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# Model of Credit Rating of Micro Enterprise Based on Fuzzy Integration

**Zhanjiang Li[a], Na Hou[b], Jinmei Su[b], Yuchun Liu[a,*]**

[a]*College of Economics and Management, Inner Mongolia Agricultural University, Hohhot 010010, China*
[b]*College of Science, Inner Mongolia Agricultural University, Hohhot 010010, China*

**Abstract.** This paper selects credit data of 1688 micro enterprises in a certain commercial bank in China from 2013 to 2016 as empirical research objects. We use the combination method of $t$ test and correlation analysis to construct credit rating indicator system, then use entropy weight method and fuzzy integration to construct credit evaluation model, and lastly divide credit rating of micro enterprises. The empirical results indicate three main points. Firstly, final constructed indicator system can significantly discriminate credit state and avoid information overlapping, and curve ROC proves credit rating indicator system is effective. Secondly, we use entropy weight method to weight indicators objectively, and evaluate credit state comprehensively based on fuzzy integration model. At last, credit rating of micro enterprises proves that upper rating has minor default enterprises, and overall micro enterprises' credit state is basically on average credit level.

## 1. INTRODUCTION

In recent years, financial market is constantly improved in China, credit operations of micro enterprises make a great breakthrough on the road that promote rapid economic development, and micro enterprises become important clients of commercial banks too. However, credit rating of micro enterprises faces numerous difficulties because of micro enterprises own weaknesses such as small scale and less fund.

Credit rating of micro enterprises mainly evaluates micro enterprises' economic strength, financial condition and credit characteristics based on scientific indicator system, then confirms credit rating of micro enterprises. Therefore, objective and rational credit rating of micro enterprises can not only improve financing environment to solve the question that micro enterprises' loan is difficult, but also help commercial banks avoid credit risk and reduce credit loss to a certain degree. Credit rating of micro enterprises has a vital practical significance.

Correlation studies about the construction of credit rating indicator system, credit evaluation and credit rating are following:

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Corresponding author: Yuchun Liu
*Email addresses:* lizhanjiang582@163.com (Zhanjiang Li), 15754884988@163.com (Na Hou), 774749318@qq.com (Jinmei Su), l1y1cc@126.com (Yuchun Liu)

(1) Studies on credit rating indicator system

First category is credit rating indicator system of international authority. There are mainly credit evaluation indicator system of enterprises constructed by authorities Moody [1], Standard & Poor [2] and Fitch Ratings [3] and rating indicator system based on principle "5C" [4] and "5P" [5] recognized by international conventions.

Second category is credit rating indicator system of domestic authorities. There are mainly evaluation method of small enterprises' clients established by China Construction Bank [6]; credit evaluation principle of peasant household raised by Agricultural Bank of China [7] and credit evaluation score linear weighted model of peasant household constructed by Postal Savings Bank of China [8].

Third category is credit rating indicator system and constructed method of classical literature. Mainly studies: Wu Shuyan (2016) uses t test and non-parametric test to confirm indicators and uses principal component analysis to screen indicators and construct Logistic model [9]; Chi Guotai et al. (2015) construct credit evaluation model of petty loan of peasant household based on comprehensive discriminant ability and partial correlation analysis [10]; Zhang Li (2015) establishes evaluation indicator system and risk rating standard [11].

Above studies of indicator system are abundant and authoritative, but lack credit evaluation indicator system that sees micro enterprises as research object. At the same time, constructed method of indicator system cannot ensure every index can significantly discriminate credit state of enterprises, so it easily appears redundancy and accidental deletion of indicators.

(2) Studies on credit evaluation model and credit rating

First class is studies on division of credit rating based on comprehensive analysis method. Representative studies are: Li Yan (2016) proposes modified multiple fuzzy comprehensive evaluation model based on decision analytic hierarchy process and variable coefficient method and apply into credit evaluation of micro enterprises [12]; Qian Shuting and Wang Gangzhen (2015) use analytic hierarchy process and fuzzy subordinating degree function to construct credit evaluation model [13]; and Dong Yizhe et al. (2015) evaluate the performance of Chinese commercial banks through comparative analysis [14].

Second class is studies on division of credit rating based on artificial intelligence method. Representative studies are: Fahmida E. Moula et al. (2017) propose credit default prediction modeling based on support vector machine [16]; Xiao Jin et al. (2015) use dynamic classifier integration selection model to evaluate credit state of clients [16]; and Shi Baofeng (2014) establishes credit rating model of small enterprises based on the principle of the pyramid of default [17].

Third class is studies on division of credit rating based on fuzzy algorithms. Representative studies are: Shi Baofeng et al. (2016) raise a credit rating model of microfinance based on fuzzy cluster analysis and fuzzy pattern recognition [18]; and Liu Dahong et al. (2013) construct credit evaluation model based on dynamic fuzzy cluster and do empirical study for 10 micro-loan companies [19].

Above studies of credit evaluation model and credit rating mainly aim at existing indicator system, so existing studies lack organic combination with indicator system construction.

This paper selects some commercial banks' credit data of 1688 micro enterprises as empirical sample data during 2013-2016 in China. Firstly this paper uses t test and correlation analysis to screen credit rating indicators. Secondly this paper weights indicators based on entropy weight method. Finally this paper constructs credit evaluation fuzzy integration model of micro enterprises and confirms credit rating on the basis of credit scores of micro enterprises.

## 2. RATING PRINCIPLE AND METHOD

### *2.1. Construction of Indicator System*

#### *2.1.1. Audition of indicator*

(1) Indicators and criterion layer

Combing with characteristics of micro enterprises in China, we select high frequency indicators of relevant credit rating in the domestic and international authorities and academic literature as the source of

indicators, and construct indicator set composed of 88 indexes. At the same time, we select three primary criterion layers.

In which, criterion layer "internal micro financial factors" contains four section. In order to reflect debt paying ability, 20 indexes are established. 13 indexes of "$X_{21}$ Net assets income rate" and so on are used to assess enterprises' profitability. To evaluate operation capacity of micro enterprises, we select "$X_{34}$ Turnover of account receivable" and so on, a total of 10 indexes. And there are five indexes are designed to describe growth ability of micro enterprises.

Since financial market is constantly improved, internal micro economic factors become more and more important. Based on the above considerations, three parts of the indexes are designed. Basic status of enterprises are measured by 11 indexes. There are 11 other indexes are selected to assess information of legal representative. And four indexes are used to reflect corporate reputation of micro enterprises.

Under criterion layer "external macro factors", economic environment and cultural environment two aspects are considered."$X_{75}$ Industrial condition index" and "$X_{76}$ GDP growth rate" reflect economic environment of micro enterprises. At the meantime, five indexes are presented to reflect cultural environment.

(2) Idea of primary screening

In indicator set, we directly delete indexes that cannot obtain sample data and missing data are more than 1/10 of total samples; supply sample data by using medium difference method for some indexes which missing data are less than 1/10 of total samples; then do further significance and information overlapping screening for some indexes that can get all sample data and completed data. Through primary screening, we delete 7 indexes, so 88 credit rating indicators of micro enterprises turn into 81 indexes.

*2.1.2. Standardization of indicator*

(1) Standardization of positive credit rating indicator

Let: $y_{ij}$- standardization value of the $j^{th}$ credit rating indicator of the $i^{th}$ micro enterprise; $x_{ij}$- observation value of the $j^{th}$ credit rating indicator of the $i^{th}$ micro enterprise; $n$-the number of micro enterprises. The standardization formula of positive credit rating indicator is defined in the formula (1) [20]:

$$y_{ij} = \frac{x_{ij} - \min\limits_{1\le i\le n} x_{ij}}{\max\limits_{1\le i\le n} x_{ij} - \min\limits_{1\le i\le n} x_{ij}} \tag{1}$$

(2) Standardization of negative credit rating indicator

The standardization formula of negative credit rating indicator is defined in the formula (2) [20]:

$$y_{ij} = \frac{\max\limits_{1\le i\le n} x_{ij} - x_{ij}}{\max\limits_{1\le i\le n} x_{ij} - \min\limits_{1\le i\le n} x_{ij}} \tag{2}$$

(3) Standardization of interval credit rating indicator

Let: $z_1$- the left point of optimum interval; $z_2$- the right point of optimum interval; the rest of the letters' meaning are same. The standardization formula of interval credit rating indicator is defined in the formula (3) [20]:

$$y_{ij} = \begin{cases} 1 - \frac{z_1 - x_{ij}}{\max(z_1 - \min\limits_{1\le i\le n}(x_{ij}), \max\limits_{1\le i\le n}(x_{ij}) - z_2)}, & x_{ij} < z_1 \\ 1 - \frac{x_{ij} - z_2}{\max(z_1 - \min\limits_{1\le i\le n}(x_{ij}), \max\limits_{1\le i\le n}(x_{ij}) - z_2)}, & x_{ij} > z_2 \\ 1, & z_1 \le x_{ij} \le z_2 \end{cases} \tag{3}$$

(4) Scoring standard of qualitative credit rating indicator

Indicator set contains some qualitative indicators, such as "years of employment in related industries" and so on. And their standardization data cannot be calculated by the formula (1)-(3). The scoring standard of qualitative credit rating indicator is shown in Table 1.

*2.1.3. Screening principle and method of indicator*

(1) Significance screening based on t test

*T* test embodies a screening idea that ensures every indicator can significantly discriminate credit state of micro enterprises. Through significant analysis, we delete some indexes that cannot discriminate credit state of micro enterprises.

Tab.1 Standardized score of qualitative indicators.

| No. | (1) Criterion layers | (2) Indicator names | (3) Setting of options | (4) Standardized score |
|---|---|---|---|---|
| 1 | Internal micro economic factors | Years of employment in related industries | 1) working years ≥ eight years | 1.00 |
| | | | 2) five years ≤ working years < eight years | 0.70 |
| | | | 3) two years ≤ working years < five years | 0.40 |
| | | | 4) zero < working years < two years, or data-missing | 0.00 |
| ... | | ... | ... | ... |
| 26 | | Corporate tax paying records | 1) tax paying records are more than 3 years,and no default tax records | 1.00 |
| | | | 2) tax paying records are less than 3 years,and no default tax records | 0.75 |
| | | | 3) only one default tax record, and fully pay tax latter | 0.50 |
| | | | 4) no tax paying records | 0.25 |
| | | | 5) two or more default tax records, or data-missing | 0.00 |

Specific calculation steps are as follows:

Step l: establish null hypothesis $H_0$: the mean values of default and non-default samples of the $j^{th}$ credit rating indicator are equal, $u_1 = u_2$ [21].

Step 2: F test. Let: $F_j - F$ statistic value of the $j^{th}$ credit rating indicator ($j = 1, 2, \ldots, m$); $s_{12}$- variance of non-default micro enterprises; $s_{22}$- variance of default micro enterprises. Calculation formula of F statistic value is defined in the formula (4) [21]:

$$F_j = S_1^2 \Big/ S_2^2 \tag{4}$$

Step 3: judge two variances. If corresponding $P_F$ value of $F_j$ value is more than or equal to significant level 0.01, two variances are the same; otherwise two variances are different.

Step 4: structure t statistic value. When two variances are unknown and equal. Let: $t_j - t$ statistic value of the $j^{th}$ credit rating indicator ($j = 1, 2, \ldots, m$); $\bar{x_1}$-sample mean of non-default micro enterprises; $\bar{x_2}$-sample mean of default micro enterprises; $S_e^2$- two samples' pooled variance; $n_1$-the number of non-default micro enterprises; $n_2$-the number of default micro enterprises; $m$- the number of indicators. Calculation formula of equal variance t statistic value is defined in the formula (5) [21]:

$$t_j = \frac{\overline{x_1} - \overline{x_2}}{\sqrt{s_e^2 \Big/ n_1 + s_e^2 \Big/ n_2}} \tag{5}$$

In which, $s_e^2$ is defined in the formula (6) [21]:

$$s_e^2 = \frac{s_1^2 (n_1 - 1) + s_2^2 (n_2 - 1)}{(n_1 - 1) + (n_2 - 1)} \tag{6}$$

When two variances are unknown and different, calculation formula of heteroscedastic $t$ statistic value is defined in the formula (7) [21]:

$$t_j = \frac{\overline{x_1} - \overline{x_2}}{\sqrt{s_1^2 \Big/ n_1 + s_2^2 \Big/ n_2}} \tag{7}$$

Step 5: significant screening. If corresponding Pt value of $t_j$ value is more than or equal to significant level 0.01, we think this indicator cannot significantly discriminate credit state of micro enterprises, so indicator should be deleted; otherwise indicator should be reserved.

(2) Information overlapping screening based on correlation analysis

Correlation analysis embodies a screening idea that removes information overlapping between indicators. We identify information overlapping between 39 reserved indicators after t test and ensure final credit rating indicator system.

Specific counting processes are as follows:

Step 1: calculate correlation coefficient between two indexes. Let: $R_{ks}$- correlation coefficient between the $k^{th}$ and $s^{th}$ credit rating indicator; $y_{ki}$- standardized data of the $k^{th}$ indicator of the $i^{th}$ micro enterprise; $y_{si}$- standardized data of the $s^{th}$ indicator of the $i^{th}$ micro enterprise. Calculation formula of $R_{ks}$ is defined in the formula(8) [22]:

$$R_{ks} = \frac{\sum_{i=1}^{n}\left(y_{ki}-\overline{y_k}\right)\left(y_{si}-\overline{y_s}\right)}{\sqrt{\sum_{i=1}^{n}\left(y_{ki}-\overline{y_k}\right)^2\left(y_{si}-\overline{y_s}\right)^2}} \tag{8}$$

Step 2: judge. If absolute value of $R_{ks}$ is less than 0.7, two indexes don't have overlapping information, and should be both reserved; otherwise, there are higher information overlapping degree between two indexes, and we should delete one of index.

Step 3: screening indicator. Compare with t statistic value of two indexes when absolute value of their correlation coefficient is more than or equal to 0.7. The bigger t statistic value contains more information, therefore we objectively delete the index with smaller t statistic value.

*2.1.4. Indicator system and its effectiveness*

Final credit rating indicator system of micro enterprises can significantly discriminate credit state of micro enterprises and avoid information overlapping between indicators based on t test and correlation analysis.

Criterion of effectiveness: through drawing curve ROC and according to the area under curve ROC, we judge that if indicator system has significant discrimination for credit state of micro enterprises. When AUC is equal to 1, the effect of discrimination is best; when AUC is greater than or equal to 0.9, the effect is better; when AUC is more than 0.7 and less than 0.9, the effect is medium; when AUC is more than 0.5 and less than 0.7, the effect is worse; when AUC is less than 0.5, the effect is worst [23]. Thus, the bigger the area under curve ROC, the stronger discrimination ability, so the effectiveness of this indicator system is higher.

*2.2. Constructed Principle and Method of Fuzzy Integration Model*

*2.2.1. Calculate weight based on entropy weight method*

Entropy weight method embodies a calculation idea that objectively confirms indicator weight. And it reflects a principle that the indicator with bigger weight has more influence on credit rating of micro enterprises.

Specific practices are as follows:

(1) establish original data matrix. Let: $r_{ij}$- evaluation value of the $j^{th}$ indicator of the $i^{th}$ micro enterprise. Original data matrix is defined in the formula (9) [24]:

$$R = \begin{vmatrix} r_{11} & r_{12} & \cdots & r_{1m} \\ r_{21} & r_{22} & \cdots & r_{2m} \\ \cdots & \cdots & \cdots & \cdots \\ r_{n1} & r_{n2} & \cdots & r_{nm} \end{vmatrix} \tag{9}$$

(2) calculate information entropy and redundancy of index. Let: $e_j$- entropy value of the $j^{th}$ indicator; $p_{ij}$- proportion of the $i^{th}$ sample's indicator value under the $j^{th}$ indicator; $h_j$- redundancy of the $j^{th}$ indicator.

The calculation formulas of information entropy and redundancy are respectively defined in the formula (10) and (11) [24]:

$$e_j = -\frac{1}{\ln(n)} \sum_{i=1}^{n} p_{ij} \ln\left(p_{ij}\right) \tag{10}$$

$$h_j = 1 - e_j \tag{11}$$

In which, $p_{ij}$ is defined in the formula (12) [24]:

$$p_{ij} = r_{ij} \Big/ \sum_{i=1}^{n} r_{ij} \tag{12}$$

(3) calculate indicator weight. Let: $w_j$- weight of the $j^{th}$ indicator. The calculation formula of weight is defined in the formula (13) [21]:

$$w_j = \frac{h_j}{\sum_{j=1}^{m} h_j} \tag{13}$$

*2.2.2. Construct fuzzy integration model*

According to indicator values and indicator weight values, we construct credit rating model of micro enterprises based on fuzzy integration to obtain rating score of every sample, and translate rating score into centesimal credit score in order to provide data preparation for the division of credit rating.

The most basic fuzzy integration model is Sugeno fuzzy integration, came up with Japanese mathematician Sugeno. Without complex equation, its operation mechanism is simple and clear, and it intuitively reflects important degree of indicators. However, mutual relation between indexes is easily ignored in practical application [24]. To make evaluation results more objective and precise, we select Choquet fuzzy integration model to do credit evaluation. The formula of Choquet fuzzy integration is defined in the formula (14) [24]:

$$E(C) = \sum_{j=1}^{m} \left[\left(y_{(j)} - y_{(j-1)}\right) w_j\right] \tag{14}$$

Through the formula (14), we get credit rating scores of micro enterprises with the scope of [0, 1]. To divide credit rating conveniently, we translate rating scores into centesimal credit scores. Let: $Z_i$- credit scores of the i$^{th}$ micro enterprise ($i = 1, 2, \ldots, n$); $E_i$- rating scores of the $i^{th}$ micro enterprise. The calculation formula of credit scores is defined in the formula (15) [24]:

$$Z_i = \frac{E_i - \min(E_i)}{\max(E_i) - \min(E_i)} \times 100 \tag{15}$$

*2.2.3. 2.2.3 Division of Credit Rating*

We obtain credit scores of micro enterprises by fuzzy integration model, and divide micro enterprises into triple nine rating according to international credit rating standard.

Credit rating is mainly divided into three ranks, every rank is divided into three levels. Rating AAA, AA and A show management of enterprises is in a positive cycle, the effect of uncertain factors is smaller, enterprises have stronger solvency; rating BBB, BB and B express management of enterprises exists some difficulties, enterprises are easily affected by uncertain factors, their solvency has volatility and risk; rating CCC, CC and C indicate management of enterprises is poor, the influence of uncertain factors is greater, enterprises are seriously lack of solvency and face with enormous risk.

Figure 1 is constructed principle of fuzzy integration model of micro enterprise credit rating.

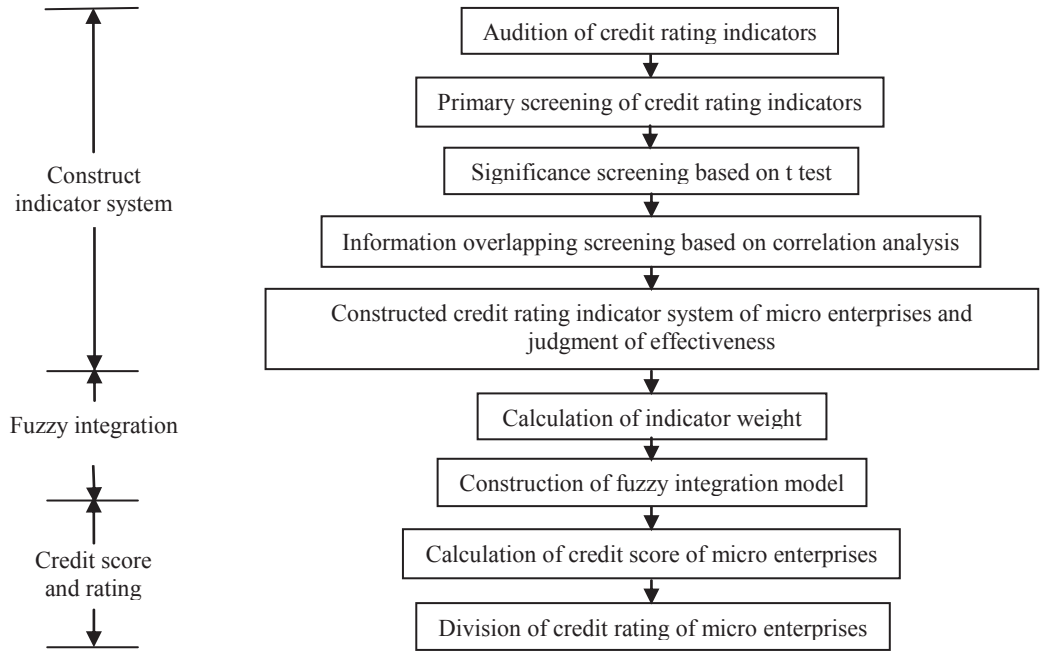


Figure 1: Constructed principle of fuzzy integration model of micro enterprise credit rating.

Tab.2 Indicator set of micro enterprise credit rating.

| No. | 1) Primary criterion layer | 2) Secondary criterion layer | 3) Indicator layer | 4) Indicator type | 5) Screening results |
|---|---|---|---|---|---|
| 1 | | $B_1$ | $X_1$ Debt asset ratio | negative | reserved |
| ... | $A_1$ | Debt paying | ... | ... | ... |
| 20 | Internal | ability | $X_{20}$ Ratio of ebitda and total debt | positive | T test deleted |
| ... | micro | ... | ... | ... | ... |
| 44 | financial | $B_4$ | $X_{44}$ Increase rate of business revenue | positive | T test deleted |
| ... | factors | Growth | ... | ... | ... |
| 48 | | ability | $X_{48}$ Growth of retained earnings | positive | T test deleted |
| ... | ... | ... | ... | ... | ... |
| 75 | | $B_8$ Economic | $X_{75}$ Industrial condition index | positive | T test deleted |
| 76 | | environment | $X_{76}$ GDP growth rate | positive | Correlation deleted |
| | $A_3$ | | $X_{77}$ per capital savings of urban | | |
| 77 | External | $B_9$ | residents at the end of year | positive | Correlation deleted |
| ... | macro factors | Cultural | ... | ... | ... |
| 81 | | environment | $X_{81}$ Engel coefficient | negative | Correlation deleted |

## 3. EMPIRICAL STUDY

### *3.1. Constructed Preparation of Indicator System*

#### *3.1.1. Audition of indicator*

On the basis of high frequency credit rating indicators, combining with characteristics of micro enterprises in China, we construct the indicator set of micro enterprises credit rating. Primary and secondary criterion layer are respectively listed in the first and second column of Table 2, indexes after primary screening are shown in the third column of Table 2, indicator type and screening results are filled in the fourth and fifth column of Table 2.

*3.1.2. Selection of sample data*

This paper selects some commercial bank's credit data of 1688 micro enterprises as empirical samples data. Original data of indexes are from internal credit information of commercial banks, and data belongs to cross-section data. In 1688 micro enterprises, there are 39 default enterprises and 1649 non-default enterprises, and they are expressed as $S_1 - S_{1688}$. Default state of micro enterprises is listed in 82 row of table 3, in which default enterprises are signed with 0 and non-default enterprises are signed with 1.

*3.1.3. Standardization of indicator*

According to the type of credit rating indicator, positive indexes are substituted into the formula (1), negative indexes are substituted into the formula (2), interval indexes are substituted into the formula (3), and qualitative indexes are marked on the basis of standardization in the table 1. We get standardized indicator data and results are shown in 1-1688 column of Table 3.

Tab.3 Standardized data of credit rating indicator.

| No. | a) Criterion layer | b)Indicator layer | Standardized data $y_{ij}$ | | | | |
|---|---|---|---|---|---|---|---|
| | | | Non-default enterprises | | | Default enterprises | |
| | | | 1) $S_1$ | ... | 1649) $S_{1649}$ | 1650) $S_{1650}$ ... | 1688) $S_{1688}$ |
| 1 | $A_1$ | $X_1$ Debt asset ratio | 0.3251 | ... | 0.3689 | 0.6510 ... | 0.3462 |
| ... | | ... | ... | ... | ... | ... ... | ... |
| 48 | | $X_{48}$ Growth of retained earnings | 0.5103 | ... | 0.5133 | 0.5130 ... | 0.5100 |
| ... | ... | ... | ... | ... | ... | ... ... | ... |
| 75 | $A_3$ | $X_{75}$ Industrial condition index | 0.7218 | ... | 0.5794 | 0.6946 ... | 0.8663 |
| ... | | ... | ... | ... | ... | ... ... | ... |
| 81 | | $X_{81}$ Engel coefficient | 0.6507 | ... | 0.7904 | 0.6507 ... | 0.6507 |
| 82 | | Default state | 1 | ... | 1 | 0 ... | 0 |

*3.2. Screening of Indicator*

*3.2.1. Significance screening based on t test*

Standardized data in 1-1688 column of Table 3 is substituted into formula (4) by row, we get $F_j$ statistic value and corresponding probability $P_F$ value of each index, and results are listed in the third and fourth column of Table 4. Comparing probability $P_F$ value with significance level 0.01, if $P_F$ is greater than or equal to 0.01, the variance of non-default and default enterprises is equal under this index. Then standardized data of this index in table 3 is substituted into the formula (5), otherwise it is substituted into the formula (7), we get $t_j$ statistic value and corresponding probability $P_t$ value of each index, and results are listed in the fifth and sixth column of Table 4. After that, comparing probability $P_t$ value with significance level 0.01, and inspection results are shown in the seventh column of Table 4. If $P_t$ value is less than 0.01, this index can significantly discriminate credit state of micro enterprises, it should be remained; otherwise, this index should be deleted, and is labeled by "t test deleted" in the fifth column of Table 2.

Because of large amount of data in this paper, we use software SPSS17.0 to calculate.

All results of $t$ test are shown in Table 4. Through screening of significance, we delete 42 indexes that cannot significantly discriminate credit state of micro enterprises.

*3.2.2. Information overlapping screening based on correlation analysis*

Through t test, we retain 39 indicators and do further information overlapping screening. Standardized data of these indicators are substituted into the formula (8), we get correlation coefficient between two indexes in the same primary criterion.

If absolute value of correlation coefficient between two indexes is less than 0.7, two indexes are remained simultaneously, and labeled by "reserved" in the fifth of Table 2. Otherwise, one of indexes should be deleted, and two indexes and their correlation coefficient are respectively listed in the second, fourth and sixth column of Table 5. In addition to, t statistic value of two indexes are respectively listed in the third and fifth column of Table 5. Through comparing t statistic values, we remain index with greater t statistic values, and deleted indexes are listed in the seventh column of Table 5. At the same time, remained indexes are labeled by "reserved", and deleted indexes are labeled by "correlation deleted" in the fifth column of Table 2.

All results of correlation analysis are shown in Table 5. Through screening of information overlapping, we delete 15 indexes. 24 surplus indexes will be final credit rating indexes of micro enterprises in this paper.

Tab.4 Results of $t$ test.

| No. | 1) Criterion layer | 2) Indicator layer | $F$ test 3) $F_i$ | 4) $P_F$ | $T$ test 5) $t_i$ | 6) $P_t$ | 7) Results |
|---|---|---|---|---|---|---|---|
| 1 | | $X_1$ Debt asset ratio | 1.167 | 0.280 | 4.026 | 0.000 | significant |
| ... | $A_1$ | ... | ... | ... | ... | ... | ... |
| 48 | | $X_{48}$ Growth of retained earnings | 27.443 | 0.000 | 1.854 | 0.071 | non-significant |
| ... | ... | ... | ... | ... | ... | ... | ... |
| 75 | | $X_{75}$ Industrial condition index | 1.347 | 0.246 | 2.358 | 0.018 | non-significant |
| ... | $A_3$ | ... | ... | ... | ... | ... | ... |
| 81 | | $X_{81}$ Engel coefficient | 32.335 | 0.000 | 5.104 | 0.000 | significant |

Tab.5 Results of correlation analysis.

| No. | 1) Criterion layer | 2) Correlation index $s$ | 3) $t_s$ | 4) Correlation index $k$ | 5) $t_k$ | 6) $R_{sk}$ | 7) Deleted index |
|---|---|---|---|---|---|---|---|
| 1 | | $X_1$ Debt asset ratio | 4.026 | $X_9$ Equity ratio | 4.016 | 0.995 | $X_9$ Equity ratio |
| ... | $A_1$ | ... | ... | ... | ... | ... | ... |
| 5 | | $X_{21}$ Net assets income rate | 2.883 | $X_{24}$ Return on total assets | 2.777 | 0.741 | $X_{24}$ Return on total assets |
| ... | ... | ... | ... | ... | ... | ... | ... |
| 13 | | $X_{77}$ per capital savings of urban residents at the end of year | 9.630 | $X_{76}$ GDP growth rate | 2.947 | 0.724 | $X_{76}$ GDP growth rate |
| ... | $A_3$ | ... | ... | ... | ... | ... | ... |
| 15 | | $X_{79}$ Controlled income of each urban resident | 11.974 | $X_{81}$ Engel coefficient | 2.777 | 0.741 | $X_{81}$ Engel coefficient |

*3.2.3. Indicator system and judgment of effectiveness*

Final credit rating indicator system of micro enterprises are constructed and is listed in the first, second and sixth column of Table 6. Based on curve ROC, we judge the effectiveness of credit rating indicator system. Curve ROC reflects the discrimination probability of credit state and it is depicted in Figure 2. We see that the area under ROC curve is more than 0.9, so the discrimination effect of indicator system is effective.

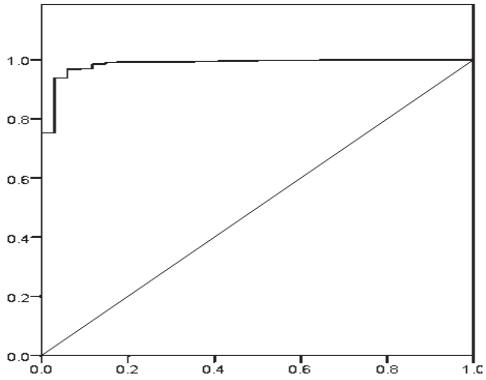


Figure 2: Curve ROC.

Tab.6 Credit rating indicator system and weights of micro enterprises.

| No. | 1) Criterion layer | 2) Indicator layer | 3) $e_j$ | 4) $h_j$ | 5) $w_j$ | 6) Indicator layer | 7) $e_j$ | 8) $h_j$ | 9) $w_j$ |
|---|---|---|---|---|---|---|---|---|---|
| 1 | $A_1$ | $X_1$ Debt asset ratio | 0.9858 | 0.0142 | 0.0082 | $X_5$ Main business income cash ratio | 0.9596 | 0.0404 | 0.0233 |
| 2 | | $X_{12}$ Capital immobilization ratio | 0.9964 | 0.0036 | 0.0021 | $X_{13}$ Net asset and year-end loan balance ratio | 0.9216 | 0.0784 | 0.0451 |
| 3 | | $X_{15}$ Long-term asset suitability ratio | 0.7619 | 0.2381 | 0.1371 | $X_{18}$ The net cash flow ratio of non-current liabilities | 0.7335 | 0.2665 | 0.1535 |
| 4 | | $X_{21}$ Net assets income rate | 0.9374 | 0.0626 | 0.0360 | $X_{27}$ Gross profit rate | 0.9408 | 0.0592 | 0.0341 |
| 5 | | $X_{28}$ Cost-profit ratio | 0.9951 | 0.0049 | 0.0028 | $X_{31}$ Retained profits | 0.9163 | 0.0837 | 0.0482 |
| 6 | | $X_{46}$ Growth rate of total assets | 0.9883 | 0.0117 | 0.0067 | - | - | - | - |
| 7 | $A_2$ | $X_{49}$ Years of employment in related industries | 0.9774 | 0.0227 | 0.0130 | $X_{51}$ New product identification level | 0.7837 | 0.2163 | 0.1246 |
| 8 | | $X_{53}$ Date of establishment | 0.9152 | 0.0848 | 0.0488 | $X_{56}$ Level of brand name product | 0.8532 | 0.1468 | 0.0845 |
| 9 | | $X_{57}$ Education background | 0.9860 | 0.0140 | 0.0081 | $X_{58}$ Proportion of the total amounts of loans made by enterprises through banks | 0.9237 | 0.0763 | 0.0440 |
| 10 | | $X_{59}$ Credit granting situation in the past three years | 0.9819 | 0.0181 | 0.0104 | $X_{61}$ Legal representative credit card record | 0.9355 | 0.0645 | 0.0372 |
| 11 | | $X_{62}$ Dwelling condition | 0.9380 | 0.0620 | 0.0357 | $X_{66}$ Total value of automobile and real estate of legal representative | 0.9073 | 0.0927 | 0.0534 |
| 12 | | $X_{70}$ Time for the job | 0.9419 | 0.0581 | 0.0334 | - | - | - | - |
| 13 | $A_3$ | $X_{78}$ Offset score | 0.9880 | 0.0120 | 0.0069 | $X_{79}$ Controlled income of each urban resident | 0.9951 | 0.0049 | 0.0029 |

*3.2.4. Calculation of indicator weight*

We use entropy weight method to weight 24 credit rating indicators, standardized data of these indicators are substituted into the formula (10), we get information entropy value, and results are filled in the third and seventh column of table 6. Then information entropy value is substituted into the formula (11), we obtain redundancy and results are listed in the fourth and eighth column of Table 6. Finally redundancy is substituted into the formula (13), we gain weight coefficient of each indicator, and results are shown in the fifth and ninth column of Table 6.

Tab.7 Credit score and rating division of micro enterprises credit rating.

| | 1) | 2) | 3) | 4) | 5) | 6) |
|---|---|---|---|---|---|---|
| No. | Enterprises | Credit score $Z_i$ | Credit rating | Number of default enterprises | Number of all samples | Score section standard |
| 1 | $S_{441}$ | 100 | AAAA | 1 | 25 | [80, 100] |
| ... | ... | ... | | | | |
| 25 | $S_{1035}$ | 80.473 | | | | |
| ... | ... | ... | ... | ... | ... | ... |
| 61 | $S_{1427}$ | 69.993 | A | 2 | 91 | [60, 70) |
| ... | ... | ... | | | | |
| 151 | $S_{731}$ | 60.029 | | | | |
| 152 | $S_{358}$ | 59.778 | BBB | 4 | 162 | [50, 60) |
| ... | ... | ... | | | | |
| 313 | $S_{1070}$ | 50.040 | | | | |
| ... | ... | ... | ... | ... | ... | ... |
| 1646 | $S_{412}$ | 9.999 | C | 9 | 43 | [0, 10) |
| ... | ... | ... | | | | |
| 1688 | $S_{921}$ | 0 | | | | |

*3.3. Fuzzy Integration Model*

*3.3.1. Credit score*

Indicator weights in table 6 and corresponding indicator's standardized data in table 3 are substituted into the formula (14), we obtain credit rating scores of all micro enterprises. In order to divide credit rating, we substitute credit rating scores into the formula (15), we get centesimal credit scores $Z_i$ of micro enterprises, and fill results in descending order in the second column of Table 7.

*3.4. Division of Credit Rating*

According to standard of credit score section, we divide credit rating for all micro enterprises, corresponding micro enterprises in each rating are listed in the first column of Table 7.

Final credit rating, number of all samples and number of default enterprises in each rating are shown in 3-5 columns of Table 7. Results indicate that the higher rating has the less default enterprises, and credit condition of all micro enterprises is in a medium credit level.

## 4. CONCLUSION

This paper constructs credit rating indicator system of micro enterprises based on t test and correlation analysis, including 24 indicators that can significantly discriminate credit state of micro enterprises and

avoid information overlapping between indicators, and we judge that credit rating indicator system is effective. Use entropy weight method to weight indicators and establish credit rating model of micro enterprises based on fuzzy integration. Finally, divide credit rating of micro enterprises according to credit scores and standard for evaluation.

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