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Social reputation loss model and application to lost-linking borrowers in a internet financial platform

Sulin Pang [1,2] · Junkun Yang [1,2]

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Abstract
A social reputation loss model for loss of social reputation upon borrower disconnection on internet financial platforms is proposed. Firstly, the characteristics of on-line social networks of the borrowers are analysed from P2P platform, Chat platforms, QQ platform, one-click help platform, etc. Secondly, the characteristics of offline social networks of the borrowers are analysed in terms of blood, geographical, business, academic, heart, and ethnic relationships. Thirdly, from the six main factors, such as amount of default funds, disconnection time point, status of joint guarantee performance, project success probability, the amount and severity of network punishment, the impacts on the social reputation of lost-link borrowers are evaluated. Then, by quantifying these six main influencing factors, we establish a social reputation loss model on the lost-linking borrowers in P2P platform, and explore the relationship between borrower disconnection time and social reputation loss. The work proves that the social reputation loss of borrowers gradually decreases with the delay of disconnection time and other mathematical propositions. Finally, the applications of the model are discussed. The impacts of dynamic changes of the project success probability, disconnection time and amount of network punishment on the social reputation loss of borrowers are analysed. Through this study, an innovative calculating method for the loss of social reputation of borrowers who are out of touch on internet financial platforms is given.

Keywords Social network · P2P platform · Lost-link borrowers · Social reputation loss model · Reputation loss attenuation · Network punishment degree

1 Introduction

The P2P on-line loan model has developed rapidly abroad because it is aligned with foreigners' spending habits. On-line peer-to-peer (P2P) lending is one of the most successful technical support programs in the financial technology revolution, revolutionising the way individual investors and borrowers meet and trade [1]. Internet loans or P2P lending are popular in China compared to other economies; however, government departments basically have no regulatory role therein resulting in a lack of both adequate oversight and disclosure on the P2P platform, involving high-risk lending operations and sometimes even fraudulent activities [2]. The P2P network lending platform is a business model that combines Internet and financing, pooling small amounts of money and lending them to those in need. The loan process can be implemented through platforms such as information and funds, contracts and procedures. The P2P e-finance platform provides an overview of definitions, characteristics, classifications, and causes. A brief overview of the design, structure, platform module framework and determinants of P2P e-finance has been undertaken [3]. Specifically, it provides a systematic classification of P2P lending by summarising different types of mainstream platforms and comparing their working mechanisms: this was then, reviewed and organised into the latest developments in P2P lending from various perspectives (for example, economics and sociology and data-driven perspectives [4]. The limited information provided by a P2P lending platform is often insufficient to allow the lender to determine whether, or not, the borrower is trustworthy and able to repay the loan. Using the dataset pertaining to the P2P lending platform, lenders can seek information directly from borrowers

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✉ Sulin Pang
pangsulin@jnu.edu.cn; pangsulin@163.com

[1] School of Management /School of Emergency Management, Jinan University, Guangzhou 510632, Guangdong, China

[2] Guangdong Emergency Technology Research Center of Risk Evaluation and Prewarning on Public Network Security, Guangzhou 510632, Guangdong, China

and borrowers to answer questions and comments by examining the impact of lender-borrowing communications on financing outcomes and loan performance. Discovering the amount and content of such direct communication is not only useful but important. In addition, lenders are affected by other credit (positive or negative) comments, and the quality of the information disclosed in the borrower's response may affect the outcome of the approval [5]. P2P loans promote loans between individuals in the on-line environment. Based on the Likelihood Model (LM), the change of attitude is explained, and the trust-establishment mechanism of P2P lending market is empirically studied and tested [6]. How the social capital dimensions of the network affect knowledge transfer between network members is examined and a set of conditions that facilitate knowledge transfer across different network types are proposed [7]. As for the relationship between self-employment and social networks in Chinese cities, Yueh has found that having social networks can help self-employed people access supply and credit networks [8]. Applying the theory of trust, they proposed a research model, including three fund-raising related, project related, and platform related factors. This is used to determine the trust factors between funders and crowd-funding [9].

Social capital theory provides a theoretical way of explaining how individuals, groups and organisations manage relationships and access knowledge resources [10]. Part of the relationship between institutions and economic growth is due to better institutional performance and more advanced social capabilities [11]. By analysing borrower's decision, we find that borrower's friends, especially off-line friends and close friends, may affect their friends' bids [12]. Earlier work is available on on-line P2P, but it is mainly limited to western environments. Exploring how social capital and other factors affect on-line P2P lending in the US and China. Based on the archival data of Prosper and PPDai, we compared the market results of two on-line P2P lending markets in the US and China. Empirical results show that social capital is not equally important in different on-line communities. It seems that social capital is more influential in China than in the United States. In contrast, social capital only affects US interest rates [13]. Borrower social information can be used not only for credit screening, but also for default and debt collection [14]. Informal financial networks rely heavily on interpersonal relationships, reputation, and trust. Research into reputation models and trust models show that these are major components of social capital in the banking and financial sectors [15]. An on-line questionnaire was used to collect Alibaba's Yu'e-bao data, and a partial least squares structural equation model was used for data analysis: four e-finance features (perceived reputation, website quality, e-funding familiarity, and situational normality) were introduced, and found that website quality, familiarity and situational normality will affect perceived ease of use (PEOU) and perceived usefulness (PU). PEOU and PU, as well as reputation and confirmation, further lead to satisfaction. The positive impact of satisfaction and trust on the continuing intention of e-finance is identified, and trust is considered to be an important regulator of the relationship between satisfaction and persistent intent [16]. By proposing a new computational model called reputation distribution conflict (RDC), it is used to evaluate the provider's credibility, namely reputation, reputation, and conflict, and to study the accuracy of the new model in computing RDC. The model was found to be significantly better than other models (Elham and Vimala [17]). If the market is weak, buyers will be affected by the reputation system, as the equilibrium growth of prices is greater than the balanced growth of trade quality. Herbig [18] describes how to use reputation models to address brand extension decisions by describing reputation creation and destruction models. Studies have shown that in any Nash equilibrium, any infrequent replacement is sufficient to prevent reputation, and its effects, from disappearing [19]. Hitchner [20] gave a good explanation of the meaning of reputation: achieving value from corporate image. Reputation has long-term sustainability in imperfect public surveillance games. In the absence of imperfect monitoring, participants are unable to maintain the reputation of untrustworthy behaviour indefinitely [21]. It is found that the dynamic general equilibrium model has moral hazard and adverse selection. A good reputation cannot be used as an effective sorting device: in a balanced state, more capable agents cannot be sold on the market at a lower price to gain a good reputation. In addition, if customers follow a company's reputation, the social surplus will fall [22]. Endogenous competition may create external choices that cause disappointed consumers to leave a company. This threat of withdrawal has made good companies choose to work hard to build a good reputation [23]. On the on-line auction site eBay, sellers have the opportunity to take advantage of the bidder's trust. Aware of this, eBay's designers have created a system that relies on a reputation for self-execution. The study found that bidders had little return on reputable sellers [24]. The impact of project sponsor reputation on a loan contract is designed, in terms of spreads and charges. By controlling the non-randomness of lenders and borrower matching (self-selection bias), we find that the reputation of top project sponsors leads to higher price differences [25]. Seller reputation affects on-line auction promotion prices. The bidding behaviour model shows how a flawed reputation signal leads to a bidder's auction failure, and the highest value of the assessment is the ability to communicate information to potential bidders [26]. Feedback history shows the price gap between different investment bankers and underwriters, it is established that the underwriting

fees charged by the more prestigious underwriters are significantly lower. For well-known underwriters, the lower yields and higher quotations indicate that the investment banker's reputation can prove the value of the bonds issued to investors [27]. The link between price, quality, seller's statement, and seller's reputation in internet auctions is found: it was found that reputable sellers did not provide better quality under conditions prevailing upon completion of the auction [28]. The reputation of an investment bank and the price and quality of bond underwriting services are related. Reputable banks were found to have lower returns and higher fees, but the issuer's net income was higher. These findings suggest that bank underwriting decisions reflect reputational issues, and that economic rents are earned through reputation, providing insurance companies with ongoing incentives to maintain their reputation [29]. A P2P reputation system based on fuzzy logic reasoning can better deal with uncertainty, ambiguity, and incomplete information in peer trust reports [30], while competitive markets can observe changes in ownership, reputation is a tradable intangible asset [31].

Since Chinese society has always been a networked society connected by interpersonal relationships, everyone has their own social relationship networks. Therefore, we propose to study a social reputation loss model of lost-link borrowers on a P2P platform. The relevant propositions are established, the mathematical proof is given, and the model is applied to an example. The rest of the paper is arranged as follows: Section 2 studies the borrower's on-line social network and off-line social network, and discusses the characteristics of the borrower's on-line social network from the P2P platform, Chat platform, QQ platform and one-click help platform, and innovatively analyses the characteristics of the borrower's off-line social network in blood, geographical, business, academic, kinship, and ethnic relationship terms. Section 3 covers the factors influencing social reputation of lost-link borrowers and the impact of the six main factors on the loss of social reputation about out-of-connection borrowers, including amount of default funds, disconnection time, status of joint guarantee performance, project success probability, the amount and severity of network punishment, and quantifies these six main influencing factors. Section 4 provides details of a model of social reputation loss of borrowers who are out of connection on a P2P platform. It innovatively explores four related propositions, such as the disconnection time of borrowers and loss of social reputation, and gives corresponding mathematical proofs. Section 5 applies the model to an example to discuss the impact of the dynamic changes of project success probability, disconnection time and the amount and severity of network punishment on the borrower's social reputation loss. Section 6 summarises the conclusions of the work.

2 Borrower's social network construction and analysis

2.1 On-line social network

First of all, the borrowers on the P2P platform studied in this paper refer to those who have incomplete lending procedures, no collateral guarantee, only rely on the so-called reputation of both borrowers and lenders, and do not follow up and supervise the investment projects after grant of loan, so the cost of losing credit among borrowers is low. Once communication equipment such as mobile telephones are shut down, it will be easy to lose contact with them, and it is difficult to find them. The method used here aims to design the borrower's social networks and try to find it through their social networks after the borrowers lose contact. Here we divide the borrower's social network into an on-line social relationship network (virtual) and off-line social relationship relation network (real), which are simply called the "on-line social network" and "off-line social network".

The on-line social network studied here includes a: P2P platform, chat platform, QQ platform, and one-click help platform, in which:

(1) P2P platform: the P2P platform establishes a network of friends for customers, such as lending groups and lending forums. Some P2P platforms will also encourage platform customers to associate with third-party social software. For example, patrolling loans encourages borrowers to associate with Alipay at the login portal (Sina Weibo). On the P2P platform, the borrower needs to provide personal information, including name, gender, age, occupation, mobile telephone number, ID number, on-line loan amount, bank cash flow, half-yearly income, etc.; the lender obtains a platform allocation when registering their P2P platform. The only user account (user ID), the user ID is associated with its friend account (friend ID), and the personal information of the friend includes: friend name, friend gender, friend age, friend occupation, friend mobile telephone number, ID card number; the friend also gets the only user account assigned by the platform (friend ID);

(2) Chat platform: this has established a chat platform for friends, friends and friends. In addition, WeChat payment and WeChat payment are also provided;

(3) QQ platform: this has established a one-to-one dating and one-to-many friend chat platform for customers;

(4) One-click help platform: this is used to build one-to-one, one-to-many and many-to-many chat platforms for customers, and also establish temporary family groups and temporary friends groups.

The on-line social network of the borrower is shown in Fig. 1.

2.2 Off-line social network

The off-line social network studied here is classified according to people's off-line social network. A person's off-line social

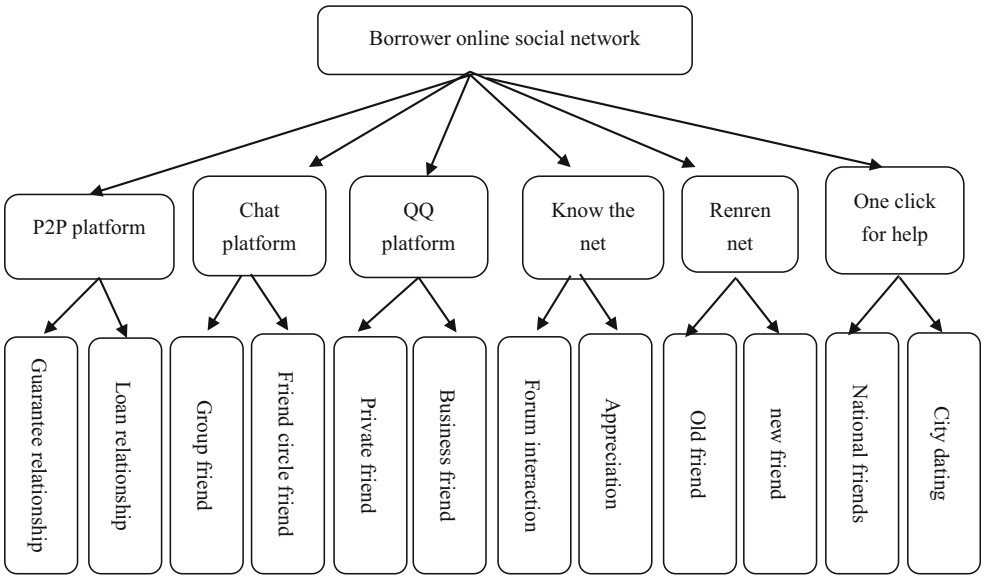

Fig. 1 Borrower on-line social network

network includes their blood, geographical, business, academic, heart, and ethnic relationship networks, among which:

(1) The blood relationship network is mainly a network of relationships generated by marriage or childbearing, such as the relationship between parents and children, the relationship between brothers and sisters, and other relatives derived therefrom. The kinship network is divided into a direct relationship network and a collateral relationship network. The direct relationship network refers to a network composed of members of immediate family members, and the collateral relationship network refers to a network composed of members of the collateral relatives. The blood relationship network is a born and innate relationship. It exists at the beginning of human society and is the earliest social network formed by human beings.

(2) The geographical relationship network mainly refers to the interpersonal relationship network, such as the neighbourhood relationship and the fellowship relationship, which are created by geographical location because of previous or present living and activities within a certain geographical range.

(3) The business relationship network is mainly the interpersonal relationship that the borrower generates due to the needs of their occupation or industry activities, such as the leadership within the industry and the superior relationship between the leader, the relationship between the colleagues and the business relationship.

(4) The academic relationship network is mainly composed of students and teachers, and includes classmate relationships, teacher-student relationships, and so on.

(5) The heart relationship network is mainly the person most often missed in the heart of the lender, or the person who most wants to work together, or the person who most actively wants to make an appointment, or the place where the dating party most often goes, or the longest time spent dating with loved ones, lovers, lovers, close friends, friends, and so on. The network of kinship is divided into a network of relatives and a network of friends. A network of relatives refers to a network of social relationships composed of people with blood relations; A close friend network is a social network composed of very close people.

(6) The ethnic relationship network is mainly a network of clan networks with the same surname as the borrower and the same ethnic network; the ethnic network refers to the minority network, because ethnic minorities are more likely to form a gang (or other grouping).

The borrower's social relationship network structure is shown in Fig. 2.

3 Analysis of factors influencing social reputation

Assume that the amount borrowed by the borrower on the P2P platform is B ($B > 0$,B is an integer), the borrowing period is T ($T \geq 0$, T is an integer), the platform joint insurance team is n, and the borrower's investment project success probability is $p(0 \leq p \leq 1)$, The monthly interest rate charged by the platform to the borrower is r.

When the borrower defaults or even "runs the road" and loses the link, this has too much impact on the reputation of the borrower. In the borrower's social network (including the borrower's off-line social network and on-line social network), If the reputation is destroyed, it will make it difficult for the borrower to start anew in the future. Even many normal dating behaviours and consumer behaviours will be restricted, therefore, it will withdraw from a large number of

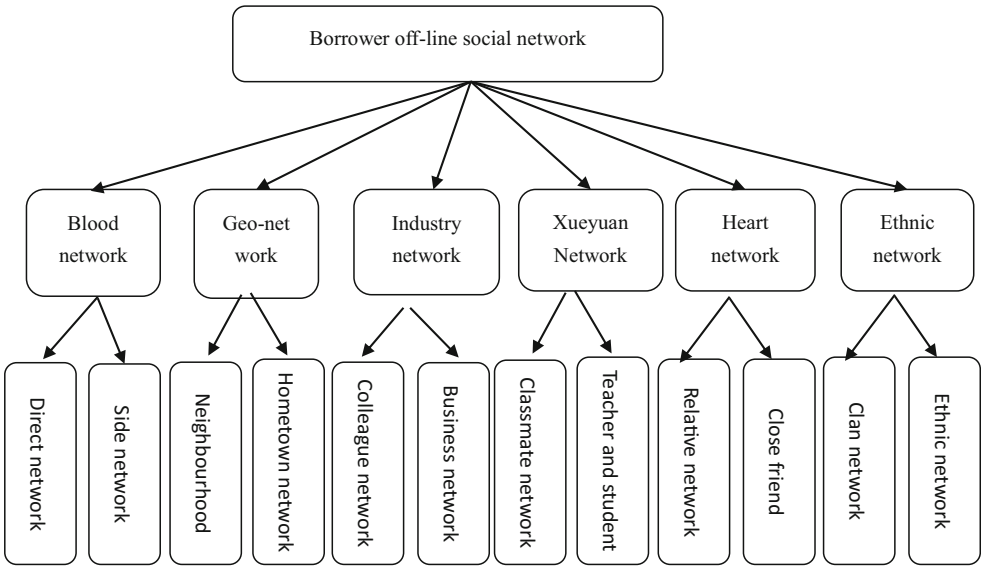

Fig. 2 Borrower on-line social network

friends, resulting in a narrow scope of activities. Borrowers with serious reputation loss, even court litigation pending or adjudged, may lead to imprisonment, therefore, we study the social reputation loss model of lost-link borrower's and applications: first we analyse the impact of borrower social reputation loss from the viewpoint of the six major influencing factors which are amount of default funds, disconnection time point, status of joint guarantee performance, project success probability, and the amount (and severity) of network punishment.

(1) **The amount of default funds**

When the borrower defaults, the amount of the breach is likely to form a societal perception of the borrower and the impact on the borrower's social reputation. Generally speaking, the large amount of default has a greater impact on the borrower's social reputation loss, and a smaller default has little impact on the borrower's social reputation loss. Assuming that the borrower loses contact at time $t(0 \le t \le T)$, we use $D(t)$ to indicate the amount of default when the borrower lost at t, then $D(t)$ can be expressed as:

$$D(t) = B(1+r)^T - Btr = B\left[(1+r)^T - tr\right] \tag{1}$$

In formula (1), $B(1+r)^T$ is the loan principal benefit, and Btr is the interest that the borrower has repaid at time point t. Below we define the default ratio $d(t)$ at time point t:

$$d(t) = \frac{D(t)}{B(1+r)^T} = \frac{B(1+r)^T - Btr}{B(1+r)^T} \tag{2}$$

For$0 \le d(t) \le 1$, the greater the default ratio $d(t)$, the greater the default amount $D(t)$ and the greater the impact on the borrower's social reputation and vice versa.

(2) **The disconnection time**

The disconnection time is also a key factor affecting borrower social reputation. Suppose the borrower loses contact at t ($0 \le t \le T$,t is an integer), t and Thave the same time unit, which can be a year, month, week, or day (here we use months). The smaller t is, the faster the borrower loses after obtaining the loan; the larger t is, the slower the borrower loses after obtaining the loan. When $t = 0$, it means that the borrower loses the loan immediately after borrowing money from the platform. This situation indicates that the borrower immediately flees after borrowing the money; When $t = T$, it means that the borrower loses the loan until the repayment period ends. This situation indicates that the borrower may have failed in the investment and cannot repay the loan before losing the loan. We use τ to indicate the difference between the disconnection time 1 and the borrower, that is,

$$\tau = 1 - \frac{t}{T} \tag{3}$$

In this way, $0 \le \tau \le 1$ and the larger τ is, the closer τ is to 1, indicating that $\frac{t}{T}$ denotes closer to 0, so t is closer to 0. This shows that the borrower's loss of speed is very fast after borrowing money. This has a significant effect on borrower social reputation; on the contrary, the smaller τ is, the closer τ is to 0, indicating that $\frac{t}{T}$ is closer to 1, so t is closer to the repayment term T. This shows that the borrower is lost when close to the repayment period ending. People naturally think that the borrower may fail to repay the debt, so the influence on borrower social reputation is relatively small.

(3) **The status of joint guarantee performance**

Suppose that on a loan platform with n guarantors, if the probability of success of the borrower's investment project is p, there are $n_p(0 \le n_p \le n)$ guarantors who are willing to perform the repayment. The proportion of guarantors who are willing to perform on the platform is $\frac{n_p}{n}$, so the proportion of guarantors who are unwilling to perform is $1-\frac{n_p}{n}$. Make

$$\delta = 1-\frac{n_P}{n} \tag{4}$$

$0 \le \delta \le 1$. Thus, the larger δ, the greater the proportion of guarantors who are unwilling to perform, and the greater the impact on the reputation of the borrower; conversely, the smaller δ is, the smaller the proportion of guarantors who are unwilling to perform, that is, the greater the proportion of guarantors who are willing to perform, the lower the impact to the reputation of the borrower.

(4) **The probability of project success**

When the moral hazard is not considered, the success of the borrower's investment project is an important factor that directly determines whether the borrower will lose contact and whether the platform guarantor is willing to continue to perform (or not). The greater the probability of success of the borrower's investment project is $p(0 \le p \le 1)$, the less likely the borrower loses the link; on the contrary, the smaller the success probability of the borrower's investment project p is, the greater the possibility that the borrower loses the link. If the probability of success of the borrower's investment project is $p = 1$, if the loss occurs, the borrower and project bear moral hazard.

On the other hand, when the probability of success of the borrower's investment project is p, $1-p$ is the failure rate of its investment project. The failure rate of the borrower's investment project directly determines the likelihood of its loss of association. The larger the probability of project success p is, the smaller the project failure rate $1-p$ is, and the less likely the borrower is to lose the link; conversely, the smaller the probability of project success A, the greater the project failure rate B, and the greater the likelihood that the borrower will lose contact. Making

$$q = 1-p \tag{5}$$

q is the borrower project failure rate,$0 \le q \le 1$.

(5) **The amount of network punishment**

Since this section studies the borrower's lost reputation loss model based on social networks, the "network disciplinary" action here refers to the social network disciplinary side of the borrower. We use the number of social networks of the borrower to express its social network punishment range. Generally speaking, the wider the disciplinary aspect of the social network of the borrower, the greater its influence on the reputation of the borrower and vice versa.

It may be assumed that the borrower has m ($m \ge 1$,m is an integer) social networks, of which k ($0 \le k \le m$) are punished for the loss of the borrower. Therefore, $\frac{k}{m}$ indicates the ratio of the number of networks that the borrower's social network punishes. It is called "the proportion of network disciplinary faces" and is represented by η. then

$$\eta = \frac{k}{m} \tag{6}$$

where $0 \le \eta \le 1$. The larger η, the greater the proportion of the social network disciplinary surface of the borrower, and the greater the number of networks that the social network imposes on its disciplinary subjects, the greater the impact on its reputation and vice versa.

When $m = 1$, the borrower has only one large social network, and this social network is no longer broken down, indicating that the borrower's social network belongs to a single social network. $m > 1$, indicating that the borrower has multiple social networks and belongs to multiple social networks.

(6) **The severity of network punishment**

Since the present research is based on the social network-based borrower's lost reputation loss model, the "cyber penalty degree" here refers to the borrower's social network penalty. Here we use the disciplinary power of the borrower to express the social network punishment imposed by the social network. Generally speaking, the greater the social network penalties on the borrower, the greater the impact on the reputation of the borrower and vice versa.

(i) When the borrower has only one social network, a single social network situation pertains, and we use $\alpha(0 \le \alpha \le 1)$ to indicate the network penalty. Obviously, the bigger α is, the greater the disciplinary social network's disciplinary action on its disengagement and vice versa.

(ii) When the borrower has more than two social networks, a multiple social network situation pertains. We use the social network average penalty to indicate the borrower's network penalty and assume that the borrower has m ($m \ge 1$,m is an integer) social networks, and we use α_i ($0 \le \alpha_i \le 1$,$i = 1, 2, \cdots, m$) to indicate the i social network penalty. If the i social network penalty severity accounts for $v_i(0 \le v_i \le 1,\ i = 1, 2, \cdots, m)$, in the social network average penalty severity, Then the borrower's social network penalty, α implies that:

$$\alpha = \frac{1}{m}(v_1\alpha_1 + v_2\alpha_2 + \cdots + v_m\alpha_m) \tag{7}$$

4 Social reputation loss model

4.1 Model establishment

We use $\psi(t)$ to indicate the loss of social reputation of the lost borrower, the value is between [0, 1], that is $0 \le \psi(t) \le 1$. When $\psi(t) = 0$, the loss of social reputation of the lost borrower is 0. That is, the social reputation of the borrower's loss of association remains unaffected. This situation is used to explain why, when the platform did not disclose the news that the borrower lost the link, thus the amount of information that the society loses about the borrower is 0, therefore, the social reputation loss of the lost borrower is 0.

When $\psi(t) = 1$ it means that the social reputation loss of the borrower is 1, which means that the social reputation loss of the borrower will reach 100%, and the social reputation damage of the borrower will reach the peak.At this point, in real life, any social activities of the borrower will be restricted.Therefore, the loss of contact in this case is of no benefit to the borrower, in this case they can hardly carry out any social activities, such as work, re-employment is basically impossible.The borrower has to make $\psi(t) < 1$ in order not to be completely cornered.

Further analysing the factors affecting the borrower's social reputation loss according to Section 3, the model of the social reputation loss of the lost borrower can be expressed as follows:

$$\psi(t) = d(t) \cdot \tau \cdot \delta \cdot q \cdot \eta \cdot \alpha \tag{8}$$

We substitute Eqs. (2), (3), (4), (5), and (6) into Eq. (8). The model of social reputation loss for a lost borrower can be further expressed as:

$$\psi(t) = \alpha \cdot \frac{k}{m} \cdot \left[1 - \frac{tr}{(1+r)^T}\right] \cdot (1-p) \cdot \left(1 - \frac{t}{T}\right) \cdot \left(1 - \frac{n_p}{n}\right) \tag{9}$$

In the social reputation loss model (9) in which the borrower loses contact, the variable t indicates the time when the borrower lost the joint contact. It is conceivable that if the borrower immediately lost the joint-contact when borrowing funds on the platform, they are escaping with money.

Hypothesis 1: in the social reputation loss model (9), when $t = 0$, there are$n_p = 0$,$p = 0$and $\alpha = 1$.

Hypothesis 1 states that, when $t = 0$, the borrower immediately lost joint contact when borrowing funds on the platform, the number of guarantors who are willing to commit to repayment on the platform is $n_p = 0$. The evaluation of the probability of success of the borrower's investment project by the platform is also meaningless, so the probability of success of the project is $p = 0$. In addition, the borrower is penalised by social networks to 100%, $\alpha = 1$.

Proposition 1: in borrowing period [0, T], the earlier the borrower disconnection time, the greater the social reputation loss $\psi(t)$.

Proof: Assume that the borrower borrows at time 0 and loses at time $t(0 \le t \le T)$.

$A = \alpha(1-p)\frac{k}{m}\left(1 - \frac{n_p}{n}\right)$, then $A \ge 0$, thus, Eq. (9) can be changed to:

$$\begin{aligned} \psi(t) &= \alpha \cdot \frac{k}{m} \cdot \frac{B(1+r)^T - Btr}{B(1+r)^T} \cdot (1-p) \cdot \left(1 - \frac{t}{T}\right) \cdot \left(1 - \frac{n_p}{n}\right) \\ &= A\left[1 - \frac{tr}{(1+r)^T}\right] \cdot \left(1 - \frac{t}{T}\right) \\ &= \frac{A}{T(1+r)^T}\left[(1+r)^T - tr\right] \cdot (T-t) \\ &= \frac{A}{T(1+r)^T}\left[(1+r)^T T - (1+r)^T t - trT + rt^2\right)\Big] \end{aligned} \tag{10}$$

then,

$$\begin{aligned} \psi'(t) &= \frac{A}{T(1+r)^T}\left(-(1+r)^T - rT + 2rt\right) \\ &= -\frac{A}{T(1+r)^T}\left\{\left[(1+r)^T - rt\right] + r(T-t)\right\} \end{aligned} \tag{11}$$

Because$0 \le t \le T$, so$T - t \ge 0$, $r(T-t) \ge 0$. Also because

$$(1+r)^T - rt \ge (1+rT) - rt = 1 + r(T-t) \ge 1 > 0 \tag{12}$$

So $\psi'(t) < 0$, and thus $\psi(t)$ is a strictly decreasing function of t. That is, the larger t, the smaller $\psi(t)$ is; in turn, the smaller t is, the larger $\psi(t)$ is, therefore, the earlier the borrower loses the link, the smaller t is, and the larger $\psi(t)$, so the borrower's social reputation loss is greater.

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Proposition 2: during the borrowing period [0, T], the borrower's social reputation loss $\psi(t)$ decays as the disconnection time t increases.

Proof: according to the proof of Proposition 1, $\psi(t)$ is a strict descending function of t. This means that as t increases, $\psi(t)$ will decrease, therefore, the borrower's social reputation loss is attenuated as the time to loss of association increases.

Proposition 3: the borrower's social reputation loss $\psi(t)$ is a downward convex function during the borrowing period [0, T].

Proof: As seen from formula (9),

$$\psi''(t) = \frac{2rA}{T(1+r)^T} = \frac{2r\alpha(1-p)}{T(1+r)^T} \cdot \frac{k}{m}\left(1 - \frac{n_p}{n}\right) \tag{13}$$

As $\psi''(t) \ge 0$, $\psi(t)$ is a convex function in [0, T].

Proposition 4: during the borrowing period [0, T], the maximum and minimum values of the borrower's social reputation loss are $\psi_{\max}(t) = \psi(0)\psi_{\min}(t) = \psi(T)$.

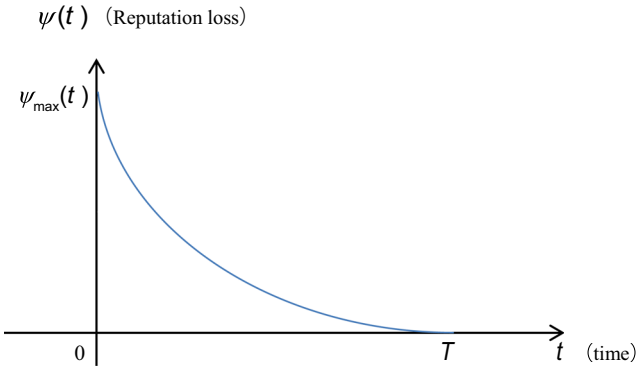

Fig. 3 Borrower's social reputation loss

Proof: as seen from the proof of Proposition 1: $\psi'(t) < 0 (0 \le t \le T)$, that is, $\psi(t)$ is a strict decreasing function of disconnection time t. As $0 \le t \le T$, so $\psi(T) < \psi(t) < \psi(0)$, thereby $\psi_{\max}(t) = \psi(0), \psi_{\min}(t) = \psi(T)$.

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The social reputation loss model (9) and hypothesis 1 about that the maximum and minimum values of the borrower's social reputation loss can be calculated as:

$$\psi_{\max}(t) = \psi(0) = \alpha \cdot \frac{k}{m} \cdot (1-p) = \alpha \eta q \tag{14}$$

$$\psi_{\min}(t) = \psi(T) = 0 \tag{15}$$

Equation (14) shows that, when the borrower loses contact at time 0, the borrower immediately escapes with money as soon as they borrow it on the platform. At this point, the borrower's loss of social reputation will all come from the disciplinary and punitive actions of the social network.

Equation (15) shows that the borrower's social reputation loss value can be 0. This means that if the borrower loses the link at the due date of the repayment, it means that the borrower is unable to raise new funds to repay the loan because of an investment failure. At this time, the sympathy given by society will exceed the extent of the borrower's loss, therefore, the loss of social reputation of the borrower has not been affected, so their social reputation loss value is 0.

The reality is that when the "borrower loses the connection when the repayment due date" occurs, the approach adopted by the platform is often to quietly search for the borrower who has lost the connection, hoping to find a repayment agreement. Since the platform initially did not disclose information about the borrower's loss of association, the borrower's social reputation loss value is really 0. Therefore, the results obtained here are consistent with the prevailing P2P platform borrowing situation.

From the conclusion of Proposition 2–4, we plot the borrower's social reputation loss (Fig. 3).

4.2 Model application and analysis

Suppose there is such a type of borrower borrowing from the P2P platform and the borrowing period is $T = 12$ (months), and the platform requires the number of joint guarantees to be $n = 6$ (persons). The borrower has six social networks, that is $m = 6$, the whole social network is: blood relationship network, heart relationship network, ethnic relationship network, geo-relationship network, academic relationship network, and business relationship network. The penalty for the loss of the borrowers by the 6 social networks is $\alpha_1 = 20\%$, $\alpha_2 = 30\%$, $\alpha_3 = 40\%$, $\alpha_4 = 50\%$, $\alpha_5 = 60\%$, $\alpha_6 = 70\%$. The following discusses the impact of the dynamic changes of the three variables of the probability of project success p, disconnection time t, and network disciplinary surface k on the social reputation of the borrower and we calculate the borrower's loss of social reputation.

(1) The impact of the probability p of project success on borrower social reputation

Suppose that the probability of success of the borrower's investment project is assumed to be p=0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, or 1; the platform has eight interest rate levels at r=20%, 24%, 28%, 30%, 32%, 35%, 38%, and 40% for lending. It is also assumed that the borrower has a corresponding disconnection time of t= 0, 1, 2, 3, 4, 6, 8, 9, 10, and 12 according to different interest rate levied. At this time,

Table 1 Calculated value of borrower social reputation loss based on 10 different datasets

	p									
Variable	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
r	40%	38%	35%	32%	30%	28%	24%	22%	20%	20%
t	0	1	2	3	4	6	8	9	10	12
n_p	0	0	1	2	2	3	3	4	5	6
k	6	5	5	4	4	3	3	2	2	1
$\psi(t)$	0.405	0.2728	0.1788	0.0869	0.0632	0.0205	0.0096	0.002	0.0003	0
	40.5%	27.28%	17.88%	8.69%	6.32%	2.05%	0.09%	0.02%	0.003%	0

the number of guarantees that the platform is willing to perform is changed to n_p=0, 0, 1, 2, 2, 3, 3, 4, 5, or 6. The network disciplinary aspect is also set to k= 6, 5, 5, 4, 4, 3, 3, 2, 2, and 1, giving 10 sets of dynamic data for interest rate r, disconnection time t, platform willingness to issue a guarantee n_p, and the network penalty k based on the change in the probability p of success of the borrower's project:

- Group 1: $(p \quad r \quad t \quad n_p \quad k) = (0.1 \quad 0.4 \quad 0 \quad 0 \quad 6)$
- Group 2:$(p \quad r \quad t \quad n_p \quad k) = (0.2 \quad 0.38 \quad 1 \quad 0 \quad 5)$
- Group 3:$(p \quad r \quad t \quad n_p \quad k) = (0.3 \quad 0.35 \quad 2 \quad 1 \quad 5)$
- Group 4:$(p \quad r \quad t \quad n_p \quad k) = (0.4 \quad 0.32 \quad 3 \quad 2 \quad 4)$
- Group 5:$(p \quad r \quad t \quad n_p \quad k) = (0.5 \quad 0.3 \quad 4 \quad 2 \quad 4)$
- Group 6:$(p \quad r \quad t \quad n_p \quad k) = (0.6 \quad 0.28 \quad 6 \quad 3 \quad 3)$
- Group 7:$(p \quad r \quad t \quad n_p \quad k) = (0.7 \quad 0.24 \quad 8 \quad 3 \quad 3)$
- Group 8:$(p \quad r \quad t \quad n_p \quad k) = (0.8 \quad 0.22 \quad 9 \quad 4 \quad 2)$
- Group 9:$(p \quad r \quad t \quad n_p \quad k) = (0.9 \quad 0.2 \quad 10 \quad 5 \quad 2)$
- Group 10:$(p \quad r \quad t \quad n_p \quad k) = (1 \quad 0.2 \quad 12 \quad 6 \quad 1)$

For each set of data, the borrower's social reputation loss value calculated according to Eqs. (7) and (9) is as summarised in Table 1.

Table 1 shows that, as the probability of success p of the project increases, the value of the social reputation loss of the borrower also decreases: however, as the platform interest rate r increases, the borrower's social reputation loss also increases, when the borrower's disconnection time is extended, the loss of social reputation declines. The relationship between the probability p of success of the borrower's investment project and its social reputation loss is as shown in TAure 4.

In Fig. 4, as the probability of project success p increases, the borrower's social reputation loss increases. For $0.1 \le p \le 0.4$, the social reputation loss decreases: for $0.4 \le p \le 0.6$, the rate of decline in social reputation loss decreases. For $0.6 \le p \le 0.8$, the attenuation of social reputation loss value is more gradual. For $0.8 \le p \le 1$, the value of social reputation loss tends to 0, that is, the social reputation of the borrower's loss of association is unaffected.

Table 2 Calculated value of borrower's social reputation loss based on dynamic changes in disconnection time

t	0	1	2	3	4	5	6
$\psi(t)$	0.3	0.0543	0.0487	0.0433	0.0379	0.0327	0.0276
	30%	5.43%	4.87%	4.33%	3.79%	3.27%	2.76%
t	7	8	9	10	11	12	
$\psi(t)$	0.0227	0.0179	0.0132	0.0087	0.0043	0	
	2.27%	1.79%	1.32%	0.87%	0.43%	0	

(2) The effect of disconnection time t on the social reputation of the borrower

Where assumption 1 is established, it is assumed that the values of the disconnection time t are 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, and 12, respectively. If the project success probability p, interest rate r, the platform willing to perform the guarantee number n_p and the network penalty face k take a specific set of data$(p \quad r \quad n_p \quad k) = (0.6 \quad 0.3 \quad 3 \quad 4)$ $(t \neq 0)$, then, under other conditions, we can see the impact of the change in disconnection time t on borrower social reputation.

According to Hypothesis 1, when $t = 0$, there are $n_p = 0$ and $p = 0$. According to Eqs. (7) and (9), we calculate the social reputation loss value of the borrower (Table 2).

We plot the impact of dynamic changes in disconnection time t on the borrower's social reputation (Fig. 5).

As seen from Fig. 5, when only the disconnection time t changes dynamically from 0 (month) to 12 (month), and the

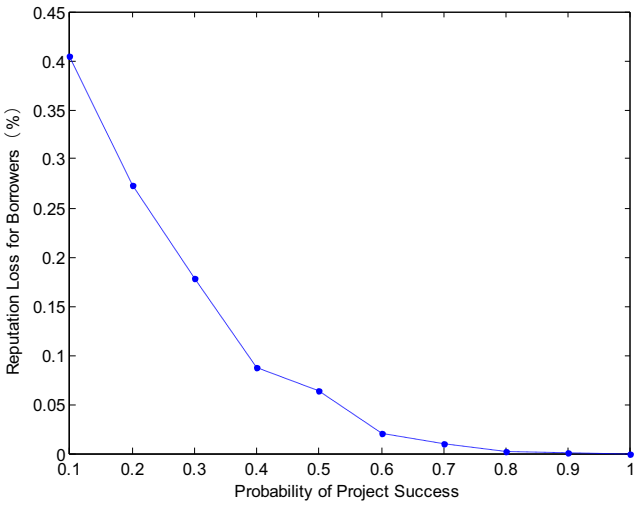

Fig. 4 The impact of changes in project success probability on borrower social reputation

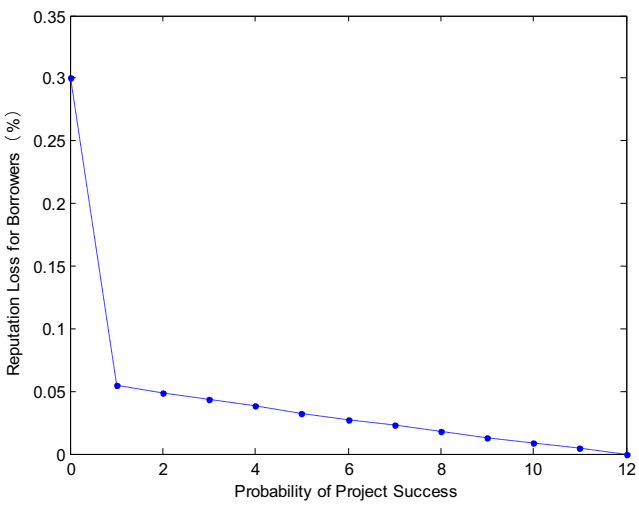

Fig. 5 The impact of the dynamic changes in disconnection time t on borrower social reputation

Table 3 The impact of changes in the number of network disciplinary actions k on the social reputation of borrowers

	k						
Reputation	0	1	2	3	4	5	6
$\psi(t)$	0	0.69%	1.38%	2.08%	2.77%	3.46%	4.15%

borrower's social reputation loss model (9) and other variables are taken under fixed conditions, when the disconnection time point changed from 0 (month) to 1 (month), the borrower's social reputation loss curve dropped sharply; at disconnection times from 1 (month) to 12 (months), the borrower's social reputation loss curve became more shallow and tended to 0.

(3) **The impact of network punishment k on the social reputation of borrowers**

In the case where Hypothesis 1 is established, it is assumed that the number of network disciplinary actions changes by 0, 1, 2, 3, 4, 5, and 6 respectively. If the project success probability p, interest rate r, platform willingness to perform the guaranteen_p, and the disconnection time t take a specific set of values $(p \quad r \quad n_p \quad t) = (0.6 \quad 0.3 \quad 3 \quad 6)$, then, with other conditions unchanged, we examine the impact of changes in network disciplinary conditions on borrower social reputation.

According to Eqs. (7) and (9), we calculate the social reputation loss value of the borrower as shown in Table 3.

We plot the impact of changes in the number of network disciplinary actions on borrower social reputation (Fig. 6).

It can be seen from Fig. 6 that as the number of network disciplinary actions k increases, the borrower's social reputation loss also rises proportionally therewith. When k is 0, that is, when the social network does not take disciplinary action against the borrower's losses, the borrower's social reputation loss is 0.

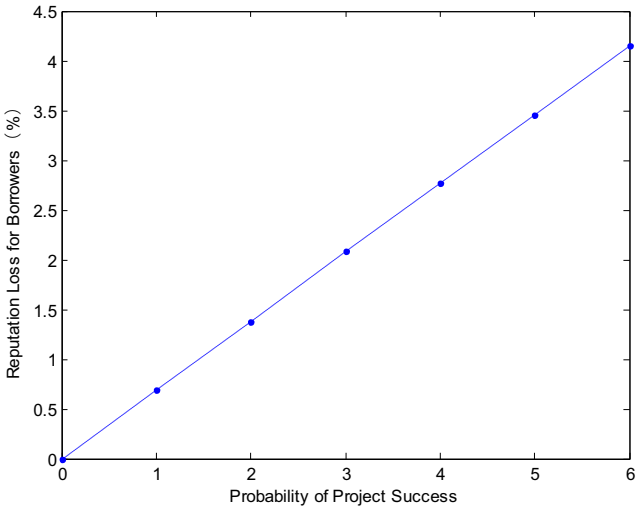

Fig. 6 The impact of changes in the number of network disciplinary actions on the social reputation of borrowers

5 Conclusions

We combine the borrower's on-line social network, off-line social network, and P2P lending platform: considering the impact of the six factors, such as amount of default funds, disconnection time, status of joint guarantee performance, probability of project success, and amount (and severity) of network punishment imposed, on the social reputation loss of the borrower, the innovation establishes the social reputation loss model of the P2P platform borrower's loss of association, gives relevant mathematical propositions and proofs, and applies the model to a case study. The following five conclusions may be drawn:

(1) The borrower's social reputation loss curve decays as the disconnection time increases. If the borrower loses contact at the beginning of the loan, the social reputation loss curve will drop sharply; however, with later disconnection, the social reputation loss curve gradually declined. The earlier the borrower's disconnection time, the greater their loss of social reputation.
(2) The borrower's social reputation loss is maximised upon immediate disconnection: at expiration of the repayment time, the minimum loss is obtained;
(3) The minimum social reputation loss is 0, which arises when the repayment due date is reached. This shows that, if the borrower loses the link on the due date of the repayment, it is because the investment fails and they are unable to raise new funds to repay the loan. At this time, the societal sympathy extended them will exceed the extent of the borrower's loss of the association, so the social reputation of the borrower is unaffected, and the social reputation loss tends to 0;
(4) As the probability of success of the project increases, the borrower's social reputation loss gradually decreases and becomes inversely proportional thereto;
(5) As the number of network disciplinary actions continues to increase, the borrower's social reputation loss increases in proportion thereto.

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Sulin Pang received her PhD from the Institute of Systems Engineering, South China University of Technology in July 2001. She was appointed Professor in Oct. 2005 at Jinan University. She is a director of the Institute of Financial Engineering, Jinan University, a chairman of Guangdong Credit Managers Association, a member of the Financial System Engineering Committee of the Chinese Society of Systems Engineering, and Vice Chairman of the Guangdong Society of Systems Engineering. She has published more than 100 papers and undertakes over 30 projects on behalf of bodies such as The National Natural Science Foundation of China. Her research interests are financial engineering and risk management, emergency management and crisis management.

Junkun Yang , Master of Jinan University, obtained a bachelor's degree in management science from the School of Business Administration, Henan University of Economics and Law in June 2016. He was admitted to the Department of Management Science and Engineering at Jinan University to study for a master's degree in September 2016. He studied under Professor Pang Sulin from Jinan University, engaging in financial engineering and risk management research.