Modelling online Peer to Peer (P2P) Lending Network: Based on Supernetworks Theory

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Abstract
In this paper, we designed online P2P lending networks that consist of borrowers, P2P lending platforms, and lenders. As the online crowdfunding are prosperous in China, the competition among those platforms, lenders, and even borrowers are becoming more and more intense. In this paper's model, we discussed the network structure of P2P lending market, the cost structure, the lending demand function of the players. We also used numerical experiment to discuss the profit vs interest elasticity parameter t for borrowers and P2P lending platforms, and the outcomes show when borrower makes decision to high-interest loan, she (he) might not get high returns because the existence of some un-observed risks.
Keywords: P2P LENDING, VARIATIONAL INEQUALITIES, FINANCIAL MARKET, SUPERNETWORKS, FINANCIAL RISKS

1. Introduction

Peer to peer (person to person, P2P) lending is becoming a more and more prosperous market in many countries. In Britain, the loan volumes are doubling every six months and passed 1.7 billion US dollars in this lending market, and in US, the two P2P lending platform leaders, lending club and Prosper.com, which have 98% of P2P lending market in US, issued \$2.4 billion in loans in 2013, up from \$871 million in 2012 (Economist 2014). In China, the growth rate of P2P lending market is 117%, and a market of staggering 68 billion RMB yuan (about 11 billion US dollars) (iResearch 2014). Lu et al (2014) discussed the effects of shadow bank in China, the how to control and monitor these shadow bans. Acting as a type of shadow banks, Online P2P platforms are becoming the most important key point for related administration. Also, these P2P lending platforms provide opportunities for borrowers to satisfy their lending demand more easily and conveniently, and on the other hand, let lenders have more choices to invest their money and thus get higher investment rates compared to conventional investment channels.

Chen et al (2014)] first analyze the Prosper auction as a game of complete information and fully characterize its Nash equilibria, and then compare the uniform-price Prosper mechanism the VCG mechanism and the borrower-optimal auction respectively, and provide tight bounds on the price for a general class of bidding strategies. Chen et al (2013) described an approach to measure the entrepreneurship orientation of online P2P lending platforms, and provided an improved way to assess the entropy of interval-valued intuitionistic fuzzy sets in this lending market. In trust and credit of P2P lending network, Duarte et al (2012) found that borrowers who appear more trustworthy have higher probabilities of having their loans funded by using photographs of potential borrowers from a peer-to-peer lending site; comparing different conditions of borrowers' social networks, Lu et al (2012) assessed social influence on borrowers' default decisions in a peer-to-peer lending market; Lin et al (2013) found that relational aspects are consistently significant predictors of lending outcomes, with a striking gradation based on the verifiability and visibility of a borrower's social capital; Freedman et al (2008) found evidence both for and against the argument that social networks may identify good risks either because friends and colleagues observe the intrinsic type of borrowers ex ante or because the monitoring within social networks provides a stronger incentive to pay off loans ex post. Michels (2012) showed that unverifiable disclosures can affect the trade of peer-to-peer lending to a certain extend. Berger et al (2009) find that online P2P platforms significantly improve borrowers' credit conditions by reducing information asymmetries.

In traditional social lending, Cassar et al (2010) also found that societal trust positively and significantly influences group loan contribution rates, that group lending appears to create as well as harness social capital, and that peer monitoring can have perverse as well as beneficial effects; Li et al (2012) quantified the importance of endogenous peer effects in group lending programs by estimating a static game of incomplete information.

From the view of behaviors of social networks, Zhang et al (2012) used a unique panel data set that tracks the funding dynamics of borrower listings on Prosper.com, and then found evidence of rational herding among lenders; Luo et al (2011) revealed that lenders are more likely to herd on listings with more friend bids which impose significant effects on the decision-making time of investors, but their benefit will be reduced as the consequence of the behavior; Berkovich(2011) also studied herding effects in peer-to-peer lending, and found that high-priced loans provide excess returns even after accounting for risk-aversion; Shen et al (2010) concluded that lenders on Prosper did not make rational investment decisions based on risk and returns.

All the research mentioned above, provides many different dimensions in the new academic topic, and the previous studies make the research of P2P lending network to a level that scholars can have broad and deep insights to make more academic contributions to the new but meaningful topic. However, these studies did not consider the complexity of hierarchy structure of a P2P lending network.

Inspired by the systematic research from Nagurney (2002), and Qiang et al (2013) constructed financial networks with socially responsible investing to derive the equilibrium of all decision-makers in such networks, and recently Nagurney (2014) constructed a multiproduct network economic model of cybercrime in financial service based on variational equality and also found the equilibrium in the financial networks, we hope to construct a P2P lending network based on the application of variational equalities, which can provide more academic contributions to the new but meaningful topic.

2. Model Construction

2.1. P2P Structure of Supernetworks

A conceptive online peer to peer lending model, which consists of borrowers , P2P platforms and lenders, is consctructed as follows. In this network, lenders decide to choose a platform to pronounce their demand, and the borrowers decide to choose a certain lender in a certain P2P lending platform to invest their capitals with comprehensive consideration of risks and profits. The structure of online three-tier P2P lending network is depicted in Figure 1.

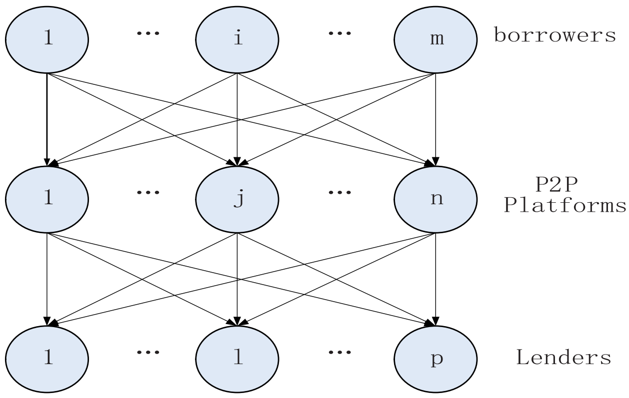

Figure 1. The structure of online three-tier P2P lending network

In this figure, the borrowers decide to choose a P2P platform to announce their lending demand and their expected borrowing interests, since the possibility of dealing with lenders in a certain P2P platforms is not high, it is a rational choice for the borrowers to announce their borrowing demand in more than one platform. The P2P platforms price the borrowers' interests associated with the borrowers' credit conditions and characteristics of the loans, and most P2P platforms have their special assessing systems to compute such interests. The lenders choose to lend their money to borrowers based on combined conditions including lenders' risk preference and the platforms' service level. It is obvious to see that borrowers have to compete with each other on different platforms since the lending demand is limited and the borrowers have different credit conditions and borrowing demand. The P2P platforms, however, compete with each other more fiercely, since they have to attract both borrowers and lenders, and finally facilitate transactions in order to get commission fees from those deals. In this paper, we suppose that all platforms have constant assessing systems to price the borrowers' interests in a certain time period, so lenders can make their decisions based on the platforms history deals data. Now we discuss the basic online P2P lending network.

2.2. P2P Model Based on Variational Inequalities

2.2.1. Function description of three types of decision-makers based on variational inequalities

There are three different types of decision-makers in the network, we describe each type starting from the top tier down.

The behavior of the borrowers and their optimality conditions

The loans demand offered by borrowers i are denoted as d_i. The aggregation of all borrowers' demand is the vector $d \in R_+^m$. Each borrower's lending cost is denoted as f_i, which is dependent on the vector of demand; that is

$$f_i = f_i(d) \tag{1}$$

The lending cost of borrowers depends not only on the borrower's own lending cost, but also on the other borrowers' lending cost, which causes competition among those borrowers.

We denote the interest between the borrowers and the P2P platforms as d_{ij}^1. There must be a flow conservation: $d_i = \sum_j d_{ij}^1$. We group the interest between the borrowers and platforms into column vector $D_1 \in R_+^{mn}$.

Borrowers advertise their demand for loans at an interest i_{ij}^1. The transactions between the borrowers and P2P platforms incur a cost $c_{ij}^1(d_{ij}^1)$ the depends on the volume of transactions between each pair.

So each borrower has its profits-maximizing objective:

$$\text{maximize } z_i = \sum_j i_{1ij}^* d_{ij}^1 - f_i(D_1) - \sum_j c_{ij}(d_{ij}^1) \tag{2}$$

We assume that the lending cost and transaction costs are continuous and convex. Meanwhile, lenders are assumed to compete with each other in a noncooperative manner. There exists a Nash equilibrium among borrowers, which means that, given other borrowers' optimal loan quantities and interests, each lender would not change its own loan quantities and interests because he would be worse off otherwise.

Under these assumptions, the optimality conditions for lender i can be expressed as follows (see Bertsekas and Tsitsiklis 1989, Bazaraa et al. 1993):

$$\sum_j \left\{ \left[\frac{\partial f_i(D_1^*)}{\partial d_{ij}^1} + \frac{\partial c_{ij}(d_{ij}^{1*})}{\partial d_{ij}^1} - i_{1ij}^* \right] \left(d_{ij}^1 - d_{ij}^{1*} \right) \right\} \geq 0, \quad \forall D_1 \in R_+^{mn} \tag{3}$$

Therefore, we can find out the optimality conditions for all lenders simultaneously as the variational inequality (see Nagurney 1999): determine $D_1^* \in R_+^{mn}$ such that

$$\sum_i \sum_j \left\{ \left[\frac{\partial f_i(D_1^*)}{\partial d_{ij}^1} + \frac{\partial c_{ij}(d_{ij}^{1*})}{\partial d_{ij}^1} - i_{1ij}^* \right] \left(d_{ij}^1 - d_{ij}^{1*} \right) \right\} \geq 0, \quad \forall D_1 \in R_+^{mn} \tag{4}$$

2.2.2. The behavior of the P2P platforms and their optimality conditions

The P2P platforms, as the intermediate players in the online P2P lending network, provide platforms for the lenders to announce their loans demand and give the borrowers opportunity to find high investment return rates compared to traditional investment channels. Once the online lending transactions have been processed, the lenders can get the loans from the borrowers through the P2P platforms, or in some special circumstances discussed above, the lenders can get the loans from the borrowers directly.

Assume P2P platform player j promote lending transactions of d_{jl}^2 units loans at lending market l through the platforms' service. Group d_{jl}^2 into vector D_2 where $D_2 \in R_+^{np}$.

Obviously a P2P platform company has a handling cost denoted as c_j, which consists of website operation, marketing costs, information technology costs and so on. It can be expressed as a function of the total loans quantity that the platform company j can obtain from its upstream customers –the borrowers:

$$c_j = c_j(D_1) \tag{5}$$

Each P2P platform player also has a transaction cost with the borrowers denoted as $\hat{c}_{ij}(d_{ij}^1)$. Considering the credit rating and risks of the borrower, the P2P platform sets the interest i_{2j}. We assume that the price offered by one P2P platform is equal across all the lenders at various demand market.

Each P2P platform player has its profits-maximizing objective

$$\text{maximize } z_j = i_{2j}^* \sum_l d_{jl}^2 - c_j(D_1) - \sum_i \hat{c}_{ij}(d_{ij}^1) - \sum_i i_{1ij}^* d_{ij}^1 \tag{6}$$

Subject to the flow conservation constraint:

$$\sum_l d_{jl}^2 \leq \sum_i d_{ij}^1 \tag{7}$$

We also assume that the handling costs and transaction costs of every P2P platform are continuous and convex. Meanwhile, we can assume that P2P platforms compete with each other in a non-cooperative way to maximize their own profits given the other P2P platforms' decisions. According to all those assumptions above, we can get that the optimality conditions for the P2P platforms non-cooperative game can be described in the following variational inequality: determine $D_1^* \in R_+^{mn}, D_2^* \in R_+^{np}, r_2^* \in R_+^n$ such that:

$$\sum_i \sum_j \left\{\left[\frac{\partial f_i(D_1^*)}{\partial d_{ij}^1} + \frac{\partial c_{ij}(d_{ij}^{1*})}{\partial d_{ij}^1} - i_{1ij}^*\right]\left(d_{ij}^1 - d_{ij}^{1*}\right)\right\} + \sum_j \sum_l \left\{\left[r_{2j}^* - i_{2j}^*\right]\left(d_{jl}^2 - d_{jl}^{2*}\right)\right\} + \sum_j \left\{\left[\sum_i d_{ij}^{1*} - \sum_l d_{jl}^{2*}\right]\left(r_{2j} - r_{2j}^*\right)\right\} \geq 0, \ \forall D_1 \in R_+^{mn}, D_2^* \in R_+^{np}, r_2^* \in R_+^n \tag{8}$$

With the Lagrange multiplier r_{2j} associated with flow constraints for the P2P platform player *j*, and $r_{2j} = (r_{2j})_n$.

Now we represent the behavior of the lenders at different lending markets. The lenders make their lending decision based on the perceived generalized interest which includes risk costs, opportunity cost and service quality costs. We assume that lenders have a homogeneous perception of these costs.

We denote the lender's perceived generalized interest as i_{3l}, and the lending demand is a increasing and continuous function of the general interest:

$$\bar{ld}_l = \bar{ld}_l(i_{3l}) \tag{9}$$

Where the interest i_{3l} is a p-dimensional column vector of the lender's perceived interest.

Let $\bar{c}_{jl}$ denote the transaction cost between lenders and P2P platforms, which mainly includes the lenders' registering fee and commission costs. We assume that $\bar{c}_{jl}$ is a function of transaction volume D_2 and could thus be written as $\bar{c}_{jl}(D_2)$.

The equilibrium conditions for lenders at market *l* are as follows.

$$i_{2j}^* + \bar{c}_{jl}(D_2^*) \begin{cases} = i_{3l}^* & \text{if } d_{jl}^* > 0 \\ \leq i_{3l}^* & \text{if } d_{jl}^* = 0 \end{cases} \tag{10}$$

Meanwhile, the equilibrium lending demand quantity at the lending market must satisfy:

$$\bar{ld}_l(i_{3l}) \begin{cases} = \sum_j d_{jl}^{2*} & if \ i_{3l}^* > 0 \\ \geq \sum_j d_{jl}^{2*} & if \ i_{3l}^* = 0 \end{cases} \tag{11}$$

The equilibrium conditions can be described in economic way as follows: Condition (10) implies that when the lending market reaches equilibrium, if the volume of the lending transactions is positive, then the P2P platform's interest plus the transaction cost is equal to the general interest at the lending demand market. Condition (11) indicates that when general interest is positive, the lending demand at this market must equal the equilibrium volume of the loans demand through the P2P platforms.

These equilibrium conditions are equivalent to the following variational inequality problem: determine d_{jl}^{2*} and i_{3l}^* such that:

$$\sum_i \sum_j \left\{\left[i_{2j}^* + \bar{c}_{jl}(D_2^*) - i_{3l}^*\right]\left(d_{jl}^2 - d_{jl}^{2*}\right)\right\} + \sum_l \sum_j \left\{\left[q_{jl}^{2*} - \bar{ld}_l\right]\left(i_{3l} - i_{3l}^*\right)\right\} \geq 0, \ \forall D_2 \in R_+^{np}, i_3 \in R_+^P \tag{12}$$

2.2.3. The Equilibrium Conditions of the Online P2P Lending Network

At the circumstances of equilibrium, the sum of the optimality conditions for all the borrowers (see at inequality (4)), the optimality of the P2P platforms (see at inequality (6)), and the lending demand market equilibrium (see at inequality (8)) is satisfied. Furthermore, the transaction volume from the P2P platforms must equal the volume accepted by the lenders.

Definition 1 (Online P2P Lending Network Equilibrium without Third-Party Agencies). The equilibrium state of such network is one where the flows among tiers of the lending network coincide and the demand quantities and interests satisfy the sum of the optimality condition and the equilibrium inequality (4) ,(6) and (8).

The summation of inequalities (4) , (6) and (8), after algebraic simplification, yields the following the results.

Theorem 1 (Variational Inequality Formulation). The equilibrium conditions of the P2P lending network model coincide with the solution of the following variational inequality problem.

$$\sum_i \sum_j \left\{\left[\frac{\partial f_i(D_1^*)}{\partial d_{ij}^1} + \frac{\partial c_j(D_1^*)}{\partial d_{ij}^1} + \frac{\partial c_{ij}(D_1^*)}{\partial d_{ij}^1} + \frac{\partial \hat{c}_{ij}(D_1^*)}{\partial d_{ij}^1} - r_{2j}^*\right]\left(d_{ij}^1 - d_{ij}^{1*}\right)\right\} + \sum_l \sum_j \left\{\left[r_{2j}^* + \bar{c}_{jl}(D_2^*) - i_{3l}^*\right]\left(d_{jl}^2 - d_{jl}^{2*}\right)\right\} + \sum_j \left[\sum_i d_{ij}^{1*} - \sum_l d_{jl}^{2*}\right] + \sum_l \left[\sum_j d_{jl}^{2*} - \bar{ld}_l(i_{3l}^*)\right]\left(i_{3l} - i_{3l}^*\right), \ \forall \left(D_1, D_2, r_2, i_3 \in R_+^{mn+np+n+P}\right) \tag{13}$$

Proof. The proof is similar to that in Nagurney (2002); by summing inequalities (4), (6), and (8), we get the inequality. For the inverse part of the equivalence, we insert $\left(\sum_i \sum_j i_{1ij}^* - \sum_i \sum_j i_{1ij}^*\right)$, $\left(\sum_l \sum_j i_{2j}^* - \sum_l \sum_j i_{2j}^*\right)$ into the first set and the second set of brackets preceding the multiplication signs in (14) respectively. The addition of the both terms above does not change (14) since both terms equal zero. So the resulting inequality can be re-arranged to be equivalent to the solutions satisfying the sum of conditions (4), (6), and (8). Q.E.D

For reference in the subsequent sections, variational inequality problem (15) can be rewritten in standard variational inequality form (see Nagurney, 1999) as follows: Determine $X^* \in K$ satisfying

$$\langle F(X^*),\ X - X^* \rangle \qquad \forall X \in K \tag{14}$$

Where $K \equiv \{(D^1, D^2, r_2, i_3) | d_{ij}^1 \geq 0, d_{jl}^2, r_2 \geq 0, i_{3l} \geq 0\}$ and $F(X) = \{F_{ij}^1, F_{jl}^2, F_j^3, F_l^4\}_{i=1,\cdots,m; j=1,\cdots,n; l=1,\cdots,p}$, where the terms of F correspond to the terms preceding the multiplication signs in inequality (14).

Note that the variables in the model (and which can be determined from the solution of variational inequality (14)) are the equilibrium loans transactions from the borrowers to the P2P lending platforms denoted by D^1, the equilibrium loans transactions from the P2P lending platforms to lenders given by D^2, the equilibrium lending interest i_3. We now discuss how to recover the interest i_1 (what the borrowers price their potential loans borrowing interests), and i_2 (what the platforms price their borrowers' customers' loans interests). First note that from (4), we have that if $d_{ij}^{1*} > 0$, then the interest $i_{1ij}^* = \partial f_i(D_1^*)/\partial d_{ij}^1 + \partial c_{ij}(d_{ij}^{1*})/\partial d_{ij}^1$. Similarly, from (6), we can get that if $d_{jl}^{2*} > 0$, $i_2^* = r_{2j}^*$.

2.2.4. Qualitative properties

In this section, we provide several qualitative properties of the solution to the variational inequality (14). Furthermore, we derive the existence and uniqueness results, and investigate properties of the function F. Although the feasible set of the variational inequality is not compact that the existence of a solution from the assumption of continuity of the functions cannot be proved, we can impose a weak condition to warrant the existence of a solution. Let

$$K_b = \left\{(D^1, D^2, r_2, i_3) \middle| \begin{matrix} 0 \leq D^1 \leq b_1; 0 \leq D^2 \leq b_2; \\ 0 \leq r_2 \leq b_3;\ 0 \leq i_3 \leq b_4 \end{matrix} \right\}$$

Where $b = \{b_1, b_2, b_3, b_4\} \geq 0$ and $D^1 \leq b_1, D^2 \leq b_2, r_2 \leq b_3, i_3 \leq b_4$ means that $d_{ij}^1 \leq b_1, d_{jl}^2 \leq b_2, r_2 \leq b_3, i_{3l} \leq b_4$ for all i, j, k. Then K_b is a bounded, closed convex subset of $R_+^{mn+np+n+p}$. Thus, the following variational inequality:

$$\langle F(X^*),\ X - X^* \rangle \qquad \forall X^b \in Kb \tag{15}$$

Admits at least one solution $X^b \in K_b$, from the standard theory of variational inequalities, since K_b is compact and F is continuous. Kinderlehrer and Stampacchia (1980) and Nagurney (1999), we now have:

Theorem 2 (Existence). Variational inequality (13) admits a solution if and only if there exists $b > 0$, so that variational inequality (13) admits at least one solution in K_b with $D^1 \leq b_1, D^2 \leq b_2, r_2 \leq b_3$, and $i_3 \leq b_4$.

Theorem 3 (Monotonicity). Assume that the borrowers' lending cost functions f_i, transactions cost with P2P lending platforms c_{ij}, the P2P lending platforms handling cost c_i, and their transactions cost with borrowers $\hat{c}_{ij}$ are convex. In addition, we suppose that $\bar{c}_{jl}$ and the interest lending demand function are monotone increasing. Then the vector function F that enters the variational inequalities(13) is monotone; that is, for any X' and X'' with $X' \neq X''$

$$\langle F(X') - F(X''), X' - X'' \rangle \geq 0 \ \forall X', X'' \in K$$

Proof. Let $X' = (D^{1\prime}, D^{2\prime}, r_2', i_3')$, $X'' = (D^{1\prime\prime}, D^{2\prime\prime}, r_2'', i_3'')$ with $X', X'' \in K$. Then, after simplifying, inequality(14) can be seen in the following deduction

$$\langle F(X') - F(X''), X' - X'' \rangle = \sum_i^m \sum_j^n \left[\frac{\partial f_i(D^{1\prime})}{\partial d_{ij}} - \frac{\partial f_i(D^{1\prime\prime})}{\partial d_{ij}}\right] \times [d_{ij}^{1\prime} - d_{ij}^{1\prime\prime}] + \sum_i^m \sum_j^n \left[\frac{\partial c_j(D^{1\prime})}{\partial d_{ij}} + \frac{\partial c_{ij}(D^{1\prime})}{\partial d_{ij}} + \frac{\partial \hat{c}_{ij}(D^{1\prime})}{\partial d_{ij}} - \frac{\partial c_j(D^{1\prime\prime})}{\partial d_{ij}} - \frac{\partial c_{ij}(D^{1\prime\prime})}{\partial d_{ij}} - \frac{\partial \hat{c}_{ij}(D^{1\prime\prime})}{\partial d_{ij}}\right] \times [d_{ij}^{1\prime} - d_{ij}^{1\prime\prime}] + \sum_j^n \sum_l^p [\bar{c}_{jl}(D^{2\prime}) - \bar{c}_{jl}(D^{2\prime\prime})] \times [d_{jl}^{2\prime} - d_{jl}^{2\prime\prime}] + \sum_j^n \sum_l^p [\overline{ld}_l(i_{3l}') - \overline{ld}_l(i_{3l}'')] \times [i_{3l}' - i_{3l}'']$$

$$= (\mathrm{I}) + (\mathrm{II}) + (\mathrm{III}) + (\mathrm{IV})$$

According to the definition of cost and demanding functions which we discussed above, it is clear to know that (I), (II), and (III) are all equal to or greater than zero. In section (VI), although $q_{jl}^{2\prime}$, $\overline{ld}_l(i_{3l}')$ are monotone increasing functions, P2P lending platforms supplying quantities to the lending markets are no less that the lending demand of borrowers according to risk preference of rational borrowers and industrial statistic of P2P lending market in U.S and China, so (IV) is also no less than zero. Q.E.D.

Theorem 4 (Strict Monotonicity). Assume all the conditions of Theorem 3 hold. Then the vector function F that enters the variational inequalities (14) is strictly monotone; that is,

$$\langle F(X^*),\ X - X^* \rangle > 0.$$

Theorem 5 (Existence and Uniqueness of a Solution to the Variantional Inequality Problem). If the conditions of Theorem 4 are hold, then the function that enters the variational inequality (14) has unique solutions in K .

3. Numerical Experiment

Now we consider an example of the P2P online lending network which consists of two borrowers, two P2P lending platforms and two lenders. The pictorial description is shown in Figure 2. The relevant variables and functions are provided below.

Decision variables are borrowing demand volume, $d_{ij}^{1}, i = 1,2, j = 1,2$; then the P2P lending platforms assess these loans and reconfigure the borrowing demand volume, $d_{jl}^{2}, j = 1,2, l = 1,2$.

The cost function at each tier are given below:

$$f_1(D_1) = 2.5d_1^2 + d_1 d_2 + 2d_1,$$

$$f_2(D_1) = 2.5d_2^2 + d_1 d_2 + 2d_2$$

The borrowers' transaction cost functions between the borrowers and the P2P lending platforms are

$$c_{11}(D_1) = (d_{11}^1)^2 + d_{11}^1,$$

$$c_{12}(D_1) = (d_{12}^1)^2 + d_{12}^1,$$

$$c_{21}(D_1) = (d_{21}^1)^2 + d_{21}^1,$$

$$c_{12}(D_1) = (d_{22}^1)^2 + d_{22}^1,$$

The handling cost functions of the P2P lending platforms are

$$c_1(D_1) = 0.5(d_{11}^1 + d_{21}^1)^2,$$

$$c_2(D_1) = 0.5(d_{12}^1 + d_{22}^1)^2,$$

The P2P lending platforms' transaction cost between them and the borrowers are:

$$\hat{c}_{11}(D_1) = (d_{11}^1)^2 + d_{11}^1,$$

$$\hat{c}_{12}(D_1) = (d_{12}^1)^2 + d_{12}^1,$$

$$\hat{c}_{21}(D_1) = (d_{21}^1)^2 + d_{21}^1,$$

$$\hat{c}_{12}(D_1) = (d_{22}^1)^2 + d_{22}^1.$$

The lenders' transaction cost between lenders and the P2P lending platforms are

$$\bar{c}_{11} = 20q_{11}^2, \quad \bar{c}_{12} = 50q_{12}^2, \quad \bar{c}_{21} = 50q_{21}^2,$$

$$\bar{c}_{22} = 20q_{22}^2.$$

The lending demand functions at the lending demand market are

$$\bar{ld}_1 = (1+t)i_{31} + 200, \bar{ld}_2 = (1+t)i_{32} + 200$$

Where we increase t from 1 to 20. In the above demand function, the coefficient associated with the interest can be interpreted as the price elasticity of demand, which measures the responsiveness or sensitivity of the lending demand market interest. In our model, we hope to see how the lenders react to the P2P lending platforms' service quality and credit assessment systems.

Through modified projection algorithm (Korpelevich 1977) implemented in MATLAB, the numerical examples are complemented.

In Figure 2. and Figure 3., we compare profits versus the interest elasticity parameter t of borrowers and lending platforms. We find that the patterns of the curves of both borrowers and the lending platforms are analogous, however there still exits some differences that might be meaningful:

We see that both curves are ascending at a certain parameter t, but after reaching point of inflection, both curves are slowly increasing, such situation coincides with the P2P lending markets, since the borrowers and the P2P lending platforms can be more profitable with the increase of loan interests, but when the interests reach a certain level, it is possible to indicate unobserved high risk of such lending deal. However, curves of Figure.3. are increasing relatively smoothly, it is reasonable since borrowers are more sensitive to the change of interests elasticity parameter. Curve of Figure 2. reaches the maximal points earlier, and this can be explained, in the P2P lending market, the borrowers are more likely to bear un-observed loan

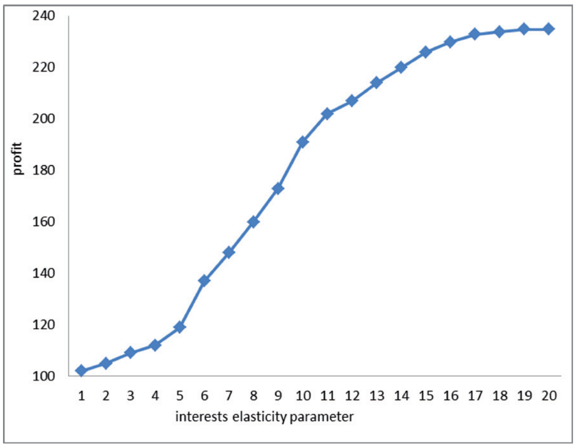

Figure 2. Profit vs. parameter t for the borrowers

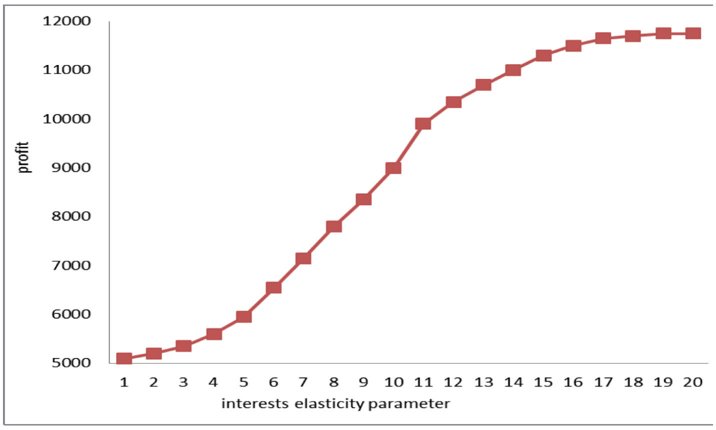

Figure 3. Profit vs. parameter t for the platforms

risks since when the borrowers are most likely the first risk bearers when lenders default.

4. Conclusion

In this paper, we designed an online P2P lending networks that consists of borrowers, P2P lending platforms, and lenders. As we concluded in the previous, the online crowdfunding are becoming one of the most prosperous and highest growing financial market in China, and the competition among those platforms, lenders, and even borrowers are becoming more and more intense. So how to model and analyze this market is very important. In our model, we discussed the network structure, the cost structure , the lending demand function of the players for the three types. Finally, we used a numerical experiment to discuss the profit vs interest elasticity parameter t for borrowers and P2P lending platforms, and the outcomes show when borrower makes decision to high-interest loan, she (he) might not get high returns because the existence of some un-observed high risks.

For future research, we would like to make the model more adaptive to the real market, such as considering the loan guarantee provided by some lending platforms or third-party institutions, which is practiced in some P2P lending platforms, for example we can consider supernetworks model that includes the third-party competitive platforms of credit information service, which might reduce the credit risks of some lenders.

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Novel Demosaicking Method Using Nonlocal Similarity Fusion

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Abstract
Although most demosaicking methods assume the existence of high local correlation in estimating the missing color components, such an assumption may fail for images with high color saturation and sharp color transitions. This paper presents a demosaicking scheme by exploiting both the variance of color differences (VCD) and the non-local similarity. First, the missing green components are estimated according to VCD along different edge directions. Then, the nonlocal pixels similar to the estimated pixel are searched to improve the initial estimate of the G channel. Based on the interpolated green plane, the missing blue and red components are preliminarily estimated. Finally, the blue and red channels are enhanced by exploiting nonlocal redundancies respectively. Experimental results show that the proposed algorithm is able to improve the CPSNR, sharpen edge and texture and lead to higher visual quality of reconstructed color images.
Keywords: COLOR DEMOSAICKING, NONLOCAL SIMILARITY, MULTI-COLOR GRADIENT, IMAGE INTERPOLATION