Research Article

Evaluating Reputation of Internet Financial Platform: An Improved Fuzzy Evaluation Approach

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Recent frequent “thunderstorm incidents” of the internet financial platforms (IFPs) have caused the panic of investors. In order to measure and reduce the investment risk of IFPs, the focus of this study is to evaluate the reputation of IFPs regarding investment risk. First, the reputation evaluation indicator system of IFPs is constructed from two dimensions of direct and indirect reputations. Then, based on this system, an improved fuzzy evaluation approach (IFEA) integrating the method of fuzzy comprehensive evaluation (FCE), the analytic hierarchy process (AHP), and the factor analysis (FA) are proposed for evaluating the reputation of IFPs. Finally, a case study based on the data of 20 peer-to-peer (P2P) lending platforms from “Home of Online Loans” (HOL) in China is used to illustrate the IFEA. Results show that the IFEA can reduce uncertainty and randomness in the determination process of indicator weight and membership degree and therefore accurately obtain the reputation level of IFPs and help investors make better decisions. Meanwhile, the key factors in determining the reputation of IFPs are identified, thereby improving the reputation level of the IFPs.

1. Introduction

With the increasing application of emerging information technology such as cloud computing (CC), big data (BD), and artificial intelligence (AI) in the financial field, Internet financial platforms (IFPs) have rapidly spread around the world [1]. IFPs include platforms of peer-to-peer (P2P) lending, crowd-funding, online banking, and supply chain finance [2, 3]. The emergence of IFPs not only effectively broadens the business boundary of financial services but also promotes the effectiveness of optimal allocation of financial resources. However, the credit risk and liquidity risk are becoming more serious problems due to the cross-market operating characteristics of IFPs [4, 5]. For example, because of malicious fraud, improper operation, and loss of contact, more than 6000 P2P lending platforms have gone bankrupt in China by the beginning of 2021, which brought huge economic loss to investors [6]. Besides, frequent “thunderstorm incidents” of IFPs such as the “Ezubao” event in 2015, the “Tuandaiwang” event in 2019 exposed the huge investment risks of IFPs. In this context, investors often encounter great investment risk in the area of the Internet finance.

As an invisible contract, reputation plays a positive role in reducing the investment risk of IFPs [7]. Since a good reputation can attract more investors to invest [8, 9], IFPs often try their best to restrain their default behaviors for long-term benefits. It was proved that reputation had a positive impact on the establishment of the trust mechanism of the P2P lending market [10] and the reduction of the defaults of the P2P lending borrowers [11]. In addition, many third-party credit rating agencies have tried to measure the investment risk of IFPs from the aspects of reputation. For instance, the reputation indicator of P2P lending platforms created by “Home of Online Loans” (HOL), the credit reputation rating ranking list of the P2P lending
platforms launched by “Wang Dai Tian Yan” (WDTY), and the reputation rating of the P2P lending platform proposed by “Rong 360” (R360). In practice, due to the information asymmetry between the IFPs and investors [12, 13], investors can only choose bidding projects based on the information disclosed by IFPs. Besides, IFPs usually disclose information that is good for enhancing their reputation. In this case, investors’ role is ineffective in the transaction process, and they only can make investment decisions based on the reputation of IFPs. Thus, it is necessary to establish a scientific evaluation system and effective approach for evaluating the reputation levels of IFPs and to reduce the investment risks for investors.

In recent years, the reputation problem of IFPs has attracted growing attention, but it is still in its infancy. First, most of the existing literature mainly focuses on the reputation of borrowers and investors in the IFP. They pay more attention to the mechanism [14–19], influencing factors [20–22], and the measurement of reputation [23]. This study regarding with evaluating the reputation of the IFP itself has not been adequately presented in the available literature. Meanwhile, the reputation evaluation method concerning the ambiguity of evaluation results is relatively lacking. Second, the previous studies concentrate on constructing a reputation evaluation indicator system from the perspective of the direct reputation indicators [20–22]. The indirect reputation of IFPs has been ignored. However, because of the time lag characteristic of the direct reputation information [24], the current method based on direct reputation may delay the evaluation. The indirect reputation information, such as the real-time evaluation by stakeholders of IFPs, can make up the time lag limitation of the direct reputation. Thus, the evaluation system for the integration of direct reputation and indirect reputation elements should be constructed. Third, for improving the objectivity and credibility of the reputation evaluation results of IFPs, a multiple criteria decision-making (MCDM) approach applying for evaluation of multiple attributes is developed to handle uncertainty and subjective vagueness during the decision-making process. Recently, several studies have used MCDM approaches, including decision-making trial and evaluation laboratory (DEMATEL), analytic hierarchical process (AHP), technique for order performance by similarity to ideal solution (TOPSIS), and so on, either independently [25–27] or hybridization of two or more MCDM approaches [28, 29]. However, these MCDM methods ignored the comprehensive consideration of subjective and objective indicator weights. For example, in the TOPSIS, the weight is determined in advance, and its value is usually subjective. In the DEMATEL, the relative weight of the experts is usually not considered when summarizing the experts’ subjective judgments into the group assessment. Therefore, addressing these research gaps inspired us to propose a comprehensive evaluation approach based on fuzzy MCDM considering the objective indicator weights.

To address these research gaps, this study focuses on the reputation evaluation problem of IFPs. A reputation evaluation indicator system including 6 criteria and 24 indicators is constructed from the two dimensions of direct and indirect reputations. Next, an improved fuzzy evaluation approach (IFEA) is designed for reputation evaluation. In this approach, fuzzy comprehensive evaluation (FCE), analytic hierarchy process (AHP), and factor analysis (FA) are integrated to evaluate the reputation level of IFPs. The case study based on the data of 20 P2P lending platforms in China has been carried out to verify the effectiveness and applicability of IFEA.

The contributions of this work include the following three points. (1) Direct and indirect reputations of IFPs are considered for constructing a reputation evaluation indicator system. The system not only fully considers the capability basis of IFPs (e.g., scale strength, financial performance, service quality, capital liquidity, and development potential) but also comprehensively examines the impact of the evaluation of stakeholders on the reputation of IFPs. (2) For evaluating the reputation of IFPs, IFEA is designed by the hybridization of three approaches (e.g., FCE, AHP, and FA), which expands the application of the traditional fuzzy MCDM approaches. Compared with other MCDM approaches (e.g., TOPSIS, DEMATEL, and AHP), the IFEA emphasizes the comprehensive consideration of subjective and objective indicator weights, which reduces uncertainty and randomness in the determination process of indicator weight and membership degree. (3) The reputation level and the impact of essential indicators on the reputation of IFPs are measured quantitatively. It is of great significance for investors to identify the platforms with high investment risks and to make better investment decisions. Moreover, it can also help managers to improve the reputation of IFPs by optimizing related factors.

The rest of this study is organized as follows: Section 2 reviews the existing literature, which concerns the mechanism and influencing factors of IFPs, the reputation evaluation problem, and the FCE method. Section 3 constructs the reputation evaluation indicator system of IFPs. In Section 4, IFEA proposes the reputation evaluation of IFPs. Section 5 presents the case study and discusses the results. Section 6 concludes and provides directions for future research.

2. Literature Review

Since the investment risk of the internet finance increases, many researchers have paid attention to the reputation evaluation problem of the IFPs. This study focuses on three research streams; the mechanism and influencing factors of the reputation of IFPs, the reputation evaluation problem, and the FCE method.

First, a significant issue of this work is the reputation of IFPs. Although this issue is significantly critical, it is still in its early stage. In terms of the reputation mechanism in IFPs, Yang and Lee found that the reputation can significantly affect the trust of lenders on the P2P lending platforms [14]. Kuwabara et al. pointed out that reputation had a curve effect on the success rate of the P2P lending [15]. Lin et al. found that the network reputation of the circle of friends can restrain the default behavior of the P2P lending borrowers.
In conclusion, although the aforementioned literature discussed either reputation evaluation problem of IFPs or FCE method from different perspectives, there is still a limitation that needs to be addressed. The following conclusions can be summarized:

1. The majority of the extant literature regarding reputation evaluation problem of the IFPs focuses on the reputation mechanism or influencing factors. Besides, establishing the reputation evaluation indicator system focuses only on the influencing factors of direct reputation. In this study, the influencing factors of the indirect reputation of the IFPs are still considered as reputation evaluation indicators of the IFPs by comparing them with the HOL [20], WDTY [21], and R360 [22]. Thus, we construct the reputation evaluation indicator system based on the direct and indirect reputations.

2. An empirical or quantitative approach relying on only clear, transparent, and easily quantifiable data of individuals or enterprises as the basis for reputation evaluation is popular in the existing literature. However, the results of the aforementioned studies [23, 33–38] ignore the uncertainty and ambiguity in reputation evaluation. In this study, an improved fuzzy evaluation approach is developed to evaluate the reputation of the IFPs.

3. In previous studies regarding the FCE method, the FCE method independently [42, 43], the method combining FCE and AHP [26, 44, 45], the method combining FCE and TOPSIS [25], the method combining FCE, TOPSIS and DEMATEL [28], and the method combining FCE, AHP, and TOPSIS [29] are often developed for evaluation, but the combined method rarely includes FA. In practice, the AHP, TOPSIS, and DEMATEL rely on the subjective judgment of experts regarding the indicator weights and ignore the consideration of objective indicator weights. The objective indicator weights calculated by FA should be concerned. Therefore, it is greatly beneficial to improve the evaluation method by integrating FCE, AHP, and FA.
3. Construction of the Reputation Evaluation Indicator System on IFPs

With the existence of the information asymmetry, investors tend to choose IFPs with a good reputation when making investment decisions. In order to attract more investors, IFPs often disclose information to enhance their reputation. Therefore, it is necessary to choose appropriate reputation indicators to quantify the reputation of IFPs.

Mohtashemi and Mui pointed out that reputation formation can be investigated from the two aspects of direct interaction experience and recommendation of other entities, and that is, direct and indirect reputations [24]. Based on a comprehensive analysis of studies on the impact of the basic information and transaction information on the reputation of IFPs, we divide the direct reputation evaluation indicators of IFPs into the following five categories. (i) Scale strength indicators, such as transaction volume per month, loan bid number, investment amount per capita, and loan balance. (ii) Financial performance indicators, such as total assets, asset-liability ratio, operating income, and registered capital. (iii) Service quality indicators, such as the average rate of return, information transparency, average loan term, full bidding period, and platform overdue loan rate. (iv) Capital liquidity indicators, such as the net capital inflow, capital adequacy ratio, loan dispersion. (v) Development potential indicators, such as the platform background, operating time, net profit growth rate, and operating revenue growth rate. However, since the direct reputation information is limited in terms of timeliness, feedback evaluation from other participants of Internet finance is often needed as the indirect reputation of the platform to make up for the lack of timeliness of the direct reputation information. The main participants of Internet finance include borrowers, investors, IFPs, and regulatory authorities. As such, the indirect reputation evaluation indicators of Internet financial platforms are as follows: (vi) Stakeholder evaluation for the platform, such as investors feedback score, regulatory authorities feedback score, borrowers feedback score, and peer platforms feedback score. Finally, the reputation evaluation indicator system including 6 criteria and 24 indicators was obtained.

Let variable \( X_i \), \( i = 1, 2, \ldots, 24 \) represent the above 24 reputation evaluation indicators, set \( \Omega = \{X_{k1}, X_{k2}, X_{k3}, \ldots, X_{k24}\}, \) \( k = 1, 2, \ldots, 24 \) represent the values of the 24 reputation evaluation indicators of IFPs. The reputation evaluation indicator system of IFPs is constructed, as given in Table 1.

4. IFEA for Evaluating Reputation of IFPs

In this study, IFEA integrating FCE and AHP with FA is developed for the reputation rating of IFPs. The combined method is based on the fuzzy comprehensive evaluation theory and comprehensive weighting method. The detailed steps of the evaluation process are shown in Figure 1. The multilevel decomposition to the evaluation question is carried on, and each level domain is established; the rating of reputation fuzzy evaluation is determined; the membership degree of each indicator to the corresponding comments is established and the fuzzy evaluation matrix is obtained; the group decision AHP method is used to determine the subjective weights of indicators; the method of FA is also used to determine the objective weights of indicators; the comprehensive weights of indicators are obtained according to the subjective and objective weights. The comprehensive evaluation value is obtained according to the indicator weight and the fuzzy evaluation vector.

4.1. Step 1: Establishing the Domain of Discourse for the Reputation Evaluation Factors. The dimensions of the reputation evaluation include direct and indirect reputations, which are expressed as \( D = \{D_1, D_2\} \). The domain of the reputation evaluation target layer is expressed as \( U = \{B_1, B_2, \ldots, B_m\} \), where \( m \) represents the number of criteria in the target layer. The domain of the reputation criterion layer \( i \) is expressed as \( B_i = \{X_1, X_2, \ldots, X_n\} \), where \( n \) represents the number of indicators in the criterion layer (the reputation evaluation indicator system is given in Table 1). To solve the comparability problem of the different data, data standardization is usually required for indicators in the criterion layer \( i \) before data analysis.

The indicator original data should be transformed into standardized values between 0 and 1 to eliminate the effect of indicators’ dimension. Let \( x_{ki} \) be the original value of the \( k \)th sample in the \( i \)th indicator, \( y_{ki} \) be the standardized value of the \( k \)th sample in the \( i \)th indicator, and \( N \) be the number of samples. The positive indicators mean that the higher original value of the indicator, the better reputation of the Internet financial platform is. Then, the data standardized value \( y_{ki} \) can be expressed by the following equation [48]:

\[
y_{ki} = \frac{x_{ki} - \min_{x_{k1,1 \leq k \leq N}} x_{k1}}{\max_{x_{k1,1 \leq k \leq N}} x_{k1} - \min_{x_{k1,1 \leq k \leq N}} x_{k1}},
\]

The negative indicators mean that the higher original value of the indicator, the worse reputation of the Internet financial platform is. Then, the data standardized value \( y_{ki} \) can be expressed by the following equation [48]:

\[
y_{ki} = \frac{\max_{x_{k1,1 \leq k \leq N}} x_{k1} - x_{ki}}{\max_{x_{k1,1 \leq k \leq N}} x_{k1} - \min_{x_{k1,1 \leq k \leq N}} x_{k1}}.
\]

4.2. Step 2: Determining the Rating of the Reputation Fuzzy Evaluation. According to Li et al. [44], this study takes the grades of the reputation evaluation on IFPs as the comment set, with five levels of “excellent,” “good,” “general,” “bad,” and “poor.” The interval of the 5-level scale corresponding to each indicator will be divided by using the normal distribution of the 5-level interval method. As shown in Figure 2, (a) and (b) are the domain division diagrams of positive and negative indicators of the reputation evaluation, respectively.
The critical value of the rating 1–5 scale of the reputation evaluation indicator will be calculated based on the sample data by using the normal distribution of the 5-level interval method. The detailed classification criteria of positive, negative, and qualitative indicators regarding "excellent," "good," "general," "bad," and "poor" ratings are given in Table 3, where \( \mu \) and \( \sigma \) represent the mean value and standard deviation of the indicator \( X_i \) for all the IFPs in the sample data, respectively.

### Table 1: The reputation evaluation indicator system of IFPs.

| Dimension                  | Criterion layer | Indicator layer | Indicator description                                                                 | Types of indicators | Source of indicators |
|----------------------------|-----------------|-----------------|---------------------------------------------------------------------------------------|---------------------|----------------------|
| Direct reputation dimension \( D_1 \) | Scale strength \( B_1 \) | Transaction volume per month \( X_1 \) | The total transaction amount that occurred on the IFPs this month | Positive            | HOL [20], WDTY [21] |
|                            |                 | Loan bid number \( X_2 \) | The number of loans actually transacted in the IFPs | Positive            | HOL [20], WDTY [21] |
|                            |                 | Investment amount per capita \( X_3 \) | Per capita investment amount of investors in the IFPs | Positive            | HOL [20], WDTY [21] |
|                            |                 | Loan balance \( X_4 \) | The total amount of loans repayable in the IFPs | Positive            | HOL [20], WDTY [21] |
|                            | Direct reputation dimension \( D_1 \) | Total assets \( X_5 \) | All assets owned or controlled by the IFPs | Positive            | Literature [46, 47] |
|                            | Financial performance \( B_2 \) | Asset-liability ratio \( X_6 \) | The ratio of total liabilities to total assets in these IFPs | Negative            | Literature [46, 47] |
|                            |                 | Operating income \( X_7 \) | The income obtained from the operation of the IFPs | Positive            | Literature [46, 47] |
|                            |                    | Registered capital \( X_8 \) | The total capital of the IFPs registered with the registration management agency | Positive            | Literature [46, 47], HOL [20] |
|                            | Service quality \( B_3 \) | Average rate of return \( X_9 \) | The ratio of the average net income of Internet financial investment to the average investment amount | Positive            | HOL [20], WDTY [21] |
|                            |                    | Information transparency \( X_{10} \) | The degree of information disclosure on the IFPs | Qualitative         | Literature [32], HOL [20] |
|                            |                    | Average loan term \( X_{11} \) | The average time from borrowing to repayment in the IFPs | Negative            | HOL [20], WDTY [21] |
|                            |                    | Full bidding period \( X_{12} \) | The time for a loan target to raise all the funds required | Negative            | HOL [20], WDTY [21] |
|                            |                    | Platform overdue loan rate \( X_{13} \) | The ratio of overdue loans to total loans in the IFPs | Negative            | HOL [20], WDTY [21] |
|                            |                    | Net capital inflow \( X_{14} \) | The net pending receipts of IFPs this month | Positive            | Literature [30], WDTY [21] |
|                            | Capital liquidity \( B_4 \) | Capital adequacy ratio \( X_{15} \) | The ratio of capital adequacy of IFPs | Positive            | Literature [31] |
|                            |                    | Loan dispersion \( X_{16} \) | The degree of dispersion of loan business carried out by the IFPs | Positive            | HOL [20], WDTY [21] |
|                            |                    | Platform background \( X_{17} \) | Types of capital for investment and construction of the IFPs | Qualitative         | Literature [46, 47], HOL [20] |
|                            | Development potential \( B_5 \) | Operating time \( X_{18} \) | The time when the platform is still operating normally so far | Positive            | HOL [20], WDTY [21] |
|                            |                    | Net profit growth rate \( X_{19} \) | The ratio of the net profit of the current period to the net profit of the previous period | Positive            | Literature [46, 47] |
|                            |                    | Operating revenue growth rate \( X_{20} \) | The ratio of the increase in operating income of the current period to the total operating income of the previous period | Positive            | Literature [46, 47] |
| Indirect reputation dimension \( D_2 \) | Stakeholder evaluation for the platform \( B_6 \) | Investors feedback score \( X_{21} \) | The evaluation score of investors for the IFPs | Qualitative         | This study proposes |
|                            |                    | Regulatory authorities feedback score \( X_{22} \) | The evaluation score of regulatory authorities for the IFPs | Qualitative         | This study proposes |
|                            |                    | Borrowers feedback score \( X_{23} \) | The evaluation score of borrowers for the IFPs | Qualitative         | This study proposes |
|                            |                    | Peer platforms feedback score \( X_{24} \) | The evaluation score of peer platforms for the IFPs | Qualitative         | This study proposes |
4.3. Step 3: Setting up the Fuzzy Evaluation Matrix. The membership relation of each indicator to the reputation alternative comment set is called the membership function \( K(x) \). The closer \( K(x) \) is to 1, the higher the membership of \( x \) to \( K \). The closer \( K(x) \) is to 0, the lower the membership of \( x \) to \( K \).

For the positive indicators, the calculation formula of the membership degree of the rating \( j \) comment is by the following equation:

\[
K(x) = \frac{x - x_{j+1}}{x_j - x_{j+1}}, \quad x_{j+1} < x < x_j. \tag{3}
\]

For the negative indicators, the calculation formula of the membership degree of the rating \( j \) comment is by the following equation:

\[
K(x) = \frac{x_{j+1} - x}{x_{j+1} - x_j}, \quad x_j < x < x_{j+1}. \tag{4}
\]
The membership degree of the rating $j+1$ comment is $1-K(x)$, where $x$ represents the actual value of the indicators, and $x_j$ and $x_{j+1}$ are the critical values of the two reputation levels adjacent to the actual value of the indicator. After calculating the membership degree of the comments on level $j$ and level $j+1$, the membership degree of the other three comments was 0.

The fuzzy evaluation matrix $K$ formed by the membership degree is expressed by the following equation:

$$K = \begin{bmatrix} M_{X_1} \\ M_{X_2} \\ \vdots \\ M_{X_n} \end{bmatrix} = \begin{bmatrix} m_{11} & m_{12} & m_{13} & m_{14} & m_{15} \\ m_{21} & m_{22} & m_{23} & m_{24} & m_{25} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ m_{n1} & m_{n2} & m_{n3} & m_{n4} & m_{n5} \end{bmatrix},$$

where $m_{ij}$ represents the membership degree of indicator $X_i$ in the reputation level $L_j$, and $M_{X_i}$ represents the membership vector of the indicator $X_i$.

4.4. Step 4: Calculating the Subjective Weight of the Indicator by Applying AHP. The group decision AHP method is developed on the basis of traditional AHP [49]. The basic idea is to ask a group of experts to give a judgment matrix for the same indicator attribute based on the premise that the hierarchy structure has been established. Therefore, in order to avoid the subjective weight of indicators being influenced by the subjective assumption of a single expert, the group decision AHP is adopted to determine the subjective weight of each reputation evaluation indicator in this study.

Let $c_j^1, c_j^2, \ldots, c_j^h$ be the different judgments of $h$ experts in the group on the importance of indicator $i$ and $j$ of Internet financial platform. The 9-point scale method is adopted to form judgment matrix $C^k = (c_{ij}^{hk})_{9 \times 9}$, where $1 \leq k \leq h$. The valuation rule of expert $k$ on the comparison scale $c_{ij}^k$ between indicators $X_i$ and $X_j$ is given in Table 4.

In this study, the geometric mean method (GMM) is used to aggregate the group judgment matrix $C = (c_{ij}^{hk})_{9 \times 9}$.

Each element $\overline{c_{ij}}$ is calculated by the following equation:

$$\overline{c_{ij}} = \left( \prod_{k=1}^{h} c_{ij}^k \right)^{1/h}.$$

According to the following equation, the maximum eigenvalue $\lambda_{\text{max}}$ and the eigenvector $W_s$ of the judgment matrix $C$ are calculated:

$$C \times W_s = \lambda_{\text{max}} \times W_s,$$

where $W_s = (\alpha_1, \alpha_2, \ldots, \alpha_i, \ldots, \alpha_n)$, and $\alpha_1, \alpha_2, \ldots, \alpha_i, \ldots, \alpha_n$ are the components of the eigenvector $W_s$.

To check the consistency of the judgment matrix $C$, CI is first calculated by the following equation.

$$\text{CI} = \frac{\lambda_{\text{max}} - h}{h-1}.$$

CI is an indicator used to measure the amount (degree) of deviation from consistency in a judgment matrix. Then, the random consistency ratio CR is calculated by the following equation:

$$\text{CR} = \frac{\text{CI}}{R},$$
4.5. Step 5: Calculating the Objective Weight of the Indicator by Applying FA. The FA is to reduce the variables with complicated relations into a few comprehensive factors by studying the dependence relation inside the correlation matrix and adopting the idea of dimensionality reduction [50]. In this study, the collected data were processed by FA to obtain the objective weight of each indicator.

\[ r_{ij} = \frac{\sum_{k=1}^{n} (x_{ki} - \bar{x}_i)(x_{kj} - \bar{x}_j)}{\sqrt{\sum_{i=1}^{n} (x_{ki} - \bar{x}_i)^2 \sum_{j=1}^{n} (x_{kj} - \bar{x}_j)^2}} \]

The correlation coefficient matrix \( E \) is calculated by the following equation:

\[
E = \begin{bmatrix}
r_{11} & r_{12} & \cdots & r_{1n} \\
r_{21} & r_{22} & \cdots & r_{2n} \\
\vdots & \vdots & \ddots & \vdots \\
r_{n1} & r_{n2} & \cdots & r_{nn} 
\end{bmatrix}
\]  

The eigenvalues of the matrix \( E \) are \( \lambda_1, \lambda_2, \ldots, \lambda_m \), and the eigenvectors of the matrix \( E \) are \( \mu_1, \mu_2, \ldots, \mu_m \). So, the load matrix \( A \) of the factor is expressed by the following equation:

\[
A = \begin{bmatrix}
a_{11} & a_{12} & \cdots & a_{1n} \\
a_{21} & a_{22} & \cdots & a_{2n} \\
\vdots & \vdots & \ddots & \vdots \\
a_{n1} & a_{n2} & \cdots & a_{nm} 
\end{bmatrix} = \begin{bmatrix}
\mu_{11} \sqrt{\lambda_1} & \mu_{12} \sqrt{\lambda_2} & \cdots & \mu_{1n} \sqrt{\lambda_n} \\
\mu_{21} \sqrt{\lambda_1} & \mu_{22} \sqrt{\lambda_2} & \cdots & \mu_{2n} \sqrt{\lambda_n} \\
\vdots & \vdots & \ddots & \vdots \\
\mu_{n1} \sqrt{\lambda_1} & \mu_{n2} \sqrt{\lambda_2} & \cdots & \mu_{nm} \sqrt{\lambda_n} 
\end{bmatrix}
\]

The variance contribution rate of the factor \( j \) is \( g_j \); then, \( g_j = \sum_{i=1}^{n} a_{ij}^2 \), \( j = 1, 2, \ldots, n \).

When \( \sum_{j=1}^{p} g_j \geq 85\% \), that is, the cumulative variance contribution rate was more than 85%; then, the number of eigenvalues is selected as the number of common factors. Next, the score function of each factor is obtained by the regression method. Finally, the score coefficient matrix \( S \) of factors is expressed by the following equation:

\[
S = \begin{bmatrix}
s_{11} & s_{12} & \cdots & s_{1p} \\
s_{21} & s_{22} & \cdots & s_{2p} \\
\vdots & \vdots & \ddots & \vdots \\
s_{n1} & s_{n2} & \cdots & s_{np} 
\end{bmatrix}
\]

The objective evaluation coefficient of each indicator is calculated by the following equation:

\[
e_i = \frac{\sum_{j=1}^{p} g_j s_{ij}}{\sum_{j=1}^{p} g_j} = \frac{g_1 s_{i1} + g_2 s_{i2} + \cdots + g_p s_{ip}}{g_1 + g_2 + \cdots + g_p}
\]

where \( e_i \) represents the objective evaluation coefficient of indicator \( X_i \); and \( S_{ij} \) represents the score coefficient of the indicator \( X_i \) with respect to factor \( j \). Next, the objective evaluation coefficients of each indicator are normalized, as shown in the following equation.

\[
\beta_i = \frac{e_i}{\sum_{i=1}^{n} e_i}
\]

where \( \beta_i \) is the objective weight value of the indicator \( X_i \).

4.6. Step 6: Calculating the Reputation Evaluation Value of IFPs. The subjective weight \( a_i \) is obtained by the group decision AHP method in Section 4.4, and the objective weight \( \beta_i \) is obtained by FA in Section 4.5. The normalized formula of multiplication is used to determine the comprehensive weight of each indicator. The comprehensive weight \( w_i \) of indicator \( X_i \) is expressed by the following equation:

\[
w_i = \frac{a_i \cdot \beta_i}{\sum_{i=1}^{n} a_i \cdot \beta_i}
\]

where \( n \) is the number of indicators.

The fuzzy comprehensive evaluation vector \( P \) is obtained by the indicator weight \( w_i \) and the fuzzy evaluation matrix \( K \), where \( P = (p_1, p_2, p_3, p_4, p_5) \). Based on the aforementioned “five levels” of reputation, the score set \( D \) for reputation evaluation is obtained. In this study, we set \( D = (100, 80, 60, 40, 20)^T \), and the reputation evaluation
value $R$ of the Internet financial platform is expressed by the following equation:

$$R = P \times D = (p_1, p_2, \ldots, p_7) \times (100, 80, 60, 40, 20)^T$$

$$= 100p_1 + 80p_2 + \cdots + 20p_7.$$  \hspace{1cm} (17)

We determine the reputation level of IFPs according to the calculation of the reputation evaluation value. The detailed rating rules are given in Table 5.

### 5. Case Study

#### 5.1. Data Sample
In this study, the transaction data of the P2P lending platforms are selected as samples to verify the performance of IFEA. The octopus data collector was used to capture (obtain) the monthly transaction data of 20 P2P lending platforms during the period from January to June 2019 (data capture time: July 24, 2019) from HOL [20]. Data include net capital inflow, transaction volume per month, loan amount per capita, borrower per month, operating time, loan balance, registered capital, investment amount per capita, platform background, platform rate of return, average loan term, and other information. By querying the financial reports of 20 P2P lending platforms in 2018, we can obtain data such as total assets, asset-liability ratio, operating income, registered capital, net profit growth rate, and operating income growth rate. From the interactive community of HOL, the qualitative evaluations of the P2P lending platform from participants of the Internet finance are obtained.

The positive and negative indicator data are standardized according to equations (1) and (2); for qualitative indicator data, it is standardized according to the scoring rules of qualitative indicators in Table 2. The standardized result of the reputation evaluation indicator data of the P2P lending platforms is given in Table 6. Due to space limitation, only the processing results of some indicators of some platforms are given.

#### 5.2. Calculating the Critical Value of the Rating and Membership Degree of Indicators
According to Tables 6 and 3, each reputation evaluation indicator of IFPs is divided into five ratings: “excellent,” “good,” “general,” “bad,” and “poor,” and it calculates the critical value of each rating of the indicator. The following examples will demonstrate the calculation process of the critical value of the rating 1–5 scale of positive, negative, and qualitative indicators.

The critical values of the rating 1–5 scale of positive indicators are divided as follows: take transaction volume per month $X_i$ for example. The mean value of indicator $X_i$ of 20 P2P lending platforms is 1201222.3, and the standard deviation is 952327.0. According to the calculation formula of the critical value of the positive indicator rating in Table 3, excellent value $= 1201222.3 + 1.8 \times 952327.0 = 2915410.9$, good value $= 1201222.3 + 0.8 \times 952327.0 = 1963083.9$, general value $= 1201222.3 - 0.2 \times 952327.0 = 1007569.6$, bad value $= 1201222.3 - 1.2 \times 952327.0 = 584299.9$, and poor value $= \min\{X_i\} = 45768.1$.

The critical values of the rating 1–5 scale of the negative indicators are divided as follows: for asset-liability ratio $X_i$, the mean value of indicator $X_i$ of 20 P2P lending platforms is 0.499, and the standard deviation is 0.297. According to the calculation formula of the critical value of negative indicator rating in Table 3, excellent value $= 0.499 - 1.2 \times 0.297 = 14.36\%$, good value $= 0.499 - 0.2 \times 0.297 = 44.01\%$, general value $= 0.499 + 0.8 \times 0.297 = 73.65\%$, bad value $= 0.499 + 1.8 \times 0.297 = 103.30\%$, and poor value $= \max\{X_i\} = 108.22\%$.

The critical value of the rating 1–5 scale of the qualitative indicator is divided as follows: the excellent value is 1.00, good value is 0.75, general value is 0.50, bad value is 0.25, and poor value is 0.00.

By analogy, the critical value of other indicators is calculated according to the above rules. The critical values of the rating 1–5 scale for all 24 indicators are given in Table 7.

According to the critical value of the rating 1–5 scale of each indicator in Table 7 and the membership function equations (3) and (4), take the internet financial platform PF1 as an example to calculate the membership degree.

For the membership degree of the positive indicator, the value of the indicator $X_i$ of PF1 is 2007634.4 thousand yuan, so the indicator rating is between “excellent” and “good.” Thus, according to equation (3), the membership degree of an “excellent” rating of this indicator is $K_x = \left(\frac{2007634.4 - 1963083.9}{(2915410.9 - 1963083.9)}\right) = 0.047$, and its membership degree of the “good” rating of this indicator is $1 - K_x = 0.953$. The membership vector of the indicator $X_i$ of PF1 is $M_{X_i} = (0.047, 0.953, 0, 0, 0)$. The membership vector of other positive indicators of PF1 can be obtained similarly.

For the membership degree of a negative indicator, in the case of $X_i$ of PF1, the value of the indicator is 44.57%, which is less than the critical value of the “general” level 73.65% and more than the critical value of “good” level 44.01%. According to equation (4), the membership degree of “good” rating of this indicator is $K_x = \left(\frac{73.65\% - 44.57\%}{73.65\% - 44.01\%}\right) = 0.981$, and the membership degree of “general” rating of this indicator is $1 - K_x = 0.019$. The membership vector of the indicator $X_i$ of PF1 is $M_{X_i} = (0.981, 0.019, 0, 0)$. The membership vector of other negative indicators of PF1 can be obtained in the same way.

For the membership degree of the qualitative indicator, when the indicator value is 1, then the membership degree of “excellent” rating of this indicator is 1, and the membership vector of the qualitative indicator of PF1 is $M_{X_i} = (1, 0, 0, 0, 0)$. Similarly, the membership vector of the qualitative indicator of platform PF1 is $M_{X_i} = (0, 1, 0, 0, 0)$, $M_{X_i} = (0, 0, 1, 0, 0)$, and $M_{X_i} = (0, 0, 0, 1, 0)$ when the indicator value is 0.75, 0.50, 0.25, and 0.00, respectively.

In summary, according to aforementioned rules, the membership degrees of all the 24 indicators of the PF1 are given in Table 8.
### Table 6: The original and standardized data of 24 indicators of P2P lending platform.

| Platform | Transaction volume per month | Total assets | Asset-liability ratio | Peer platforms feedback score |
|----------|-------------------------------|-------------|-----------------------|-------------------------------|
|          | Original value | Standardized value | Original value | Standardized value | Original value | Standardized value | Original value | Standardized value |
| PF1      | 2007634.4   | 0.5125   | ... | 389065.1   | 0.0456   | 44.57% | 0.5923 | ... | Good | 0.75 |
| PF2      | 2140942.1   | 0.5473   | ... | 1471955.3   | 0.1863   | 71.56% | 0.3411 | ... | Good | 0.75 |
| PF3      | 2055776.6   | 0.5251   | ... | 4545000.0   | 0.5868   | 64.89% | 0.4032 | ... | Good | 0.75 |
|          | ...         | ...      | ... | ...         | ...      | ...    | ...    | ... | ...  | ...  |
| PF9      | 592942.1    | 0.1429   | ... | 220764.3    | 0.0238   | 88.46% | 0.2304 | ... | Low | 0.50 |
| PF10     | 482487.7    | 0.1141   | ... | 1174026.8   | 0.1476   | 101.59% | 0.0617 | ... | Low | 0.25 |
| PF11     | 410774.8    | 0.0954   | ... | 754038.3    | 0.0049   | 43.47% | 0.6025 | ... | Low | 0.50 |
|          | ...         | ...      | ... | ...         | ...      | ...    | ...    | ... | ...  | ...  |
| PF18     | 45768.1     | 0.0000   | ... | 71686.1     | 0.0044   | 40.74% | 0.6280 | ... | Low | 0.25 |
| PF19     | 254442.5    | 0.0545   | ... | 330475.6    | 0.0380   | 45.18% | 0.5866 | ... | General | 0.50 |
| PF20     | 300803.2    | 0.0666   | ... | 11788.8     | 0.0104   | 0.75%  | 1.0000 | ... | Low | 0.25 |

### Table 7: The critical value of the rating 1–5 scale of 24 indicators.

| Indicator | Excellent | Good | General | Bad | Poor | Indicator | Excellent | Good | General | Bad | Poor |
|-----------|-----------|------|---------|-----|------|-----------|-----------|------|---------|-----|------|
| X₁ (1000 yuan) | 2915410.9 | 1963083.9 | 1010756.9 | 58429.9 | 45748.1 |
| X₂ (number) | 1012435 | 676653 | 340870 | 5088 | 3063 |
| X₃ (1000 yuan) | 140.9 | 95.7 | 50.4 | 05.2 | 108.2 |
| X₄ (1000 yuan) | 54532230.8 | 32065237.5 | 9878244.2 | 892512.0 | 600318.2 |
| X₅ (1000 yuan) | 4585112.1 | 2690059.4 | 795006.7 | 55936.1 | 37880.0 |
| X₆ (%) | 14.36 | 44.01 | 73.65 | 103.30 | 108.22 |
| X₇ (1000 yuan) | 4799375.0 | 2797328.4 | 795281.7 | 34503.9 | 37880.0 |
| X₈ (1000 yuan) | 1180843.5 | 696214.9 | 211586.3 | 17734.8 | 6550.0 |
| X₉ (%) | 11.93 | 10.56 | 9.18 | 7.81 | 7.08 |
| X₁₀ (score) | 1.00 | 0.75 | 0.50 | 0.25 | 0.00 |
| X₁₁ (month) | 4.16 | 9.81 | 15.45 | 21.09 | 27.69 |
| X₁₂ (minute) | 111.29 | 67.57 | 23.85 | 6.36 | 0.10 |
| X₁₃ (%) | 0.79 | 1.97 | 4.90 | 7.84 | 10.68 |
| X₁₄ (1000 yuan) | 1015677.2 | 264802.6 | −486072.0 | −1236946.7 | −3411750.4 |
| X₁₅ (%) | 68.86 | 57.94 | 47.01 | 36.08 | 12.90 |
| X₁₆ (degree) | 3.02 | 1.85 | 0.68 | 0.21 | 0.05 |
| X₁₇ (%) | 1.00 | 0.75 | 0.50 | 0.25 | 0.00 |
| X₁₈ (month) | 111.37 | 87.30 | 63.24 | 39.17 | 0.00 |
| X₁₉ (%) | 249.00 | 133.78 | 18.55 | −62.11 | −72.17 |
| X₂₀ (%) | 272.48 | 158.65 | 44.82 | −69.01 | — |
| X₂₁ (score) | 1.00 | 0.75 | 0.50 | 0.25 | 0.00 |
| X₂₂ (score) | 1.00 | 0.75 | 0.50 | 0.25 | 0.00 |
| X₂₃ (score) | 1.00 | 0.75 | 0.50 | 0.25 | 0.00 |
| X₂₄ (score) | 1.00 | 0.75 | 0.50 | 0.25 | 0.00 |

### Table 8: The membership degrees of all 24 indicators of platform PF1.

| Indicator | Excellent | Good | General | Bad | Poor | Indicator | Excellent | Good | General | Bad | Poor |
|-----------|-----------|------|---------|-----|------|-----------|-----------|------|---------|-----|------|
| X₁       | 0.047     | 0.953 | 0       | 0   | 0    | X₁₃       | 0       | 0.648 | 0.352  | 0   | 0    |
| X₂       | 0.391     | 0.609 | 0       | 0   | 0    | X₁₄       | 0       | 0.255 | 0.745  | 0   | 0    |
| X₃       | 0        | 0.203 | 0.797   | 0   | 0    | X₁₅       | 0       | 0.381 | 0.619  | 0   | 0    |
| X₄       | 0        | 0.216 | 0.784   | 0   | 0    | X₁₆       | 0       | 0.487 | 0.513  | 0   | 0    |
| X₅       | 0        | 0     | 0.451   | 0.549 | 0    | X₁₇       | 1       | 0    | 0       | 0   | 0    |
| X₆       | 0        | 0.981 | 0.019   | 0   | 0    | X₁₈       | 0       | 0    | 0.616   | 0.384 | 0    |
| X₇       | 0        | 0     | 0.769   | 0.231 | 0    | X₁₉       | 0       | 0.615 | 0.385  | 0   | 0    |
| X₈       | 0        | 0     | 0.476   | 0.524 | 0    | X₂₀       | 0       | 0.696 | 0.304  | 0   | 0    |
| X₉       | 1        | 0     | 0       | 0   | 0    | X₂₁       | 0       | 0    | 0       | 0   | 0    |
| X₁₀      | 0        | 0     | 1       | 0   | 0    | X₂₂       | 0       | 0    | 1       | 0   | 0    |
| X₁₁      | 0        | 0     | 0.929   | 0.071 | 0    | X₂₃       | 0       | 1    | 0       | 0   | 0    |
| X₁₂      | 0        | 0     | 0.176   | 0.824 | 0    | X₂₄       | 0       | 1    | 0       | 0   | 0    |
5.3. Calculating the Subjective Weight of Indicators. In order to achieve the reputation evaluation indicator system in Table 1, 10 experts including 3 associate professors and 7 doctoral candidates in the field of Internet finance are selected to score the importance of each reputation evaluation indicator according to the 1–9 scale method in Table 4. The comparative judgment matrix of the 10 experts was obtained. According to equation (6), the indicator comparison judgment matrix of the 10 experts was assembled.

The judgment matrix and weights of the criterion layer indices are given in Table 9.

The judgment matrix and weights of the indicator layer indices are given in Tables 10–15.

Whereas, Tables 10–15 are the judgment matrices and weights of indicator layer indices in criterion B1, B2, B3, B4, B5, and B6, respectively. The subjective weight of indicator X1 is \( \alpha_1 = 0.2502 \times 0.3626 = 0.0907 \), the subjective weight of X2 is \( \alpha_2 = 0.2502 \times 0.2382 = 0.0596 \), and the subjective weight of X5 is \( \alpha_5 = 0.2578 \times 0.2650 = 0.0683 \). All the subjective weights of the 24 indicators are given in Table 16.

\[
\frac{23.042\% \times 0.106 + 12.628\% \times 0.045 - 10.559\% \times 0.018 + \cdots + 6.085\% \times 0.155 - 4.451\% \times 0.115}{23.042\% + 12.628\% + 10.559\% + 9.362\% + 7.521\% + 6.432\% + 6.085\% + 4.451\%} = 0.0417. \tag{18}
\]

Similarly, the objective evaluation coefficient of the other indicators can be obtained.

Meanwhile, the objective weight of the indicator is obtained by normalizing the objective evaluation coefficient according to equation (16). The objective weight of indicator X1 is \( \beta_1 = 0.0453 \). The objective weights of other indicators are given in Table 16.

5.4. Calculating the Objective Weight of Indicators. According to the data of the 24 indicators of the 20 P2P lending platforms, Bartlett sphericity and the KMO test in SPSS20.0 statistical analysis software are used to verify whether the original variables are suitable for the factor analysis. Then, 8 common factors are extracted according to the gravel analysis diagram, as given in Table 17.

The score coefficient matrix of the 8 factors is obtained by regression calculation by the SPSS software. The results are given in Table 18.

According to equation (14), the score coefficient matrix of the factors is calculated to obtain the objective evaluation coefficient of the indicator. In case of \( X_1 \), the detailed steps of the objective weight calculation process of this indicator are demonstrated as follows.

The objective evaluation coefficient of the indicator \( X_1 \) is

\[
0.042\% \times 0.106 + 12.628\% \times 0.045 - 10.559\% \times 0.018 + \cdots + 6.085\% \times 0.155 - 4.451\% \times 0.115
\]

\[
= 0.0417. \tag{18}
\]

0.3507, 0.1303, 0.1065, 0.0750, and 0.0681, respectively. So, the weight vector of the criterion layer \( B_1 \) is \( W_1 = (0.0961/0.2693), (0.0626/0.2693), (0.0723/0.2693), (0.0838/0.2693) = (0.3569/0.2324, 0.2685, 0.1422) \). Correspondingly, the weight vector of indicators in the criterion financial performance \( B_2 \) is \( W_2 = (0.2207/0.3456, 0.2640, 0.1697) \), the weight vector of indicators in the criterion service quality \( B_3 \) is \( W_3 = (0.2452/0.2058, 0.0854, 0.2301, 0.2335) \), the weight vector of indicators in the criterion capital liquidity \( B_4 \) is \( W_4 = (0.3299/0.3736, 0.2695) \), the weight vector of indicators in the criterion development potential \( B_5 \) is \( W_5 = (0.2328/0.1042, 0.3462, 0.3168) \), and the weight vector of indicators in the criterion stakeholder evaluation for platform \( B_6 \) is \( W_6 = (0.5165/0.1445, 0.0317, 0.3073) \).

The first-order fuzzy synthesis vector from the indicators layer to the criterion layer is calculated. Taking PF1, for example, the first-order fuzzy synthesis vector of the scale strength is as follows:

\[
P_1 = W_1 \times \begin{pmatrix} M_{X_1} \\ M_{X_2} \\ M_{X_5} \end{pmatrix} = (0.3569, 0.2324, 0.2685, 0.1422) \times \begin{pmatrix} 0.047 & 0.953 & 0 & 0 \\ 0.391 & 0.609 & 0 & 0 \\ 0 & 0.203 & 0.797 & 0 \\ 0 & 0.216 & 0.784 & 0 \end{pmatrix}
= (0.1075, 0.5670, 0.3255, 0, 0). \tag{19}
\]
Table 9: Judgment matrix and weights of criterion layer indices.

| Criterion layer | \( B_1 \) | \( B_2 \) | \( B_3 \) | \( B_4 \) | \( B_5 \) | \( B_6 \) | Maximum eigenvalue | Relative weight | CR         |
|-----------------|----------|----------|----------|----------|----------|----------|-------------------|----------------|------------|
| \( B_1 \)       | 1        | 1.7118   | 1.8760   | 1.4727   | 1.5683   | 2.7742   | 6.3024            | 0.2502         | 0.0504     |
| \( B_2 \)       | 0.5842   | 1        | 2.3191   | 2.5779   | 2.2179   | 3.0837   |                   | 0.2578         |            |
| \( B_3 \)       | 0.5330   | 0.4313   | 1        | 1.4767   | 1.7617   | 2.3522   |                   | 0.1566         |            |
| \( B_4 \)       | 0.6790   | 0.3879   | 0.6771   | 1        | 2.6360   | 2.2036   |                   | 0.1551         |            |
| \( B_5 \)       | 0.6376   | 0.4508   | 0.5676   | 0.3794   | 1        | 2.7019   |                   | 0.1138         |            |
| \( B_6 \)       | 0.3604   | 0.3243   | 0.4251   | 0.4538   | 0.3701   | 1        |                   | 0.0665         |            |

Table 10: Judgment matrix and weights of indicator layer indices in criterion \( B_1 \).

| Indicator layer | \( X_1 \) | \( X_2 \) | \( X_3 \) | \( X_4 \) | Maximum eigenvalue | Relative weight | CR |
|-----------------|----------|----------|----------|----------|-------------------|----------------|----|
| \( X_1 \)       | 1        | 2.3097   | 1.5971   | 1.335    |                   | 4.1258         | 0.3626 |
| \( X_2 \)       | 0.4330   | 1        | 1.8564   | 1.1161   |                   | 5.1772         | 0.2650 |
| \( X_3 \)       | 0.6261   | 0.5387   | 1        | 1.1822   |                   | 5.7892         | 0.2382 |
| \( X_4 \)       | 0.7490   | 0.8960   | 0.8459   | 1        |                   | 5.7892         | 0.2071 |

Table 11: Judgment matrix and weights of indicator layer indices in criterion \( B_2 \).

| Indicator layer | \( X_5 \) | \( X_6 \) | \( X_7 \) | \( X_8 \) | Maximum eigenvalue | Relative weight | CR |
|-----------------|----------|----------|----------|----------|-------------------|----------------|----|
| \( X_5 \)       | 1        | 4.8225   | 4.8638   | 5.6992   |                   | 4.8966         | 0.2650 |
| \( X_6 \)       | 0.2074   | 1        | 6.5041   | 6.3374   |                   | 5.1772         | 0.3489 |
| \( X_7 \)       | 0.2056   | 0.1537   | 1        | 6.9599   |                   | 6.3374         | 0.2474 |
| \( X_8 \)       | 0.1764   | 0.1578   | 0.1437   | 1        |                   | 6.3374         | 0.1388 |

Table 12: Judgment matrix and weights of indicator layer indices in criterion \( B_3 \).

| Indicator layer | \( X_9 \) | \( X_{10} \) | \( X_{11} \) | \( X_{12} \) | \( X_{13} \) | Maximum eigenvalue | Relative weight | CR |
|-----------------|----------|--------------|--------------|--------------|--------------|-------------------|----------------|----|
| \( X_9 \)       | 1        | 1.4727       | 2.0476       | 1.6141       | 0.9895       |                   | 5.7892         | 0.2613 |
| \( X_{10} \)    | 0.6790   | 1            | 2.6052       | 2.4307       | 1.3110       |                   | 5.7892         | 0.2681 |
| \( X_{11} \)    | 0.4884   | 0.3839       | 1            | 2.1074       | 0.6520       |                   | 5.7892         | 0.1475 |
| \( X_{12} \)    | 0.6196   | 0.4144       | 0.4745       | 1            | 0.7892       |                   | 5.7892         | 0.1202 |
| \( X_{13} \)    | 1.0106   | 0.7628       | 1.5337       | 1.2671       | 1            |                   | 5.7892         | 0.2028 |

Table 13: Judgment matrix and weights of indicator layer indices in criterion \( B_4 \).

| Indicator layer | \( X_{14} \) | \( X_{15} \) | \( X_{16} \) | Maximum eigenvalue | Relative weight | CR |
|-----------------|--------------|--------------|--------------|-------------------|----------------|----|
| \( X_{14} \)    | 1            | 2.2442       | 1.6141       |                   | 3.1108         | 0.4842 |
| \( X_{15} \)    | 0.4456       | 1            | 1.9433       |                   | 3.1108         | 0.3005 |
| \( X_{16} \)    | 0.6196       | 0.5146       | 1            |                   | 3.1108         | 0.2154 |

Table 14: Judgment matrix and weights of indicator layer indices in criterion \( B_5 \).

| Indicator layer | \( X_{17} \) | \( X_{18} \) | \( X_{19} \) | \( X_{20} \) | Maximum eigenvalue | Relative weight | CR |
|-----------------|--------------|--------------|--------------|--------------|-------------------|----------------|----|
| \( X_{17} \)    | 1            | 1.6438       | 0.9819       | 0.9704       | 4.0058           | 0.2772         | 0.0016 |
| \( X_{18} \)    | 0.5179       | 1            | 0.9330       | 0.6711       |                   | 4.0058         | 0.1909 |
| \( X_{19} \)    | 1.0184       | 1.1487       | 1            | 1.3493       |                   | 4.0058         | 0.2800 |
| \( X_{20} \)    | 1.0537       | 1.4902       | 0.6452       | 1            |                   | 4.0058         | 0.2519 |

Table 15: Judgment matrix and weights of indicator layer indices in criterion \( B_6 \).

| Indicator layer | \( X_{21} \) | \( X_{22} \) | \( X_{23} \) | \( X_{24} \) | Maximum eigenvalue | Relative weight | CR |
|-----------------|--------------|--------------|--------------|--------------|-------------------|----------------|----|
| \( X_{21} \)    | 1            | 1.8882       | 1.5971       | 1.5060       | 4.1225           | 0.3533         | 0.0329 |
| \( X_{22} \)    | 0.5296       | 1            | 1.6438       | 2.5048       |                   | 4.1225         | 0.2907 |
| \( X_{23} \)    | 0.6261       | 0.6084       | 1            | 1.4142       |                   | 4.1225         | 0.1987 |
| \( X_{24} \)    | 0.6640       | 0.3992       | 0.7071       | 1            |                   | 4.1225         | 0.1573 |
Similarly, the first-order fuzzy synthesis vector of the financial performance is \( P_2 = (0.0.3391, 0.3896, 0.2713, 0) \), the first-order fuzzy synthesis vector of the service quality is \( P_3 = (0.2452, 0.1514, 0.3672, 0.0465, 0.1897) \), the first-order fuzzy synthesis vector of the capital liquidity is \( P_4 = (0.3391, 0.3896, 0.2713, 0) \), the first-order fuzzy synthesis vector of the development potential is \( P_5 = (0.2328, 0.4332, 0.2940, 0.0400, 0) \), and the first-order fuzzy synthesis vector of the capital liquidity is \( P_4 = (0.3391, 0.3896, 0.2713, 0) \), the first-order fuzzy synthesis vector of the development potential is \( P_5 = (0.2328, 0.4332, 0.2940, 0.0400, 0) \), and the first-order fuzzy synthesis vector of the development potential is \( P_5 = (0.2328, 0.4332, 0.2940, 0.0400, 0) \), and the first-order fuzzy synthesis vector of the development potential is \( P_5 = (0.2328, 0.4332, 0.2940, 0.0400, 0) \), and the first-order fuzzy synthesis vector of the development potential is \( P_5 = (0.2328, 0.4332, 0.2940, 0.0400, 0) \).
vector of the stakeholder evaluation for the platform is $P_6 = (0, 0.8555, 0.1445, 0, 0)$.

The order of factors of reputation of PF9 is the indicators evaluation value of PF9 is calculated. As shown in Figure 3, impact of each reputation indicators on the reputation indicators on the reputation of the PF9, the results of the IFEA. verified the effectiveness and adaptability of the evaluation information media disclosed that PF9 had been investigated in other platforms. In addition, the existing online information is negative, and the capital adequacy ratio is lower than negative. In terms of capital liquidity, the net capital inflow in 2018, it is found that the scale strength of the platform is ample, according to the financial report of the platform PF9. The results of DEMATEL show that the weights and ranking of the reputation indicators among the IFPs obtained by applying DEMATEL [28] to validate its performance in terms of the differentiation. The three IFPs with the "bad" reputation rating of "bad," and it has good rating differentiation. The three IFPs with the "bad" reputation level (PF9, PF18, and PF20) are consistent with the reputation rating of "bad," and it has good rating differentiation. Therefore, the reputation level of the platform PF1 belongs to the "excellent" rating with a membership degree of 0.0784, the membership in the "good" rating is 0.4216, the membership in the "general" rating is 0.3710, the membership in the "bad" rating is 0.1042, and the membership in the "poor" rating is 0.0247. According to equation (17), the final reputation comprehensive evaluation value of PF1 is obtained.

$$R = P \times D = (0.0784, 0.4216, 0.3710, 0.1042, 0.0247) \times (100, 80, 60, 40, 20)^T = 68.49.$$  (21)

According to the rating rules of the reputation level in Table 5, it can be determined that the reputation level of the Internet financial platform PF1 is "good." The reputation levels of the other 19 IFPs are given in Table 19.

The results in Table 19 provide that the reputation level of the 20 IFPs is between "good" and "low." Six platforms are in the reputation rating of "good," 11 platforms are in the reputation rating of "general," and 3 platforms are in the reputation rating of "bad," and it has good rating differentiation. The three IFPs with the "bad" reputation level (PF9, PF18, and PF20) are consistent with the reputation status quo of the platforms, respectively. For example, according to the financial report of the platform PF9 in 2018, it is found that the scale strength of the platform is relatively weak. The total assets and operating income are relatively low compared with other platforms. The asset-liability ratio is relatively high, and the profit growth rate is negative. In terms of capital liquidity, the net capital inflow is negative, and the capital adequacy ratio is lower than other platforms. In addition, the existing online information media disclosed that PF9 had been investigated in March 2020 due to the illegal fund-raising, which further verified the effectiveness and adaptability of the evaluation results of the IFEA.

To further explore the impact of various reputation evaluation indicators on the reputation of the PF9, the impact of each reputation indicators on the reputation evaluation value of PF9 is calculated. As shown in Figure 3, the order of factors of reputation of PF9 is the indicators $X_6$, $X_1$, $X_7$, and $X_5$. Therefore, if managers want to improve the reputation of the PF9, the "asset-liability ratio" of PF9 should be reduced, and the "transaction volume per month," "operating income," and "total assets" of the PF9 should be enhanced.

In this work, Table 16 provides that the weights of "asset-liability ratio," "operating income," and "total assets" are the highest in direct reputation evaluation indicators, which indicates that the financial performance is crucial for direct reputation of the IFPs. Besides, the weight of "investors feedback score" is the highest in indirect reputation evaluation indicators, which indicates that the evaluation of investors is attached more important for indirect reputation of the IFPs. Moreover, the reputation level of the entire Internet finance industry can be obtained by appropriately expanding the sample based on IFEA. Besides, the results can provide decision-making references on the investment of Internet finance for the investors. Meanwhile, the results of the IFEA can also help the managers find ways to improve the reputation of the platform. In detail, the financial performance and evaluation of investors have a great influence on the direct and indirect reputations of the IFPs. Thus, the managers can improve the reputation level of the platform by optimizing these factors.

$$P = W \times \begin{pmatrix} P_1 \\ P_2 \\ P_3 \\ P_4 \\ P_5 \\ P_6 \end{pmatrix} = (0.2693, 0.3507, 0.1303, 0.1065, 0.0750, 0.0681) \times \begin{pmatrix} 0.1075 & 0.5670 & 0.3255 & 0 & 0 \\ 0 & 0.3391 & 0.3896 & 0.2713 & 0 \\ 0.2452 & 0.1514 & 0.3672 & 0.0465 & 0.1897 \\ 0 & 0.3708 & 0.6292 & 0 & 0 \\ 0.2328 & 0.4332 & 0.2940 & 0.0400 & 0 \\ 0 & 0.8555 & 0.1445 & 0 & 0 \end{pmatrix} = \begin{pmatrix} 0.4216 \\ 0.3710 \\ 0.1042 \\ 0.0247 \end{pmatrix}.$$  (20)

5.6. Discussion regarding the Results of IFEA, TOPSIS, and DEMATEL. In this study, IFEA-integrated FCE, AHP, and FA is designed for evaluating the reputation of the IFPs. In this subsection, IFEA is compared with TOPSIS [29] and DEMATEL [28] to validate its performance in terms of the comparative analysis of the 24 reputation indicators.

The overall importance weights and ranking of the reputation indicators among the IFPs obtained by applying TOPSIS, DEMATEL, and IFEA are given in Table 20. The results of the IFEA show that the weights and ranking of the reputation indicators $X_6 > X_1 > X_7 > X_5 > X_2 > X_3$ are the highest-ranking among the 24 indicators. Similarly, the results of TOPSIS show $X_1 > X_2 > X_3 > X_4 > X_5 > X_6$ as the highest priority reputation indicators. The results of DEMATEL show $X_6 > X_1 > X_2 > X_3 > X_4$ as the highest priority reputation indicators. Subsequently, the relative weights obtained by IFEA are compared with TOPSIS and DEMATEL. We can
Table 19: The reputation level of IFPs.

| Platform | Reputation evaluation value | Reputation level | Platform | Reputation evaluation value | Reputation level |
|----------|-----------------------------|------------------|----------|-----------------------------|------------------|
| PF1      | 68.49                       | Good             | PF11     | 57.36                       | General          |
| PF2      | 69.13                       | Good             | PF12     | 47.84                       | General          |
| PF3      | 70.20                       | Good             | PF13     | 55.62                       | General          |
| PF4      | 53.50                       | General          | PF14     | 77.91                       | Good             |
| PF5      | 55.99                       | General          | PF15     | 43.30                       | General          |
| PF6      | 54.85                       | General          | PF16     | 75.33                       | Good             |
| PF7      | 54.83                       | General          | PF17     | 71.61                       | Good             |
| PF8      | 53.22                       | General          | PF18     | 32.74                       | Bad              |
| PF9      | 39.31                       | Bad              | PF19     | 44.31                       | General          |
| PF10     | 53.41                       | General          | PF20     | 31.68                       | Bad              |

Figure 3: The degree of impact of each indicator on reputation evaluation value of PF9.

Table 20: Fuzzy importance weights and ranking of reputation indicators, as obtained by TOPSIS, DEMATEL, and IFEA.

| Reputation indicator | Results of TOPSIS [29] | Results of DEMATEL [28] | Results of this work |
|----------------------|------------------------|-------------------------|----------------------|
|                      | Weights ($W_i$)        | Rank                    | Weights ($W_i$)      | Rank                    | Weights ($W_i$) | Rank               |
| X_1                  | 0.0513                 | 1                       | 0.0464               | 7                       | 0.0961          | 2                  |
| X_2                  | 0.0471                 | 5                       | 0.0508               | 4                       | 0.0626          | 6                  |
| X_3                  | 0.0495                 | 3                       | 0.0533               | 3                       | 0.0723          | 5                  |
| X_4                  | 0.0462                 | 7                       | 0.0489               | 6                       | 0.0383          | 9                  |
| X_5                  | 0.0502                 | 2                       | 0.0495               | 5                       | 0.0774          | 4                  |
| X_6                  | 0.0455                 | 9                       | 0.0584               | 1                       | 0.1212          | 1                  |
| X_7                  | 0.0461                 | 8                       | 0.0325               | 23                      | 0.0962          | 3                  |
| X_8                  | 0.0363                 | 20                      | 0.0374               | 16                      | 0.0595          | 7                  |
| X_9                  | 0.0385                 | 18                      | 0.0357               | 19                      | 0.0320          | 12                 |
| X_10                 | 0.0406                 | 16                      | 0.0348               | 21                      | 0.0268          | 16                 |
| X_11                 | 0.0406                 | 17                      | 0.0397               | 12                      | 0.0111          | 21                 |
| X_12                 | 0.0477                 | 4                       | 0.0579               | 2                       | 0.0300          | 15                 |
| X_13                 | 0.0414                 | 14                      | 0.0384               | 14                      | 0.0304          | 14                 |
| X_14                 | 0.0452                 | 10                      | 0.0409               | 10                      | 0.0351          | 11                 |
| X_15                 | 0.0451                 | 11                      | 0.0366               | 17                      | 0.0398          | 8                  |
| X_16                 | 0.0347                 | 21                      | 0.0399               | 11                      | 0.0316          | 13                 |
| X_17                 | 0.0470                 | 6                       | 0.0448               | 8                       | 0.0175          | 20                 |
| X_18                 | 0.0416                 | 13                      | 0.0411               | 9                       | 0.0078          | 23                 |
find that the indicators $X_1 > X_3 > X_4$ have a significant impact, and they are consistent with TOPSIS, the indicators $X_6 > X_3 > X_2$ have significant impact, and they are consistent with DEMATEL too. In other words, the highly significant indicators obtained from the IFEA are almost consistent with the TOPSIS and DEMATEL, which indicates that IFEA has a great performance for displaying the effectiveness of the reputation indicators. Moreover, Kendall’s coefficient of concordance computed for TOPSIS, DEMATEL, and IFEA rankings is 0.673, which indicates a very high correlation among rankings.

Therefore, we can conclude that the IFEA is a robust and efficient approach for evaluating the reputation of IFPs. The evaluation results of IFPs improved by the IFEA comprehensively consider the objectiveness and fuzziness of the results, which can reduce uncertainty and randomness in the determination process of the indicator weight and membership degree. By emphasizing these reputation indicators, the managers can obtain the key factors in determining the reputation of IFPs.

### 6. Conclusions and Future Research

The focus of this study is to design a reputation evaluation approach for IFPs. Since the credit challenge of IFPs commonly exposed in China recently, it is urgent and beneficial to construct a reputation evaluation system for the Chinese IFPs to reduce the investment risk and to help investors make better decisions. The research results are shown as follows:

1. The reputation evaluation indicator system of the IFPs, which includes 6 criteria (e.g., scale strength, financial performance, service quality, capital liquidity, development potential, and stakeholder evaluation for the platform) and 24 indicators, is constructed from the two dimensions of direct and indirect reputations. The results of the case study show that this system can more comprehensively reflect the reputation levels of the IFPs, and the financial performance and evaluation of investors have a great influence on the direct and indirect reputation of the IFPs, respectively.

2. The methods of FCE, AHP, and FA are integrated to develop an improved fuzzy evaluation approach (IFEA) for evaluating the reputation of IFPs. Results of the case study are presented to show that IFEA can significantly distinguish the reputation level of the IFPs and effectively identify the IFPs with high investment risks. The reputation evaluation results of IFPs improved by the IFEA comprehensively consider the objectiveness and fuzziness of the results compared with other MCDM approaches (e.g., TOPSIS and DEMATEL), which can improve the robustness and closeness with the reality of the evaluation results.

3. The reputation levels of the IFPs can be calculated by the transaction data extracted during the period of June 2019. The results of the case study are consistent with the actual reputation level of the IFPs in China. With the reputation evaluation results of IFPs, which is more objective and reliable, the investors can make the correct investing decisions and reduce the investment risk of Internet finance. Moreover, it can also help managers to find out the key factors of reputation in determining the reputation of IFPs, such as asset-liability ratio, operating income, total assets, and investors feedback score, thereby improving the reputation level of IFPs by optimizing these factors.

This study makes several contributions to the field of the MCDM approach and its applications. First, the IFEA is designed for evaluating the reputation level of IFPs, which is easy to operate and can help investors make the better investing decisions. Second, the IFEA considers the uncertainty of a complex large group decision-making and combines the subjective weighting method and objective weighting method during the indicator weight in decision-making problems. It not only overcomes the shortcomings of the traditional subjective factors’ empowerment method but also takes full account of objective factors. Third, the IFEA expands the application of the traditional fuzzy MCDM approaches. It can not only evaluate the reputation of IFPs but also apply to reputation evaluation of other industry platforms (e.g., e-commerce platform and logistics information platform).

This study can be further extended. The reputation evaluation indicators are summarized based on literature and the related reputation evaluation indicator system of the third-party credit rating agencies in this work. Since the factors influencing the reputation of IFPs varies with the change of external environments, it is recommended that big data can be used to discover the potential factors. Besides, the method of artificial intelligence, such as the support vector machine (SVM) and neural network (NN), can also be
incorporated into FCE to further improve the effectiveness of the fuzzy evaluation method.

Data Availability

The data used to support this research article are available from the first author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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