Article

Personal Credit Risk Evaluation Model of P2P Online Lending Based on AHP

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Abstract: With the rapid development of the P2P (peer-to-peer) online lending industry, which is facing significant credit risk, personal credit evaluation is an important method to reduce credit risk. Based on the various indexes of personal credit risk evaluation of domestic and foreign commercial banks, and according to the characteristics of P2P online lending, this paper analyzes the factors that affect the credit risk of P2P online borrowers, introduces the unique risk factors in the field of Internet information, and constructs an index system of personal credit risk evaluation of P2P online lending, which combines qualitative and quantitative indexes, including six major indexes and 21 small indexes. It then quantifies each index and defines the judgment standard of the evaluation results. Using analytic hierarchy process (AHP), expert scoring method, and fuzzy comprehensive evaluation method, this paper establishes a personal credit risk evaluation model of P2P online lending based on AHP method. The public information of two borrowers on the “PaiPai Lending” platform are selected for experimental verification. The results show that the improved personal credit risk evaluation model has better applicability and can evaluate the borrower’s credit status more scientifically, accurately, and comprehensively; thus, it is an effective method of personal credit risk evaluation of P2P online lending.

Keywords: P2P online lending; borrower credit; credit risk; evaluation model; AHP

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1. Introduction

In recent years, with the advancement of inclusive financial policies and the development of Internet plus, big data, and cloud computing, Internet finance has achieved leapfrog growth. The Internet finance peer-to-peer lending platform (P2P) marked the rise of the platform with the establishment of “PaiPai Lending” platform (<https://www.ppdai.com/>) in 2007, and then the number and scale of the platform showed a new trend of rapid growth. After 2013, it has been showing a blowout trend at the speed of 1–2 online companies per day. According to the statistical results of “Home of Online Lending” (<https://www.wdzy.com/>), as of August 2020, the total number of P2P online lending platforms in China has reached 6607, the number of closed and problematic platforms has reached 6277, and only 330 have been in normal operation. With the rapid development of the industry, risks are also exposed; the default of borrowers has caused serious losses to P2P online lending platforms and lenders and personal credit risk has become the main risk faced by P2P online lending platforms. At present, in most cases, the lender is unable to know the credit status of the borrower and cannot make an objective evaluation of the borrower’s credit status before lending. In view of this, this paper attempts to build a model to evaluate the personal credit risk of P2P online lending, so that the lender and online lending platform can better understand the credit status of borrowers and reduce the possibility of loss.

2. Literature Review

At present, there is no specific credit evaluation method for P2P online lending. In terms of evaluation indexes and methods, P2P online lending has unique characteristics. The credit evaluation indexes of P2P online lending are different from those of traditional financial institutions; they emphasize the importance of non-standard data such as gender, age, and photo. Amichai-Hamburger [1] studied the relationship between personality characteristics and network behavior and carried out a large number of empirical studies. The experimental results show that personality characteristics are a highly related factor determining network behavior. Lin [2] confirmed the importance of “soft information” in P2P online lending platform. Sydnor [3] investigated discrimination in online lending bids. They found that this phenomenon is obvious: for darker, older, and obese borrowers, they need to pay higher interest rates, while women or military borrowers pay relatively low interest rates. Freedman [4] found that, compared with traditional financial institutions, investors on P2P online lending platform generally face the problem of lack of “hard information” of borrowers, but the “soft information” in social network platforms can effectively alleviate the lack of “hard information”. From the perspective of gender, Barasinska [5] found that the gender of investors will lead to choosing different borrowers. In general, women are more likely than men to choose relatively low-risk borrowers and demand relatively higher interest rates. Lin [6] showed that borrowers who have many friends have to pay lower borrowing rates and have a lower risk of default. Gonzalez [7,8] discussed the impact of borrowers’ personal characteristics on the investment decisions of P2P online lending investors, showing that the success of obtaining loans was affected by gender, age, and appearance. Zhang [9] empirically analyzed the impact of geographic distance on default risk and drew the following conclusions: the farther the borrower is from the network, the greater is the probability of default; geographic distance increases the cost of platform monitoring and mitigating moral hazard; different loan amounts have different geographic distance impacts on the default risk of the borrower; and, after the revision of the platform, the loan interest rate can reflect the default risk caused by geographic distance. Feng [10] found that female borrowers have lower default risk and higher lending success rate; male borrowers with poor quality (low credit) have a lower success rate of borrowing, and they are easily squeezed out of the online lending market.

In terms of evaluation methods, Angelini [11] developed two neural network systems for credit risk assessment and used the real data of an Italian small enterprise for empirical study. The results show that the neural network is very successful in assessing the possibility of default of borrowers. Jagric [12] built a credit evaluation model using learning vector quantization (LVQ) neural network and compared the model with the Logistic regression model. Finally, the real data of Slovenian Bank were used for empirical research. The results show that the LVQ neural network model is accurate: it is better than logistic regression model and can obtain more accurate evaluation results. Capotorti [13] proposed a hybrid algorithm based on the rough set, conditional probability assessment, and fuzzy set. The results show that the algorithm improves the classification performance of standard rough set theory in credit risk assessment, and they believed that the algorithm is also suitable for other application fields. Du [14] applied the rough set support vector machine method combined with a rough set and support vector machine to personal credit evaluation. The results show that the accuracy and stability of classification results were improved and the prediction effect was better. Based on the approximate support vector machine method, Yao [15] proposed a fuzzy approximate support vector machine. The empirical results show that the model can significantly improve the accuracy of credit risk classification compared with other models. Song [16] determined the personal credit risk evaluation index according to the characteristics of P2P online lending platform and established BP neural network model with the platform borrower’s personal credit rating as the prediction output target, which can predict the borrower’s credit status to a certain extent. To improve the convergence speed and accuracy of the BP neural network, Zhang [17] established a set of lending index system which has guiding significance for

personal credit risk control based on the selection of evaluation indexes and credit rating models of traditional Chinese commercial banks. From the perspective of game theory, Han [18] combined online credit with insurance industry to find a reasonable way for credit risk control of P2P online lending. Wu [19] used the improved fruit fly optimization algorithm as the learning algorithm of the BP neural network to train the weights of the neural network. Pei [20] believed that the cross reproduction of multi- and multi-level information of borrowers in spatial dimension and the continuous presentation of borrowers' social activity information in time dimension can more accurately reflect the credit status of borrowers and then constructed a P2P borrower credit evaluation model based on Bayesian network (BN). Li [21] used a factor analysis method to extract eight "common factors" from 22 independent variables, established a credit evaluation index system, and used the logistic model to predict the behavior of borrowers. This kind of personal credit evaluation index system retained a lot of information and used the logistic model to give the probability of user default. Qi [22] adopted a credit risk assessment model based on the PSO algorithm and BP neural network model. From the perspective of big data credit reporting, Jiang [23] used a group decision-making method to integrate individual learners generated by random forest, neural network, and gradient lifting tree and constructed a P2P credit risk assessment model based on group decision-making. Wang [24] used the logit model to analyze the impact of personal information on default risk probability. Cox proportional risk model was used to analyze the relationship between loan maturity and default risk. At the same time, the risk premium formed by theoretical loan interest rate and actual loan interest rate of different credit rating borrowers was calculated and compared. Yuan et al. [25] first used web crawler technology to obtain the objective data of 80 health platforms. Secondly, they built an early warning index system of credit risk; used the K-means clustering method to build a credit risk early warning model for P2P online lending platforms; and optimized the model. Finally, through the analysis of the 80 health platforms in operation, they conducted a risk assessment and reasonably predicted the risk situation and provided a reference for investors and borrowers [26,27]. Lei [28] adopted crawler technology to conduct qualitative and quantitative analysis on relevant public data, used factor analysis method and logistic regression to quantitatively analyze the relevant information of "RenRen lending" customers, constructed the measurement model of the default probability of P2P online lending borrowers, and put forward reasonable and effective suggestions from investors and platforms. Chen [29] established a logistic regression model to quantitatively study the influencing factors of the credit risk of borrowers on P2P online lending platform, which improved the credibility and interpretability of the model. Cui [30] selected the loan record data of the lending club, a P2P online lending platform in the United States, to empirically study the credit risk of borrowers in P2P online lending through a logistic regression model, Probit regression model, linear discriminant analysis, and random forest model based on ensemble learning. Feng [31] mainly used behavioral asset pricing theory and "RenRen lending" data from 2014 to 2018 to study the influencing factors of pricing bias of P2P online lending borrowers and their relationship with passive default risk.

Inspired by the existing literature, this paper further studies the borrower credit index system and evaluation model from the following perspectives.

First, based on the various indexes of personal credit risk evaluation of domestic and foreign commercial banks, and according to the characteristics of P2P online lending, this paper analyzes the factors that affect the credit risk of P2P online borrowers, introduces the unique risk factors in the field of Internet information, and constructs an index system of personal credit risk evaluation of P2P online lending, which combines qualitative and quantitative indexes, including six major indexes and 21 small indexes. It then quantifies each index and defines the judgment standard of the evaluation results.

Second, using AHP, expert scoring method, and fuzzy comprehensive evaluation method, this paper establishes a personal credit risk evaluation model of P2P online lending based on AHP method.

Third, using the personal information of borrowers published on the “PaiPai Lending” platform, the model is used to score and give credit ratings to test its the applicability.

3. Optimization Framework and Ideas of Personal Credit Risk Evaluation Method for P2P Online Lending

3.1. Optimization Framework

Compared with the traditional credit risk evaluation methods, the credit risk evaluation of P2P online lending under the modern network environment not only includes the evaluation of personal credit risk but also needs to conduct a comprehensive risk evaluation from the perspective of P2P online lending intermediaries and borrowers. Table 1 presents the proposed framework of the credit risk evaluation method for P2P online lending.

Table 1. The framework of credit risk evaluation system for P2P online lending.

Evaluation Object	Evaluation Content	Evaluation Method
Borrower	Risk level	Both qualitative and quantitative analysis
Lender	Investment diversification	Quantitative analysis is main, qualitative analysis is auxiliary
Online lending platform	Compensation mechanism	Qualitative analysis

3.2. The Introduction of Basic Personal Credit Risk Evaluation Method

1. American FICO credit evaluation method

According to the credit evaluation principle of FICO in the United States, the evaluation of personal credit risk mainly adopts the method of model calculation and sets up a credit scoring mechanism ranging from 325 to 900 points for each financial credit customer. The loan opportunity is proportional to the score, and the score is inversely proportional to the default risk. The specific factors included in the American FICO credit evaluation method include the age of credit account, customer credit history, and the number and type of credit account. According to the actual data for the FICO credit evaluation system in the United States, Table 2 shows the specific indexes of scoring.

Table 2. American FICO credit evaluation method.

Scoring Items	Proportion of Project Scores	Specific Evaluation Indexes
Credit type currently used	10%	Number of account types
		Specific account types
New credit accounts	10%	Number of new credit accounts
		Aging of new credit account
		Number of credit accounts applied
Historical credit status	15%	How long is the credit used
Number of credit accounts	30%	Repayment of accounts
		Utilization rate of credit account
		Number of credit accounts to be repaid
Historical repayment	35%	Repayment record of credit account
		Overdue repayment
		Public record of credit consumption

2. German IPC micro lending technology evaluation method

To establish a lending and financing platform for small and micro enterprises and reasonably evaluate the credit risk of their customers, Germany established the IPC micro

lending technology evaluation method. In this method, the credit risk evaluation of small and micro enterprises should consider the following aspects: the borrower's solvency, the borrower's willingness to repay, and the control of the borrower's solvency credit risk. For each link of credit risk evaluation, the evaluation agency has listed targeted evaluation indexes, as shown in Table 3. Generally, these indexes can be divided into hardware information and software information according to their nature. Personal finance, income, and fixed assets constitute the hardware information content, while personal education and life constitute the software information content. The details are shown in Table 3.

Table 3. German IPC micro lending technology evaluation method.

Information Type	Specific Evaluation Index
Soft information	Age, Gender
	Education
	Race
	Marital status, Family status
	Personality traits
Hard information	Personal income
	Relevant business information

3. Credit evaluation methods of Chinese commercial banks

According to the current situation of credit risk evaluation of Chinese major commercial banks, the credit risk evaluation methods adopted by each bank are different, and the evaluation indexes are also different, as shown in Table 4.

Table 4. Credit evaluation methods of Chinese Commercial Banks.

		China Construction Bank	Bank of Communications	Industrial and Commercial Bank of China	China Minsheng Banking Corp	China Everbright Bank
Personal basic information	Age	✓	✓	✓	✓	✓
	Gender	✓	✓	✓		✓
	Healthy	✓				✓
	Marital status	✓	✓	✓		✓
	Account status	✓	✓	✓	✓	✓
	Educational background	✓	✓	✓	✓	✓
	Work unit	✓	✓		✓	✓
	Working years	✓	✓	✓	✓	✓
Economic situation	Personal income	✓	✓	✓	✓	✓
	Personal assets	✓		✓		✓
	Average household income	✓	✓	✓	✓	
Personal credit status	Accounts with the bank	✓	✓	✓	✓	✓
	Credit record	✓	✓	✓	✓	✓

Taking Chinese large state-owned commercial banks as an example, the personal credit risk evaluation methods adopted by large state-owned commercial banks mainly

focus on personal repayment ability evaluation indexes. For individual businesses, small- and medium-sized enterprises, and small and micro enterprises, in addition to assessing whether the owners of enterprises have repayment ability, they should also evaluate the business status and assets of enterprises and debt situation. The credit risk evaluation of Chinese commercial banks is often based on a certain credit system, which requires a comprehensive investigation and analysis of the borrower's credit status and risk. At present, there is still a lack of a unique credit risk evaluation system in the field of online lending, and there is also a lack of sufficient professional personnel in the field of financial credit risk evaluation and investigation to implement credit risk evaluation. Relying on the existing online lending platform, it is difficult to achieve an offline lending subjective qualification and credit audit as in Germany. According to the existing traditional credit risk evaluation model of commercial banks, personal credit risk evaluation still occupies the main position. The survey content mainly includes personal basic information, occupation, income, and family assets. These evaluation indexes are more consistent with the current construction of the personal credit system. Therefore, when optimizing the P2P online lending credit risk system, they can be directly used as a reference. The project template is simplified. Learning from the current traditional commercial bank's personal credit risk evaluation scheme, as well as learning from the experience of Germany and the United States about the credit risk system, is very useful for the optimization of P2P online lending credit evaluation method.

3.3. Optimization Ideas

In view of the basic methods of traditional personal credit risk evaluation and the analysis of their advantages and disadvantages introduced, this section develops the optimization ideas of risk evaluation methods suitable for the development of P2P online lending. The main points to further optimize the P2P online lending credit evaluation method are summarized as follows.

The first is to learn from the traditional credit risk evaluation methods and establish a personal credit evaluation system. To evaluate borrowers' credit risk, we can rely on the risk rating method to evaluate the risk coefficient of their loan project. However, at present, the risk rating of loan projects is generally applicable to large- and medium-sized loan projects, which is still quite different from the risk rating of personal credit. Based on the personal credit rating method of China Construction Bank, considering the current situation of the personal credit system, the characteristics of online lending and the availability of information data, through the comparative analysis of typical personal credit risk evaluation projects and indexes, as well as comparing the research conclusions of domestic and foreign scholars on personal credit evaluation, this paper establishes a risk evaluation model suitable for the online lending evaluation system.

The second is to use the investment theory of "do not put all your eggs in one basket" as reference to evaluate the degree of diversification of investment funds when evaluating the credit risk of the lender. To reduce the investment risk, the risk of the lender's investment funds is spread to different channels as far as possible, which meets the requirements of maximizing the investment income and is a good risk control method. This method of risk diversification is suitable for individual investors, but it is not suitable for the credit risk management of traditional commercial banks two reasons: First, as an independent financial institution, traditional commercial banks are different from individual investors. They can only bear the loan risk by themselves and cannot disperse the investment risk brought by loan funds. Second, diversifying funds and increasing the number of loans will increase the bank's loan management cost. For P2P online lending platforms for lending transactions, as individual lenders, the authorization and issuance of loans are directly related to the interests of investors. From the perspective of creditors, analyzing the capital risk of loans to different borrowers can reduce the risk of default and reduce the amount a single loan can reduce capital losses, thus reducing the role of loan capital risk coverage. From the perspective of the overall creditors, due to the

involvement of lending risk, one investor has the loss risk in online lending, and other investors also suffer from the risk, becoming the risk co-bearers. Similarly, if the loan funds on the online lending platform are issued by different investors, the operational risk of the entire platform can be reduced to a certain extent.

Third, for the debtor's solvency and risk assessment, it often takes whether the creditor's compensation mechanism is reasonable and scientific as the reference index. In the traditional lending field, many original debtors will bear compensation liability, which should be borne by one person because of the platform's transmissibility and transferability of loan fund risk, resulting in multiple debtors bearing the compensation liability. Due to the shifting nature of the online lending platform's liability to the debtor, many overdue repayments are constantly included in the new default blacklist. If there is insolvency on the online lending platform, the principal promised to be paid in advance will also be lost, and the compensation mechanism can only be a dead letter, which greatly affects the reliability of credit risk management.

4. Hypotheses and Index System Construction of Personal Credit Risk Evaluation of P2P Online Lending

4.1. Conceptions and Hypotheses

This paper is based on the various indexes of personal credit risk evaluation of domestic and foreign commercial banks, combined with the research results of domestic and foreign scholars on Internet credit evaluation indexes (American FICO credit evaluation method, IPC micro-credit technology evaluation method, etc.), and refers to the statistical analysis of China's P2P online lending borrowers in the "Blue Book of China's online lending industry" [32] jointly released by "Home of Online Lending" and the SME research center of Peking University HSBC Business School. According to the characteristics of P2P online lending, this paper analyzes the factors that affect the credit risk of P2P online lending borrowers and adds unique risk factors in the field of Internet information.

Based on the comprehensive analysis of the characteristics of credit risk, this paper puts forward the following conceptions and hypotheses for the establishment of the personal credit risk evaluation system in the network credit risk.

C1: By adjusting the indexes of the traditional personal credit rating method of China Construction Bank, six primary indexes are obtained. The original indexes of "basic information, occupation information and economic status" are retained, and the indexes of "certification status" are supplemented. In the online lending platform, the two sides cannot meet each other, they can only communicate with each other through the Internet. When evaluating the risk of the borrower, we should also strengthen the authentication of the borrower's identity. This is based on the credit risk evaluation experience of small and micro enterprises in Germany.

Hypothesis 1 (H1). *"Certification situation" index is more suitable for the characteristics of loan transactions on the network platform and meets the needs of credit risk evaluation in the network environment.*

C2: The statistical data of online transactions of nearly 10,000 users of a large number of British online lending platforms in recent years are studied, and it is found that there is a direct proportion between the overdue repayment rate and the loan term. The overdue repayment rate and default rate of the debtor will increase with the increase of the loan term. Therefore, this paper introduces the evaluation index of the "borrowing period" for the risk evaluation system of online lending borrowers.

Hypothesis 2 (H2). *The establishment of the "loan term" index will more accurately assess the risk of borrower's default.*

C3: Considering the difference between the evaluation index of the online lending platform and the bank, the index of "relationship with the bank" is changed to "loan record".

Hypothesis 3 (H3). *The change of the “relationship with the bank” index to the “loan record” index is more suitable for the online lending operation mechanism, so as to comprehensively consider and evaluate the borrower’s credit status.*

C4: To evaluate some evaluation indexes other than conventional indexes, the evaluation indexes of “monthly repayment/monthly disposable income” and “debt-to-income ratio” are added.

Hypothesis 4 (H4). *The establishment of the evaluation index of “monthly repayment/monthly disposable income” and “debt-to-income ratio” will more accurately evaluate the borrower’s repayment ability and willingness.*

C5: Qualitative analysis of each evaluation index, based on the calculation of the original quantitative weight, establishes a mechanism to distinguish the importance of the borrower’s credit risk evaluation, which makes the evaluation score of the borrower more objective and reasonable

Hypothesis 5 (H5). *After calculating the weight of each index, the borrower credit score will be more accurate.*

According to the above adjustment of the borrower risk evaluation indexes of the current P2P online lending credit risk evaluation, the details of the evaluation indexes are explained in detail, which is mainly divided into three parts: scoring items and index system, quantitative standards of i index, and criteria for evaluation results.

4.2. Scoring Items and Index System

The scoring items can be divided into basic Items A and additional Items B. The basic items include the borrower’s basic information A1, career information A2, economic status A3, and certification status A4. Additional items include loan term B1 and loan record B2. The loan term item is an added item based on studying the actual situation of foreign loan and default rate, and the loan record takes into account the borrower’s P2P online loan history. The past loan history of the borrower will not have any impact on basic Item A, as shown in Table 5.

Basic Items A are not affected by the borrower’s previous loan experience, while additional Items B are only applicable to borrowers with loan records.

4.3. Quantitative Standard of Personal Risk Evaluation Index

This paper draws on the survey and analysis data of residents’ personal information in the book “Empirical Analysis of Chinese Residents’ Income Distribution” and the opinions of professionals who have long been engaged in personal credit business in commercial banks to derive the quantitative standard of personal risk evaluation index of P2P online lending. The details are shown in Table A1 in the Appendix A.

4.4. Criteria for Evaluation Results

Evaluation of the borrower’s credit risk coefficient, 4–6 grades are often used, namely AA, A, B, C, D, and HR, as shown in Table 6.

Table 5. Scoring items and index system for personal risk evaluation of P2P online lending.

Item	Primary Index	Secondary Index
Basic Item A	Basic information A1	Gender A11
		Age A12
		Degree of education A13
		Years of residence in local area A14
		Marital status A15
	Career information A2	Post A21
		Occupation type A22
		Current unit years A23
	Economic status A3	Monthly income A31
		Debt-to-income ratio A32
		Monthly repayment/monthly disposable income A33
		Housing situation A34
		Vehicle condition A35
	Certification status A4	Mobile phone authentication A41
		Video authentication A42
		Identity authentication A43
		Central bank credit report A44
Additional Item B	Loan term B1	Loan term B11
	Loan record B2	Overdue times B12
		Maximum overdue days B13
		Number of repayments B14

Table 6. Criteria for credit rating.

Grade	Score	Explain
AA	>95	The borrower's credit status is excellent, with very strong repayment ability and willingness
A	85–95	The borrower's credit status is very good, with strong repayment ability and repayment willingness
B	75–85	The borrower's credit status is good, with moderate strong repayment ability and repayment willingness
C	65–75	The borrower's credit status is general, and the repayment ability and repayment willingness are a little weak
D	55–65	The borrower's credit status is poor, solvency and repayment willingness are weak
HR	<55	The borrower's credit status is very poor, solvency and repayment willingness are very weak

5. Construction of Personal Credit Risk Evaluation Model for P2P Online Lending

5.1. Using Analytic Hierarchy Process to Calculate Index Weight

The whole index system is constructed by the target layer and the index layer. The specific hierarchical model is shown in Table 1. This paper uses expert analysis to determine the relative importance of indexes. In pairwise comparison between indexes, Satty's 1–9 ratio scale [33,34] (Table 7) is used to compare the importance of internal indexes between the criterion layer and the variable layer and obtain the relative scale value of the internal indexes of the layer.

Table 7. Standard degree of judgment matrix at all levels.

Importance Intensity	Definition
1	Equal importance
3	Moderate importance of one over another
5	Strong importance of one over another
7	Very strong importance of one over another
9	Extreme importance of one over another
2,4,6,8	Intermediate values
Reciprocal	If the ratio of the importance of element i to element j is a_{ij} , the ratio of the importance of element j to element i is $a_{ji} = 1/a_{ij}$

The judgment matrix of each level index is obtained by experts in related fields according to their work and practical experience. The specific index judgment matrix is shown in Table 8.

Table 8. The judgment matrix of the first level index.

	Basic Information A1	Career information A2	Economic Status A3	Certification Status A4
Basic information A1	1	1	1/2	3
Career information A2	1	1	1/3	3
Economic status A3	2	3	1	4
Certification status A4	1/3	1/3	1/4	1

The calculation process of the first level index single-sort is as follows:

1. The product square root method is used to calculate the geometric mean value ($\bar{W}_i$):

$$\bar{W}_i = \left(\prod_{j=1}^n a_{ij} \right)^{\frac{1}{n}} \quad i, j = 1, 2, \dots, n \quad (1)$$

where a_{ij} represents the elements of the i th row and j th column of the original judgment matrix, n represents the number of indexes, and $\bar{W}_i$ represents the geometric average value of the i th row of the original judgment matrix.

The results are as follows:

$$\bar{W} = \begin{pmatrix} 1.1067 \\ 1.0000 \\ 2.2134 \\ 0.4082 \end{pmatrix} \quad (2)$$

2. The geometric mean of each row is normalized to obtain the eigenvector:

$$W_i = \frac{\bar{W}_i}{\sum_{j=1}^n \bar{W}_j} \quad i, j = 1, 2, \dots, n \quad (3)$$

where W_i represents the weight of the i th index, n represents the number of indexes, and $\bar{W}_i$ represents the geometric average of the i th row of the original judgment matrix.

The calculation results of the weight coefficient of the first level index are as follows:

$$W = \begin{pmatrix} 0.2341 \\ 0.2115 \\ 0.4681 \\ 0.0863 \end{pmatrix} \quad (4)$$

3. Calculate the maximum eigenvalue of the judgment matrix $\lambda_{\max}$:

$$\lambda_{\max} = \frac{1}{n} \sum_{i=1}^n \frac{(\sum_{j=1}^n a_{ij} W_j)}{W_i} \quad i, j = 1, 2, \dots, n \quad (5)$$

where a_{ij} represents the elements in the i th row and j th column of the original judgment matrix, n represents the number of indexes, W_i represents the weight of the i th index, and $\lambda_{\max}$ represents the maximum eigenvalue of the judgment matrix.

From this, the maximum eigenvalue can be calculated: $\lambda_{\max} = 4.0620$

4. Calculate the consistency index CI and the consistency ratio CR:

$$CI = \frac{\lambda_{\max} - n}{n - 1} \quad (6)$$

When $n = 2$, the positive reciprocal matrix of order 2 is always consistent, so there is no need to check the consistency. When n is greater than 2, the consistency of the matrix is represented by CR. $CR = CI/RI$. RI values are shown in Table 9.

Table 9. Average random consistency index.

Order	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

It is calculated as $CI = 0.0207$.

When $n = 4$, $RI = 0.90$, and $CR = 0.0230$, thus $CR < 0.1$; therefore, the first level index judgment matrix and consistency test meet the requirements.

According to the above results, the weight and consistency of the residual matrix can be calculated. The specific calculation results are shown in Tables A2–A6 in the Appendix B.

Using the results of single-sort of all indexes in the same layer, the weight of the importance of all factors in the previous level can be calculated; this is the hierarchical whole-sort.

The results of this example are shown in Table A7 in the Appendix B. The whole-sort in the table is the comprehensive weight corresponding to each index.

Finally, it is necessary to check the consistency of the hierarchical whole-sort, as shown below.

$$\begin{aligned} CI_{whole-sort} &= \sum_{i=1}^4 W_i CI_i = 0.2341 * 0.0345 + 0.2115 * 0.0091 \\ &\quad + 0.4681 * 0.0126 + 0.0863 * 0.0035 \\ &= 0.0162 \end{aligned} \quad (7)$$

$$\begin{aligned} RI_{whole-sort} &= \sum_{i=1}^4 W_i RI_i = 0.2341 * 1.12 + 0.2115 * 0.58 \\ &\quad + 0.4681 * 1.12 + 0.0863 * 0.90 \\ &= 0.9868 \end{aligned} \quad (8)$$

$$\begin{aligned} CR_{whole-sort} &= CI_{whole-sort} / RI_{whole-sort} = 0.0162 / 0.9868 \\ &= 0.0164 < 0.1 \end{aligned} \quad (9)$$

Therefore, it meets the consistency test. W_i represents the weight of the i th index in the first-level index, CI_i represents the consistency index of the corresponding matrix of the i th index of the first level index, and RI_i represents the average random consistency index of the corresponding matrix of the i th index of the first level index.

5.2. Personal Credit Risk Evaluation Model of P2P Online Lending

Combined with the quantitative standards in Table 2, the standardized score value X_{ij} of the j th second-level index under the i th first-level index can be obtained. Combined with the weight of each index calculated above, the evaluation score Z_1 of the basic information can be obtained as follows:

$$Z_1 = \sum_{i=1}^n (w_i \sum_{j=1}^m w_{ij} x_{ij}) \quad (i = 1, 2, 3, \dots, n; j = 1, 2, 3, \dots, m) \quad (10)$$

Since the borrower's credit rating adopts the percentage system, the credit evaluation score should also be converted into the percentage system: $Z = 10 * Z_1 + Z_2$; the obtained Z is the borrower's credit score. Among them, Z_1 is the comprehensive evaluation value of the basic score of the evaluated object, Z_2 is the additional score of the evaluated object, and Z is the total score.

6. Empirical Analysis

6.1. Source of Instance Data

In the empirical process, the public information of two borrowers on the platform of "PaiPai Lending" was selected to evaluate the credit of borrowers with the credit evaluation model of this paper.

Borrower A is from Chuzhou, Anhui, male, 25 years old, with a bachelor's degree, unmarried, and childless. His average monthly income is RMB 20,000. This borrower has run a sushi restaurant in Chuzhou City for about two years and has lived at the current address for three years. The sushi restaurant is a rental shop with an annual rent of RMB 90,000. A mortgage purchase of a 95 square meters residential housing, term of 20 years, monthly repayment amount of RMB 1800, has been paid back for seven months. He owns a minivan worth RMB 70,000. The total monthly expenditure is about RMB 11,400, including RMB 2000 for food and beverage, RMB 900 for automobile and insurance, RMB 7500 for house rent, RMB 500 for mobile phone and Internet, and RMB 500 for other expenses. Through the borrower's credit report, we know that the borrower has five credit cards, which have been overdue two times in total. The longest overdue time is 10 days, and the overdue reason is not the subjective intention. This borrower pays the mortgage on time every month. The debt-to-income ratio is 37.56%, and he has no bad judicial record. The purpose of the loan is to expand the business project. This borrower plans to borrow RMB 500 million with an annual interest rate of 20% and a term of six months, with the same amount of principal and interest to repay. The average monthly repayment amount of principal and interest is RMB 8826.14, and the percentage of monthly repayment amount to monthly disposable income is 44.13%. This borrower has no loan records from other platforms, and borrowing on the P2P online lending platform is his first behavior. He has passed the mobile phone authentication and identity authentication, and the bank credit report has also been submitted, but video authentication has not been carried out.

Borrower B is male, 36 years old, with a master's degree, married, and has a son who has just started to primary school. This borrower has lived in Jiangsu for six years and has been running a technology company for four years. The average monthly income is RMB 40,000. He has just bought a 170 square meter commercial house with a mortgage and has obtained the purchase contract. He owns an RMB 300,000 private car under his name, and his family is in stable condition. Currently, he needs long-term borrowing due to expanding operations. He has three loan records in commercial banks in Jiangsu Province (all paid off). In August 2017, he borrowed RMB 50,000 from China Everbright Bank for

12 months. The purpose of the loan is for personal consumption, and the outstanding debt is RMB 16,667. The debt-to-income ratio is 49.46%, and he has no bad judicial record. The monthly disposable amount of this borrower in the future repayment period is RMB 42,746. He expects to borrow RMB 150 million with an annual interest rate of 20%, with a term of six months and repayment of the same amount of principal and interest on a monthly basis. The average monthly repayment amount of principal and interest is RMB 26,478.42. The percentage of monthly repayment amount to monthly disposable income is 61.94%. Video authentication, mobile phone authentication, and identity authentication have been passed, and the bank credit report has also been submitted.

6.2. Evaluation Results

According to the above information about Borrowers A and B, the personal credit risk evaluation results of the two borrowers are shown in Table 10.

Table 10. Credit evaluation index scores of borrowers.

Second Level Index	Borrower A	Borrower B	Second Level Index	Borrower A	Borrower B
Gender A11	5	5	Housing situation A34	3	3
Age A12	7	10	Vehicle condition A35	3	5
Degree of education A13	8	10	Mobile phone authentication A41	10	10
Years of residence in local area A14	6	8	Video authentication A42	0	10
Marital status A15	5	10	Identity authentication A43	10	10
Post A21	3	3	Central bank credit report A44	10	10
Occupation type A22	9	9	Loan term B11	4	4
Current unit years A23	4	4	Overdue times B12	−5	0
Monthly income A31	10	10	Maximum overdue days B13	−4	0
Debt-to-income ratio A32	8	6	Number of repayments B14	0	4
Monthly repayment/monthly disposable income A33	8	6			

The P2P personal credit risk evaluation model of this paper is used to calculate the credit scores of Borrowers A and B. The main calculation results are shown in Table 11. The credit score of Borrower A is 63.60, and the credit rating is D. Borrower B's credit score is 79.14, and the credit rating is B. The results show that Borrower A's personal credit status is poor, with weak solvency and repayment willingness; Borrower B's personal credit status is good, with moderate strong repayment ability and repayment willingness.

6.3. Analysis of Evaluation Results

It can be seen that the personal credit risk evaluation model based on the AHP method is more applicable:

1. When evaluating the professional status of borrowers, the traditional personal credit evaluation index focuses on the evaluation of individuals with fixed units, which is not suitable for the evaluation of individual business information. In this paper, considering that the types of P2P online lending borrowers are diverse, and the personal situation is complex and changeable, the division of occupation is adjusted, and the index project is designed according to the characteristic distribution of P2P online lending borrowers. Compared with the traditional personal credit evaluation standard, the occupational evaluation index proposed in this paper is more in line with the actual situation.

2. In terms of personal monthly income and household monthly income, the borrower's data value is significantly higher than the evaluation standard given by the bank, and the credit score is the highest. The reason is that borrowers operate small-scale businesses, and their monthly income is much higher than that of ordinary wage earners. However, high monthly income does not mean that the monthly liquidity is large. As a result, banks will overestimate the economic situation of such borrowers simply by using monthly income or household monthly income. The evaluation system designed in this paper not only includes monthly income but also introduces the ratio of monthly repayment to monthly disposable income and asset-to-liability ratio, which can measure the economic status of borrowers more scientifically and accurately.
3. The bank focuses on the relationship between the borrower and the bank and seldom considers other credit conditions of the borrower. For example, if the borrower has a loan history in the bank, when the evaluation criteria of the bank are used, the score of the borrower will be increased. However, for P2P online lending, this situation will not benefit the borrower's credit evaluation, and it is impossible to get additional points. In the personal credit evaluation system of P2P online lending constructed in this paper, if the borrower has loans in the bank, they should be included in the proportion of assets and liabilities. If the bank borrows too much, the debt will increase, which will reduce the borrower's economic repayment ability and reduce the credit score and grade. The evaluation index system designed in this paper focuses on the borrowing history of borrowers on P2P online lending and uses the credit report of the central bank to understand other borrowing histories of borrowers, thus the evaluation results are more accurate and comprehensive.

Table 11. Calculation results of the borrower's credit score.

Total score		W _i	X _i		W _{ij}	X _{ij}	
Borrower A	Borrower B		Borrower A	Borrower B		Borrower A	Borrower B
Z ₁ = 6.8604 Z ₂ = −5 Z = 63.60	Z ₁ = 7.1144 Z ₂ = 8 Z = 79.14	0.2341	5.9136	8.5981	0.1164	5	5
					0.1417	7	10
					0.0735	8	10
					0.4098	6	8
					0.2586	5	10
		0.2115	6.0479	6.0479	0.1692	3	3
					0.4434	9	9
					0.3874	4	4
					0.1600	10	10
		0.4681	7.5411	6.3222	0.2483	8	6
					0.4359	8	6
					0.0810	3	3
					0.0747	3	5
		0.0863	7.7265	10.0000	0.1222	10	10
					0.2274	0	10
					0.2274	10	10
					0.4231	10	10

7. Conclusions

Credit evaluation is an indispensable credit certificate in lending service and an important decision index for investors to invest. Compared with the traditional bank's borrower credit evaluation, the credit evaluation of P2P online lending borrowers is not mature, and there is no recognized evaluation method for P2P online lending platforms. Therefore, it is necessary to continue to research this aspect. In the extant literature, for the P2P online lending evaluation index, the main research of scholars is to analyze a single index. In terms of evaluation methods, at present, most scholars use qualitative analysis. In recent years, the quantitative analysis methods in the literature mostly establish a single model to explore the influence of relevant indicators on personal credit evaluation and have not considered the impact of different indicators on the evaluation results.

This paper makes the following contributions:

1. Based on the various indexes of personal credit risk evaluation of domestic and foreign commercial banks, and according to the characteristics of P2P online lending, this paper introduces the unique risk factors in the field of Internet information and constructs an index system of personal credit risk evaluation of P2P online lending, including six major indexes and 21 small indexes.
2. This paper uses a combination of qualitative and quantitative methods. Through the comparison of the importance of indexes, the judgment matrix of the index is obtained. Then, the index weight is obtained by AHP, and the consistency test of each index is carried out.
3. The model was tested through empirical analysis, using the data of "PaiPai lending" website to verify the model. The experimental results show that the credit evaluation model based on AHP can distinguish the scores. The improved model is more suitable for the characteristics of network platform loan transaction and meets the needs of credit risk evaluation in the network environment compared with the traditional evaluation model by adding the relevant indexes such as "certification", "loan record", "loan term", "debt-to-income ratio" (H1). The evaluation results are more accurate (H2, H4, and H5) and more suitable for the operation mechanism of online lending (H3). The overall credit evaluation model has application value. It is expected that the credit evaluation model in this paper can contribute to the credit evaluation research of the borrowers of P2P online lending platform in the future and the formulation of relevant platform risk management policies.

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Appendix A

Quantitative standards of personal risk evaluation t indexes for P2P online lending.

Table A1. Quantitative standards of personal risk evaluation t indexes for P2P online lending.

Item	Index	Quantitative Standards			
Basic item	Gender	Female	Male		
		10	5		
	Age	21–25/51–55	26–30/46–50	31–35/41–45	36–40
		7	8	9	10
	Degree of education	Postgraduate	Undergraduate	Junior college/Technical secondary school	High school
		10	8	6	4
	Years of residence in local area	16–20	11–15	6–10	3–5
		10	9	8	6
	Marital status	Married	Unmarried	Divorce	
		10	5	0	
	Post	Institutions	Bureau level and above	Division level	Section level
			10	8	5
	Company	Company representative	Department head	Self-employed	Employee
		8	5	3	0
	Occupation type	Class I/II	Class III	Class IV	Class V
		10	9	8	6
	Current unit Years	1 year	1–5 years	5–8 years	8–10 years
		2	4	6	8
	Monthly income (RMB)	>20,000	10,001–15,000	6001–10,000	2001–6000
		10	9	7	4
	Debt-to-income ratio	<30%	31–40%	41–60%	61–70%
		10	8	6	4
	Monthly repayment/monthly disposable income	>81%	66%–80%	46%–65%	31%–45%
		0	2	6	8

Table A1. Cont.

Item	Index	Quantitative Standards				
	Housing situation	Own >150 m ²	Own 100–150 m ²	Own 50–100 m ²	Own <50 m ² /Mortgage	Renting
		10	8	5	3	0
	Vehicle condition	>50 million	30–50 million	30–10 million	<10 million	No car
		10	8	5	3	0
	10 points for identity authentication, video authentication, and mobile phone authentication, and 0 points for not passing the verification					
	Central bank credit report	Excellent	Good	Moderate	Poor	
		10	9	7	0	
Additional item	Loan term	3 months	6 months	9 months	12 months	>18 months
		5	4	3	2	0
	Overdue times	The first time overdue is −2 points, and each additional time overdue is −3 points/time, with no upper limit.				
	Maximum overdue days	>61 days	31–60 days	16–30 days	7–15 days	0–7 days
		−10	−8	−6	−4	−2
	Number of repayments	2 points will be given for the first repayment, and one point will be added for each repayment in the future. The maximum cumulative score is 10 points.				

Appendix B

Weight and consistency test results of each index.

Table A2. Weight and consistency test results of each index of first level indexes.

	Basic Information A1	Career Information A2	Economic Status A3	Certification Status A4	Weight
Basic information A1	1	1	1/2	3	0.2341
Career information A2	1	1	1/3	3	0.2115
Economic status A3	2	3	1	4	0.4681
Certification status A4	1/3	1/3	1/4	1	0.0863
Consistency test	$\lambda_{\max} = 4.0620$, CI = 0.0207, CR = 0.0230 < 0.1, pass the consistency test				

Table A3. Weight and consistency test results of A1 indexes.

Basic Information A1	Gender A11	Age A12	Degree of Education A13	Years of Residence in Local Area A14	Marital Status A15	Weight
Gender A11	1	1/2	2	1/3	1/2	0.1164
Age A12	2	1	2	1/3	1/3	0.1417
Degree of education A13	1/2	1/2	1	1/5	1/3	0.0735
Years of residence in local area A14	3	3	5	1	2	0.4098
Marital status A15	2	3	3	1/2	1	0.2586
Consistency test	$\lambda_{\max} = 5.1379$, CI = 0.0345, CR = 0.0308 < 0.1, pass the consistency test					

Table A4. Weight and consistency test results of A2 indexes.

Career Information A2	Post A21	Occupation Type A22	Current Unit Years A23	Weight
Post A21	1	1/3	1/2	0.1692
Occupation type A22	3	1	1	0.4434
Current unit years A23	2	1	1	0.3874
Consistency test	$\lambda_{\max} = 3.0183$, CI = 0.0091, CR = 0.0158 < 0.1, pass the consistency test			

Table A5. Weight and consistency test results of A3 indexes.

Economic Status A3	Monthly Income A31	Debt-to-Income Ratio A32	Monthly Repayment/Monthly Disposable Income A33	Housing Situation A34	Vehicle Condition A35	Weight
Monthly income A31	1	1/2	1/3	2	3	0.1600
Debt-to-income ratio A32	2	1	1/2	3	3	0.2483
Monthly repayment/monthly disposable income A33	3	2	1	5	5	0.4359
Housing situation A34	1/2	1/3	1/5	1	1	0.0810
Vehicle condition A35	1/3	1/3	1/5	1	1	0.0747
Consistency test	$\lambda_{\max} = 5.0505$, CI = 0.0126, CR = 0.0113 < 0.1, pass the consistency test					

Table A6. Weight and consistency test results of A4 indexes.

Certification Status A4	Mobile Phone Authentication A41	Video Authentication A42	Identity Authentication A43	Central Bank Credit Report A44	Weight
Mobile phone authentication A41	1	1/2	1/2	1/3	0.1222
Video authentication A42	2	1	1	1/2	0.2274
Identity authentication A43	2	1	1	1/2	0.2274
Central bank credit report A44	3	2	2	1	0.4231
Consistency test	$\lambda_{\max} = 4.0104$, $CI = 0.0035$, $CR = 0.0038 < 0.1$, pass the consistency test				

Table A7. Comprehensive weight.

First Level Index	Single-Sort	Second Level Index	Single-Sort	Whole-Sort
Basic information A1	0.2341	Gender A11	0.1164	0.0273
		Age A12	0.1417	0.0332
		Degree of education A13	0.0735	0.0172
		Years of residence in local area A14	0.4098	0.0959
		Marital status A15	0.2586	0.0605
Career information A2	0.2115	Post A21	0.1692	0.0358
		Occupation type A22	0.4434	0.0938
		Current unit years A23	0.3874	0.0819
Economic status A3	0.4681	Monthly income A31	0.1600	0.0749
		Debt-to-income ratio A32	0.2483	0.1162
		Monthly repayment/monthly disposable income A33	0.4359	0.2040
		Housing situation A34	0.0810	0.0379
		Vehicle condition A35	0.0747	0.0350
Certification status A4	0.0863	Mobile phone authentication A41	0.1222	0.0105
		Video authentication A42	0.2274	0.0196
		Identity authentication A43	0.2274	0.0196
		Central bank credit report A44	0.4231	0.0365

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