}^{m}x_{i_r}^2=\left\{\alpha^*\beta+\left[m\left(k^*-1\right)+\left(1-\alpha^*-k^*+s^*\right)\right]x_{i_r}+m\omega x_{i_r}^2\right\}\Big/\omega.\end{cases} \tag{14}$$

Or

$$\begin{cases} \sum_{r=1}^{m} x_{i_r} = \left(k^* + \alpha^* - s^* - 1\right) \big/ \omega, \\ \sum_{r=1}^{m} x_{i_r}^2 = \left[\alpha^* \beta\omega + \left(k^* - 1\right)\left(\alpha^* + k^* - s^* - 1\right)\right] \big/ \omega^2 . \end{cases} \tag{15}$$

To analyze the singular point of system (6), we should discuss the solutions of (14) and (15).

Case1. If the solutions of equation (10) are comprised of *m* equations of (14), then it follows from the first equation of (14) that $x_{i_1} = x_{i_2} = \ldots = x_{i_m}$.

Put it into the second equation of (14), we can obtain the following equilibrium point of system (6).

$$P_i^m : \begin{cases} x_{i_r} = \alpha^* \beta \big/ \left[\alpha^* - s^* + (1-m)\left(k^* - 1\right)\right] = \alpha\beta \big/ \left[\alpha - s + (1-m)(k-\gamma)\right] \\ x_{i_l} = 0 \end{cases}, r = 1, \ldots, m, l = m+1, \ldots, n. \tag{16}$$

Obviously, if k satisfies $0 \le k \le \gamma + \left[\alpha(1-\beta) - s\right] \big/ (m-1)$, then the equilibrium point P_i^m will be meaningful ($0 \le x_{i_r} \le 1$). Notice that

$$\left(x_{i_r}\right)_k' = \left[\alpha\beta(m-1)\right] \big/ \left[(\alpha - s) + (1-m)(k-\gamma)\right]^2 \ge 0, \left(x_{i_r}\right)_s' = \alpha\beta \big/ \left[(\alpha - s) + (1-m)(k-\gamma)\right]^2 \ge 0 .$$

That is, x_{i_r} is a monotonic increasing function with regard to k and s, which implies that the market share of P2P platforms will be risen with the deepening of cooperation no matter how much the natural growth rate α, the saturated growth rate β and the competition strength γ are. Actually, it also confirms the fact that cooperation will help P2P platforms achieve mutual benefit and win-win.

Case2. If the solutions of equation (10) are composed of $P(0 < P < m)$ equations of (14) and $(m-P)$ equations of (15), then it follows from the first equation of (14) and (15) that

$$x_{i_r} = \left(\alpha^* + k^* - s^* - 1\right) \big/ m\omega, r = 1, 2, \ldots, m. \tag{17}$$

Substituting (17) into the second equation of (14),

$$\sum_{r=1}^{m} x_{i_r}^2 = \left[\alpha^* \beta\omega + \left(k^* - 1\right)\left(\alpha^* + k^* - s^* - 1\right)\right] \big/ \omega^2 . \tag{18}$$

Obviously, (18) is the second equation of (15). Namely, Case 2 is the special circumstance of Case 3. This is not discussed here.

Case3. If the solutions of equation (10) are composed of *m* equations of (15), then we need to consider the nonnegative solutions of (15).

Set

$$\sum_{r=1}^{m} x_{i_r} = \left(k^* + \alpha^* - s^* - 1\right) \big/ \omega = M, \tag{19}$$

$$\sum_{r=1}^{m} x_{i_r}^2 = \left[\alpha^* \beta\omega + \left(\alpha^* - s^*\right)\left(k^* - 1\right) + \left(k^* - 1\right)^2\right] \big/ \omega^2 = N. \tag{20}$$

Clearly, if $M \geq 0, N \geq 0$, then $k^* \geq 1 + s^* - \alpha^*$. (Here, $\alpha^* \leq s^* \leq \alpha^* + 2\sqrt{\alpha^* \beta\omega}$) or $k^* > 1 + \left[\left(s^* - \alpha^*\right) + \sqrt{\left(\alpha^* - s^*\right)^2 - 4\alpha^* \beta\omega}\right] \big/ 2$ (Here, $\alpha^* - 2\sqrt{\alpha^* \beta\omega} \leq s^* \leq \alpha^*$) or. $1 + s^* - \alpha^* \leq k^* < 1 + \left[\left(s^* - \alpha^*\right) - \sqrt{\left(\alpha^* - s^*\right)^2 - 4\alpha^* \beta\omega}\right] \big/ 2$. This is the first condition of (15) having non-negative solutions.

Because $x_{i_r} \geq 0$, $M^2 / m \leq N \leq M^2$.

1) If $N \leq M^2$, then $k^* \geq 1 + s^* - \alpha^* + \alpha^* \beta\omega \big/ \left(\alpha^* - s^*\right)$ (Here, $\alpha^* \geq s^*$) or $k^* \leq 1 + s^* - \alpha^* + \alpha^* \beta\omega \big/ \left(\alpha^* - s^*\right)$ (Here, $\alpha^* < s^*$). This is the second condition of (15) having non-negative solutions.

2) If $N \geq M^2 / m$, then $k^* \in R^+$ (Here, $\alpha^* - 2\sqrt{\left(1 - \frac{1}{m}\right)\alpha^* \beta\omega} \leq s^* \leq \alpha^* + 2\sqrt{\left(1 - \frac{1}{m}\right)\alpha^* \beta\omega}$) or $k^* > 1 + \left[(2 - m)\left(\alpha^* - s^*\right) + \sqrt{m^2\left(\alpha^* - s^*\right)^2 - 4m(m - 1)\alpha^* \beta\omega}\right] \big/ 2(m - 1)$ or $k^* < 1 + \left[(2 - m)\left(\alpha^* - s^*\right) - \sqrt{m^2\left(\alpha^* - s^*\right)^2 - 4m(m - 1)\alpha^* \beta\omega}\right] \big/ 2(m - 1)$ (Here, $s^* > \alpha^* + 2\sqrt{\left(1 - \frac{1}{m}\right)\alpha^* \beta\omega}$ or $s^* < \alpha^* - 2\sqrt{\left(1 - \frac{1}{m}\right)\alpha^* \beta\omega}$). This is the third condition of (15) having non-negative solutions.

In short, if three non-negative conditions above are satisfied, then the equations (15) have nonnegative solutions. By further calculation, we know that the equations (15) have nonnegative solutions if and only if the following lemma is satisfied.

Lemma1. When the cooperation strength k and s satisfy

$$\gamma + s - \alpha + \alpha\beta\gamma\omega / (\alpha - s) \leq k < \gamma + \left[(s - \alpha) - \sqrt{(\alpha - s)^2 - 4\alpha\beta\gamma\omega}\right] \big/ 2$$

or

$$k > \gamma + \left[(s - \alpha) - \sqrt{(\alpha - s)^2 - 4\alpha\beta\gamma\omega}\right] \big/ 2, \ \alpha - 2\sqrt{\left(1 - \frac{1}{m}\right)\alpha\beta\gamma\omega} \leq s \leq \alpha.$$

or

$$\begin{cases} \gamma+s-\alpha+\alpha\beta\gamma\omega/(\alpha-s)\le k<\gamma+\left[(s-\alpha)-\sqrt{(\alpha-s)^2-4\alpha\beta\gamma\omega}\right]\Big/2 \text{ or } k>\gamma+\left[(s-\alpha)-\sqrt{(\alpha-s)^2-4\alpha\beta\gamma\omega}\right]\Big/2, \\ k>\gamma+\left[(m-2)(s-\alpha)-\sqrt{m^2(\alpha-s)^2-4m(m-1)\alpha\beta\gamma\omega}\right]\Big/2. \end{cases}$$

$$\alpha-2\sqrt{\alpha\beta\gamma\omega}\le s\le\alpha-2\sqrt{\left(1-\frac{1}{m}\right)\alpha\beta\gamma\omega}.$$

then there exists a singular curve in m-dimensional subspace, that is, all solutions x^* satisfying (15) are the equilibrium points of system (6).

For the stability of equilibrium points of system (6), we have

Theorem1. 1) For all $k\in R^+$ and $s\in R^+$, the equilibrium point $P_0: x_i=0, i=1,2,\ldots,n$ is unstable.

2) If $0\le s\le\alpha(1-\beta)$ and $0\le k<\gamma-\alpha+s+\alpha\beta\gamma\omega/(\alpha-s)$, then the equilibrium point $P_i: x_i=\alpha\beta/(\alpha-s), x_j=0, j\ne i$ is stable; If $0\le s\le\alpha(1-\beta)$ and $k>\gamma-\alpha+s+\alpha\beta\gamma\omega/(\alpha-s)$, then it is unstable.

3) If $0\le s<\alpha-2\sqrt{\left(1-\frac{1}{m}\right)\alpha\beta\gamma\omega}$ or $s>\alpha+2\sqrt{\left(1-\frac{1}{m}\right)\alpha\beta\gamma\omega}$ and

$$\left\{k \,|\, 0\le k\le\gamma+\frac{\alpha(1-\beta)-s}{m-1}, \gamma+\frac{(2-m)(\alpha-s)-\sqrt{\Delta}}{2(m-1)}<k<\gamma+\frac{(2-m)(\alpha-s)+\sqrt{\Delta}}{2(m-1)}\right\}\ne\varnothing$$

then the equilibrium point of system (6) $P_i^m: x_{i_r}=\alpha\beta/\left[\alpha-s+(1-m)(k-\gamma)\right], x_{i_l}=0\,(r=1,\ldots,m, l=m+1,\ldots,n)$ exists in m-dimensional subspace and is stable. However, it is unstable in (n-m) dimensions subspace, where $\Delta=m^2(\alpha-s)^2-4m(m-1)\alpha\beta\gamma\omega$.

Proof. Consider the nonlinear of system (6), we employ the Lyapunov's first method in stability theory to recognize the stability of its equilibrium points. Namely, by judging the sign of real part of eigenvalues of Jacobian matrix in system (6), we can determine the stability of equilibrium points, like the following.

1) The system (6) has eigenvalues $\alpha\beta>0$ at equilibrium point $P_0: x_i=0, i=1,2,\ldots,n$. So, for all cooperation strength $k\in R^+$ and $s\in R^+$, $P_0: x_i=0, i=1,2,\ldots,n$ is unstable.

2) The system (6) at each equilibrium point $P_i: x_i=\alpha\beta/(\alpha-s), x_j=0, j\ne i$ has eigenvalues

$$\lambda_i=-\alpha\beta<0,$$

$$\lambda_j=\alpha\beta+\frac{\alpha\beta(k-\gamma)}{\alpha-s}-\gamma\omega\left(\frac{\alpha\beta}{\alpha-s}\right)^2, j\ne i.$$

Obviously, when $0\le s\le\alpha(1-\beta)$ and $0\le k<\gamma-\alpha+s+\alpha\beta\gamma\omega/(\alpha-s)$, $\lambda_j<0$. That is, the equilibrium point $P_i: x_i=\alpha\beta/(\alpha-s), x_j=0, j\ne i$ exists and is stable. In contrast, if

$0 \le s \le \alpha(1-\beta)$ and $k > \gamma - \alpha + s + \alpha\beta\gamma\omega/(\alpha - s)$, then the equilibrium point P_i is unstable.

3) The system (6) at each equilibrium point $P_i^m : x_{i_r} = \alpha\beta/[\alpha - s + (1-m)(k-\gamma)], x_{i_l} = 0$ $(r = 1,\dots,m, l = m+1,\dots,n)$ has eigenvalues

$$\lambda_{i_1} = -\alpha\beta < 0,$$
$$\lambda_{i_r} = \frac{\alpha\beta}{[\alpha - s + (1-m)(k-\gamma)]^2} + \left\{-[\alpha - s + (1-m)(k-\gamma)]^2 - m(k-\gamma)[\alpha - s + (1-m)(k-\gamma)] + m\alpha\beta\gamma\omega\right\},$$
$$\lambda_{i_l} = \frac{\alpha\beta}{[\alpha - s + (1-m)(k-\gamma)]^2} + \left\{[\alpha - s + (1-m)(k-\gamma)]^2 + m(k-\gamma)[\alpha - s + (1-m)(k-\gamma)] - m\alpha\beta\gamma\omega\right\}$$
$$= -\lambda_{i_r}, r = 2,3,\dots,m, l = m+1, m+2,\dots,n.$$

Through the computation, we know that if $0 \le s < \alpha - 2\sqrt{\left(1-\frac{1}{m}\right)\alpha\beta\gamma\omega}$ or $s > \alpha + 2\sqrt{\left(1-\frac{1}{m}\right)\alpha\beta\gamma\omega}$ and $\gamma + \frac{(2-m)(\alpha-s) - \sqrt{\Delta}}{2(m-1)} < k < \gamma + \frac{(2-m)(\alpha-s) + \sqrt{\Delta}}{2(m-1)}$ (Here, $\Delta = m^2(\alpha-s)^2 - 4m(m-1)\alpha\beta\gamma\omega$), then $\lambda_{i_r} < 0, \lambda_{i_l} > 0$. Combine these with the existence condition of $P_i^m \left(0 \le k \le \gamma + \frac{\alpha(1-\beta) - s}{m-1}\right)$, the equilibrium point P_i^m exists in m-dimensional subspace and is stable if and only if the cooperative strength satisfies

$$0 \le s < \alpha - 2\sqrt{\left(1-\frac{1}{m}\right)\alpha\beta\gamma\omega} \ \ or \ \ s > \alpha + 2\sqrt{\left(1-\frac{1}{m}\right)\alpha\beta\gamma\omega}$$

and $\left\{k \mid 0 \le k \le \gamma + \frac{\alpha(1-\beta) - s}{m-1}, \gamma + \frac{(2-m)(\alpha-s) - \sqrt{\Delta}}{2(m-1)} < k < \gamma + \frac{(2-m)(\alpha-s) + \sqrt{\Delta}}{2(m-1)}\right\} \ne \varnothing$.

From Theorem 1, we know that the adjustment for cooperation strength may change the local distribution of China's online lending industry. For P2P platforms with similar strength, if natural growth rate α, saturated growth rate β, competitive strength γ, user preference degree ω are known, the cooperative strength s between P2P platforms and traditional banks, insurance companies, the third party payment institutions satisfies $0 \le s \le \alpha(1-\beta)$, and the cooperation degree k among P2P platforms fulfils $0 \le k < \gamma - \alpha + s + \alpha\beta\gamma\omega/(\alpha - s)$, then the phenomenon of `winner-take-all' will appear. At this time, the initial stronger P2P platforms may occupy the whole market, and other initial weaker P2P platforms will tend to close down (see Fig. 1). Therefore, to obtain future competitive advantage, P2P platforms should enhance the cooperation with other P2P platforms and external institutions. Meanwhile, they should enhance the initial strength by advertising, technical improvement , differential operation, and so on. Once the cooperation strength s and k satisfy $0 \le s < \alpha - 2\sqrt{\left(1-\frac{1}{m}\right)\alpha\beta\gamma\omega}$ or $s > \alpha + 2\sqrt{\left(1-\frac{1}{m}\right)\alpha\beta\gamma\omega}$,

$$\left\{k \mid 0 \le k \le \gamma + \frac{\alpha(1-\beta)-s}{m-1}, \gamma + \frac{(2-m)(\alpha-s)-\sqrt{\Delta}}{2(m-1)} < k < \gamma + \frac{(2-m)(\alpha-s)+\sqrt{\Delta}}{2(m-1)}\right\} \neq \varnothing$$

(Here, $\Delta = m^2(\alpha-s)^2 - 4m(m-1)\alpha\beta\gamma\omega$), all P2P platforms will share the same customer rate no matter what their initial strength is (see Fig. 2). In other words, the small P2P platforms can narrow the gap with the powerful P2P platforms by adjusting their cooperation strength reasonably. Actually, from Theorem 1, we also find that the cooperation strength k between P2P platforms is related with the cooperation strength s. The conclusion seems to imply that P2P platforms may prioritize to cooperate with other external institutions like traditional banks, insurance companies, etc.

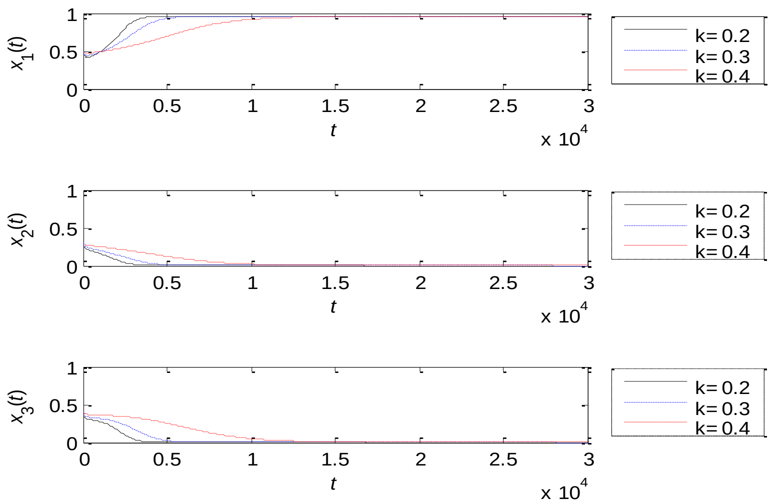

Fig. 1. Phase portrait of system (6), where $n = m = 3, k = 0.2, 0.3, 0.4, \alpha = 0.8, \beta = 0.9, \gamma = 1, \omega = 0.2,$ $s = 0.05$, the initial fraction that clients visit P2P platforms are $\left(x_1^0, x_2^0, x_3^0\right) = (0.5, 0.3, 0.4)$.

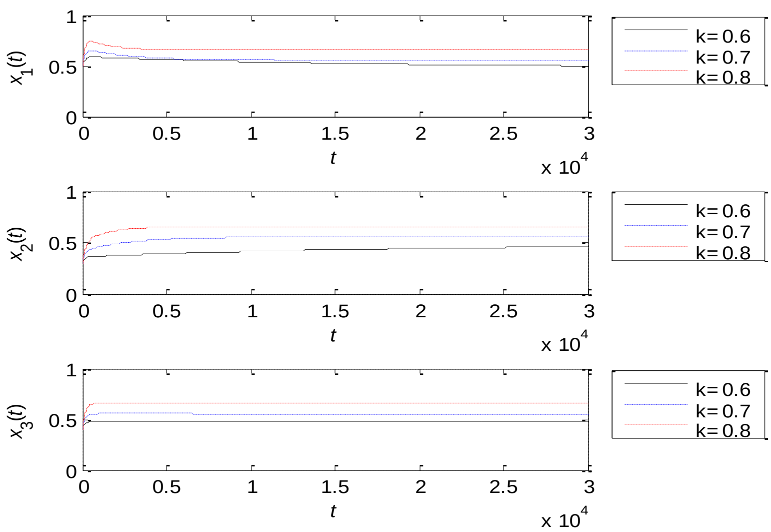

Fig. 2. Phase portrait of system (6), where $n = m = 3, k = 0.6, 0.7, 0.8, \alpha = 0.8, \beta = 0.9, \gamma = 1, \omega = 0.2$ $s = 0.1$, the initial fraction that clients visit P2P platforms are $\left(x_1^0, x_2^0, x_3^0\right) = (0.5, 0.3, 0.4)$.

5. Conclusion and Discussion

This paper studies the competition and cooperation in China's online lending industry. By analyzing the existence and stability of equilibrium solutions of a coopetition dynamics model, we obtain the following conclusions. On the one hand, the initial stronger P2P platform may occupy the whole online lending market in the future by adjusting the cooperation strength properly. On the other hand, the small and medium-sized P2P platforms can also narrow the gap with the powerful P2P platform by cooperating with other platforms or institutions. To provide China's P2P platforms with scientific guidance, we put forward the following suggestions:

(1) Comply with monitoring rules strictly, make legal operation, and do not touch the bottom line of law. Accelerate transformation and upgrading, back to the nature of information intermediary, small dispersion and inclusive finance. With the introduction of several regulatory filings, the online lending industry entered the industry reshuffle stage. Any P2P platforms which violate the monitoring rules or law will be banned or be eliminated. To ensure survival, it is essential for P2P platforms to operate lawfully.

(2) As described in conclusion, the powerful P2P platforms may occupy the local online lending marketplace by improving the initial strength and coordinating the cooperation intensity reasonably. For this purpose, P2P platform should increase investment in advertising, integrate the resource of assets, technology and talent advantage, improve user service level, enhance risk control ability, raise research and development capability, and promote self competition power. On the other hand, we know when the cooperation strength s and k are controlled in terms of Theorem 1(3), the small and medium-sized P2P platforms can narrow the gap with the powerful P2P platforms. Even they can enjoy the same market share in the future. So, it is extremely necessary for certain small and medium-sized P2P platforms to enhance the cooperation with commercial banks, insurance company, small loan company and other P2P platforms. They can enhance the cooperation with commercial banks in capital depository, explore the potential collaboration with insurance company and small loan company in transaction fund security and business, and strengthen the cooperation with other P2P platforms in data resource sharing.

Actually, as a complement to previous studies [20] and [22]-[25], this paper expands the research field of commercial websites and enriches the coopetition theory. To a certain extent, the results provide P2P operators with certain valuable theoretical guidance. However, which is yet unsatisfying is that there are some defects in this paper, such as strict parameter assumption and limited impact factor in obtained model. To further this line of research, other growth models fitting for China's online lending environment are worth studying.

Acknowledgment

This work was sponsored by Huaqiao University's Academic Project supported by the Fundamental Research Funds for the Central Universities (Grant No.14SKGC-QG17), Huaqiao University's High Level Talent Research Start-up Funding Project (Grant No.14SKBS205), the Natural Science Foundation of Fujian Province (Grant No.2015J01581), the National Natural Science Fund of China (Grant No.71672023).

References

[1] Puro, L, Teich, J. E, Wallenius, H., & Wallenius, J. (2010). Borrower decision aid for people-to-people lending. *Decision Support Systems*, *49*, 52-60.

[2] Wu, J., & Xu, Y. (2011). A decision support system for borrower's loan in P2P lending. *Journal of Computers*, *6*, 1183-1190

[3] Herzenstein, M., Andrews, R. L., Dholakia, U. M., & Lyandres, E. (2008). The democratization of personal consumer loans? Determinants of success in online peer-to-peer lending communities. *Bulletin of the University of Delaware*, *15*, 274-277.

[4] Ryan, J., Reuk, K., & Wang, C. (2007). *To Fund Or Not To Fund: Determinants of Loan Fundability in the Prosper. Com Marketplace* (Woking paper). The Standord Graduate School of Business.

[5] Garman, S., Hampshire, R., & Krishnan, R. (2008, June). A search theoretic model of person-to-person lending. Retrieved from the website: http://researchgate.net/publication/255596288

[6] Ceyhan, S., Shi, X., & Leskovec, J. (2011). Dynamics of bidding in a P2P lending service: Effects of herding and predicting loan success. *Proceedings of International Conference on World Wide Web* (pp. 547-556). ACM.

[7] Lee, E., & Lee, B. (2012). Herding behavior in online p2p lending: an empirical investigation. *Electronic Commerce Research & Applications*, *11(5)*, 495-503.

[8] Krumme, K. A., & Herrero, S. (2009). Lending behavior and community structure in an online peer-to-peer economic network. *Proceedings of International Conference on Computational Science and Engineering Vol. 4.* (pp. 613-618). IEEE Computer Society.

[9] Herzenstein, M., Dholakia, U. M., & Andrews, R. L. (2011). Strategic herding behavior in peer-to-peer loan auctions. *Journal of Interactive Marketing, 25(1)*, 27-36.

[10] Wang, H., & Greiner, M. E. (2010). Herding in multi-winner auctions. *Proceedings of International Conference on Information Systems* (p. 235). Saint Louis, Missouri, Usa.

[11] Puro, L., Teich, J. E., Wallenius, H., & Wallenius, J. (2011). Bidding strategies for real-life small loan auctions. *Decision Support Systems*, *51(1)*, 31-41.

[12] Guo, Y., Zhou, W., Luo, C., Liu, C., & Xiong, H. (2015). Instance-based credit risk assessment for investment decisions in p2p lending. *European Journal of Operational Research*, *249(2)*, 417-426.

[13] Luo, C. (2012). Investment decision models in P2P lending. PHD dissertation, University of Technology, Dalian.

[14] Berkovich, E. (2011). Search and herding effects in peer-to-peer lending: evidence from propser.com. *Annals of Finance*, *7(3)*, 389-405.

[15] Jin, G. Z. (2008). Do social networks solve information problems for peer-to-peer lending? *Seth Freedman*, 8-43.

[16] Seth, F., Ginger, Z. J. (2011). Learning by doing with asymmetric information: evidence from prosper.com. *Nber Working Papers*, 203-212.

[17] Lin, M., Prabhala, N. R., & Viswanathan, S. (2013). Judging borrowers by the company they keep: Friendship networks and information asymmetry in online peer-to-peer lending. *Management Science, 59*, 17-35.

[18] Maurer, S. M., & Huberman, B. A. (2003). Competitive dynamics of web sites. *Journal of Economic Dynamics & Control, 27(11–12)*, 2195-2206.

[19] López, L., & Sanjuán, M. A. F. (2001). Defining strategies to win in the internet market. *Physica A Statistical Mechanics and Its Applications, 301(1)*, 512-534.

[20] Wang, Y., & Wu, H. (2004). Dynamics of a cooperation–competition model for the www market. *Physica A Statistical Mechanics and Its Applications, 339(3–4)*, 609-620.

[21] Jiang, J., Cheng, Z., Dawson, K. A., Indekeu, J. O., Stanley, H. E., & Tsallis, C. (2006). The complete strategic classification for a cooperation–competition model in the www market. *Physica A Statistical Mechanics and Its Applications, 363(2)*, 527-536.

[22] Li, Y., & Zhu, S. (2003). Analysis of a type of competition model of e-commerce sites. *Acta Scientiarum Naturalium Universitatis Sunyatseni, 5(5)*, 6-10.

[23] Li, Y., & Zhu, S. (2006). Qualitative analysis of n-dimensional competitive systems. *Nonlinear Analysis Real World Applications, 7(4)*, 700-719.

[24] Li, Y., & Zhu, S. (2007). Competitive dynamics of e-commerce web sites. *Applied Mathematical Modelling,*

31(5), 912-919.
[25] Wan, X, & Deng, G. (2015). Analysis on competitive strategy of peer-to-peer online lending platforms. *Journal of Systems Engineering, 30*, 650-658.

Xiaoji Wan is a lecturer of College of Business Adminstration, Huaqiao University, Quanzhou, Fujian, China. His eduational background: 2002-2006 the bachelor of science degree at Yunnan Normal University, Kunming, China; 2006-2009 the master of science degree at Kunming University of Technology, Kunming, China; 2009-2013 the doctor of engineering degree at Dalian Univerity of Technology, Dalian, China. From 2014 until now, he works as lecturer at College of Business Adminstration, Huaqiao University.

Liping Zhang is a PhD candidate of College of Business Adminstration, Huaqiao University, Quanzhou, Fujian, China. Her eduational background: 2003-2007 the bachelor of Arts at Jiangxi Normal University, Nanchang, Jiangxi, China; 2007-2010 the master of Pedagogy at Southwest University, Chongqing, China.

Zhiguo Zhu is an associate professor of School of Management Science and Engineering, Dongbei University of Finance and Economics, Dalian, Liaoning, China. His eduational background: 1995-1999 the bachelor of engineering degree at Dalian University of Technology, Dalian, China; 1999-2002 the master of engineering degree at Dalian University of Technology, Dalian, China; 2006-2010 the doctor of engineering degree at Dalian Univerity of Technology, Dalian, China. From 2009 until now, he works as associate professor at School of Management Science and Engineering, Dongbei University of Finance and Economics.