Research on Credit Decision of Small and Medium-Sized Enterprises by Risk Quantification Model

Kexin Huang, Kehan Wei
742708771@qq.com, 1326998517@qq.com

Department of E-commerce, Shandong Normal University, Changqing District, Jinan, Shandong, China

Abstract—Small and medium-sized enterprises are an important force in China's economic and social development. Since the reform and opening up, the proportion of small and medium-sized enterprises in China's economic structure has gradually increased, and the scale of bank credit services for small and medium-sized enterprises is also expanding. For banks, making credit decisions and maximizing income are the key problems faced by banks at present. Based on the big data analysis, this paper forecasts the enterprise credit risk coefficient by constructing the enterprise credit risk quantitative model, and determines the enterprise's annual loan limit and annual interest rate by studying the relationship between each credit grade and customer churn rate, to make the best credit strategy for the bank. The results show that the credit risk coefficients of most enterprises are between 0.4-0.6, and when the total amount of bank loans is a fixed value, the annual interest rate is basically about 7%, and the bank income will reach the maximum. In addition, the credit risk quantification model constructed in this paper has certain generalizations, and is of great significance of the judgment on bank credit decision-making from a quantitative point of view.

Keywords-quantitative analysis; credit strategy; combination weight; risk coefficient

1 INTRODUCTION

As a new force of technological innovation, small and medium-sized enterprises are an important driving force for a country's economic development. With the continuous development of China's economy, small and medium-sized enterprises have become the most innovative enterprise group in China. However, due to the relatively small scale of small and medium-sized enterprises and the lack of mortgage assets, a major dilemma in their development is the problem of difficult and expensive financing.

As for the credit decision-making process of banks of small and medium-sized enterprises, compared with domestic, foreign relevant research literature is more abundant. Kreps, David M. and Wilson, Robert B. found in the research on SME loans that most SMEs hope to seek long-term cooperation with banks and obtain a stable credit relationship. However, due to the lack of access to information of SMEs, the information is not honest, and the benefits of long-term cooperation between commercial banks and SMEs are limited [1]. Winfred agbeibor found that with the passage of operation time, the financing attitude to commercial banks of small and medium-sized enterprises changes. The results show that small and medium-sized commercial banks are more suitable for issuing loans to small and medium-sized enterprises [2]. Liu, H.Y. and others analyzed the correlation between SME credit scores and commercial bank credit from

ICEMME 2022, November 18-20, Nanjing, People's Republic of China

DOI 10.4108/eai.18-11-2022.2326867

the perspective of SME credit scoring technology [3]. In a word, the research on the credit decision-making of banks of small and medium-sized enterprises mainly focuses on the research of macro policy and theory, and there is less quantitative research.

In practice, banks usually provide loans to enterprises with strong strength and stable supply demand relationship according to credit policies, enterprise transaction bill information, and the influence of upstream and downstream enterprises, and give preferential interest rates to enterprises with high reputation and low credit risk. Therefore, in order to better provide financial support for small and medium-sized enterprises and maximize bank income, it is necessary to deeply study the credit decision-making process of small and medium-sized enterprises from a quantitative perspective.

Based on big data analysis, this paper makes a quantitative analysis of enterprise credit risk, constructs an enterprise risk coefficient model, and gives the optimal selection strategy of bank credit schemes according to the quantitative analysis results and the customer churn rate.

2 MATERIALS AND METHODS

2.1 Data source

This paper uses the relevant statistical data of a bank's lending to small and medium-sized enterprises in 2019, including loan amount, annual interest rate, loan term, relevant data of 123 enterprises with credit records, and the relationship between loan interest rate and customer churn rate. Among them, the loan limit of a certain bank to the enterprise determined to lend is 100000 ~ 1 million yuan; The annual interest rate is 4% ~ 15%; The loan term is 1 year.

2.2 Analysis of influencing factors and model construction

1) Analysis of influencing factors

Through analysis, this paper mainly quantifies the credit risk of enterprises from two first-class indicators: enterprise strength and enterprise reputation. According to the principles of comprehensiveness, scientificity and operability of the index system, seven secondary indicators of enterprise strength are selected, as shown in Tab. 1.

Table 1 Enterprise credit risk evaluation index system

Primary index	Secondary index
Enterprise reputation	Reputation level
Enterprise strength	Quarterly profit, Revenue stability, Number of quarterly upstream enterprises, Number of quarterly downstream enterprises, Stability of upstream relationship, Stability of downstream relationship

Standardize the six secondary indicators to measure the strength of the enterprises, empower each indicator through the combination weighting method, and then quantify the credit rating. The risk index of the enterprises can be obtained by adding the weights of the two primary indicators of enterprise strength and enterprise reputation.

When banks make credit decisions, the customer loss rate is also an important factor affecting their income, and there is an obvious correlation between the annual credit interest rate and customer loss rate at all levels. Therefore, we use linear fitting to measure the relationship between the annual credit interest rate and customer loss rate.

2) Construction of a quantitative model of credit risk

Step 1: measure the strength of the enterprises. First, calculate the quarterly profit p_1 ,income stability p_2 ,the number of upstream enterprises p_3 ,the number of downstream enterprises p_4 , the stability of the upstream relationship p_5 and stability of the downstream relationship p_6 . The calculation method is shown in (1).

$$p_1 = s_{output} - s_{input}, p_2 = \sqrt{\sum_{i=1}^{m} (p_{2i} - \bar{p}_2)^2 \Big/ m} \tag{1}$$
$$p_3 = \sqrt{\sum_{i=1}^{m} (p_{3i} - \bar{p}_2)^2 \Big/ m}, p_4 = \sqrt{\sum_{i=1}^{m} (p_{4i} - \bar{p}_4)^2 \Big/ m}$$

Where S_{output} represents the output amount, S_{input} represents the total input price and tax, m represents the number of enterprises, p_{2i}, p_{3i}, p_{4i} respectively represent the index values of the second income stability of the i -th industry, the number of upstream enterprises in the third quarter, and the number of downstream enterprises in the fourth quarter.

Step 2: calculate the weight of the secondary index of enterprise strength based on the combined weighting method of entropy weight method and coefficient of variation method [4]. As an objective evaluation method, the entropy method can not only avoid the subjective judgment of researchers, but also solve the problem of information overlap between multiple indicators. Therefore, according to the enterprise credit risk evaluation index system given in Tab. 1, we use the entropy method and coefficient of variation method to determine the combination weight of each index.

a) The entropy method

Firstly, in order to eliminate the unit difference, large size difference, and positive and negative direction between various indicators, the original data are standardized. The formulas of positive indicator and negative indicator are shown in (2) and (3) respectively:

$$x'_{ij} = \left(x_{ij} - \min x_j\right) \Big/ \left(\max x_j - \min x_j\right) \tag{2}$$

$$x'_{ij} = \left(\max x_j - x_{ij}\right) \Big/ \left(\max x_j - \min x_j\right) \tag{3}$$

Where x_{ij} , x'_{ij} represent the j -th index value of the i -th enterprise and the standardized index value respectively. $\max x_j$, $\min x_j$ represent the maximum and minimum values in the j -th index.

Secondly, calculate the characteristic specific gravity f_{ij} as shown in (4):

$$f_{ij} = \left(x'_{ij} + 1\right) \Big/ \sum_{i=1}^{m} \left(x'_{ij} + 1\right) \tag{4}$$

Finally, calculate the entropy e_j and the weight w_j of the enterprise's strength index p_j. The calculation formula is shown in (5):

$$\begin{aligned} e_j &= \left(-1/\ln m\right) \sum_{i=1}^{m} f_{ij} \ln f_{ij,} \\ w_j &= \left(1 - e_j\right) \sum_{j=1}^{n} \left(1 - e_j\right) \end{aligned} \tag{5}$$

Where m represents the number of enterprises and n represents the number of indicators

b) Coefficient of variation method

The coefficient of variation method directly uses the information contained in each index to calculate the weight of the index. Calculate the coefficient of variation c_j according to the standard deviation and the mean value, as shown in (6):

$$c_j = s_j \Big/ \left|\overline{v}_j\right| \tag{6}$$

Where s_j is the standard deviation of the data under the j-th index of all enterprises, and $\overline{v}_j$ is the average of the data under the j-th index of all enterprises.

Then normalize the coefficient of variation c_j to calculate the weight w'_j. the normalization process is shown in (7):

$$w'_j = c_j \Big/ \sum_{j=1}^{n} c_j \tag{7}$$

c) The combination weight of the enterprise strength index is calculated based on the entropy method and coefficient of variation method

The improved AHP method is mainly used to determine the subjective weight, while the improved entropy weight method is mainly used to determine the objective weight. In order to comprehensively consider the subjective weighting method and objective weighting method and scientifically determine the weight of each index, this paper determines the comprehensive weight W_j of the evaluation index according to the principle of minimum discrimination information. The objective function is shown in (8):

$$\begin{cases} \min J(W) = \sum_{j=1}^{n} \left(W_j \ln\left(W_j / w_j\right) + w_j \ln\left(W_j / w'_j\right)\right) \\ s.t. \sum_{j=1}^{n} W_j = 1, W_j \geq 0,\ j = 1, 2, \ldots, n \end{cases} \tag{8}$$

The optimization model is solved to obtain the combined weight W_j, and the calculation method is shown in (9):

$$W_j = \sqrt{w_j w'_j} \Big/ \sum_{j=1}^{n} \sqrt{w_j w'_j} \tag{9}$$

Step 3: Calculate the risk index of enterprises.

a) The credit rating of each enterprise is quantified by using the membership function of partial large Cauchy distribution[5]:

Firstly, the corresponding values of reputation evaluation grade A, B, C and D are: 5, 4, 3 and 2, and then the partial large Cauchy distribution membership function is used for correction and standardization. The specific process is shown in (10):

$$f(x) = \begin{cases} \left[1 + a(x-b)^{-2}\right]^{-1}, 1 \le x \le 3 \\ c \ln x + d, 3 \le x \le 5 \end{cases} \tag{10}$$

Where a, b, c, d are undetermined constants.

b) Calculate the credit risk index of each enterprise:

this paper assumes that the importance of enterprise strength and enterprise reputation is the same, that is, the weight of both is 0.5, and the calculation formula is shown in (11):

$$z = 0.5\left(\sum_{j=1}^{6} W_j p_{ij}\right) + 0.5 f(i) \tag{11}$$

Where, $f(i)$ represents the quantified enterprise reputation index corresponding to the i-th enterprise, and p_{ij} represents the value of the j-th index of the i-th enterprise.

Step 4: Solving the optimal credit decision of banks to enterprises [6].

c) Expression of calculating customer churn rate:

By using the values of loan annual interest rate and customer churn rate, the relationship between loan annual interest rate and customer churn rate of each credit level is fitted, and the linear expression of customer churn rate expressed by loan annual interest rate is obtained.

d) Calculate the default rate of each enterprise:

According to the value of risk coefficient, the enterprises with credit records are grouped to obtain the default rate of each group of data, and the default rate is taken as the default rate of each enterprise in this group.

e) The objective function expression for calculating the annual return of banks (12):

$$\begin{aligned} &\max I_i = \alpha_i \beta_i (1-k_i)(1-y_i) - \alpha_i \beta_i k_i (1-y_i) \\ &s.t. \begin{cases} \alpha \in (10,100) \\ \beta \in (4\%,15\%) \end{cases} \end{aligned} \tag{12}$$

Where α_i and β_i respectively represent the annual loan amount and annual interest rate of the i-th enterprise, y_i represents the customer churn rate of the i-th enterprise, and k_i represents the enterprise default rate.

3 RESULTS AND DISCUSSION

3.1 Credit risk analysis

Firstly, the combination weight of secondary indicators of enterprise strength is obtained by entropy method and coefficient of variation method, as shown in Tab. 2.

Table 2 Combination weight of secondary indicators of enterprise strength

Secondary index	Weight	Secondary index	Weight
The average profit	0.3066	The standard deviation of the profit	0.1518
The downstream mean	0.1375	The standard deviation of the downstream	0.1075
The upstream mean	0.1012	The standard deviation of the upstream	0.0949

Secondly, the credit rating of enterprises is quantified by the Cauchy distribution membership function. This paper assumes that when the grade is A, the membership degree is 1, that is, $f(5)=1$; When the grade is C, the membership degree is 0.8, that is, $f(3)=0.8$.It can be concluded from (10): $a=1.1086, b=0.8942, c=0.3915, d=0.3699$. Further, we can calculate $f(2)=0.5245$, $f(4)=0.9126$, that is, the quantitative results of each reputation level are A=1, B=0.9126, C= 0.8, D=0.5245.

Finally, the risk coefficient of each enterprise is calculated through (11), partial results are shown in Tab. 3.

Table 3 Enterprise risk coefficient

Enterprise number	Risk coefficient	Enterprise number	Risk coefficient
E1	0.598	E2	0.734
E3	0.631	E4	0.654
E5	0.680	E6	0.727
…	…	…	…
E121	0.519	E122	0.538
E123	0.526		

It can be seen that the credit risk coefficients of most enterprises are densely distributed among 0.4-0.6, and the average profit has the greatest impact on the risk coefficient (z), with a weight of 0.31; The stability of upstream enterprises has the least impact on z value, and the weight is 0.095. The greater the z value, the stronger the strength of the company and the smaller the loan risk of the bank to the enterprise.

3.2 Optimal credit decision analysis

Firstly, the fitting results of the annual loan interest rate and the customer churn rate of each credit rating are shown in Fig. 1.

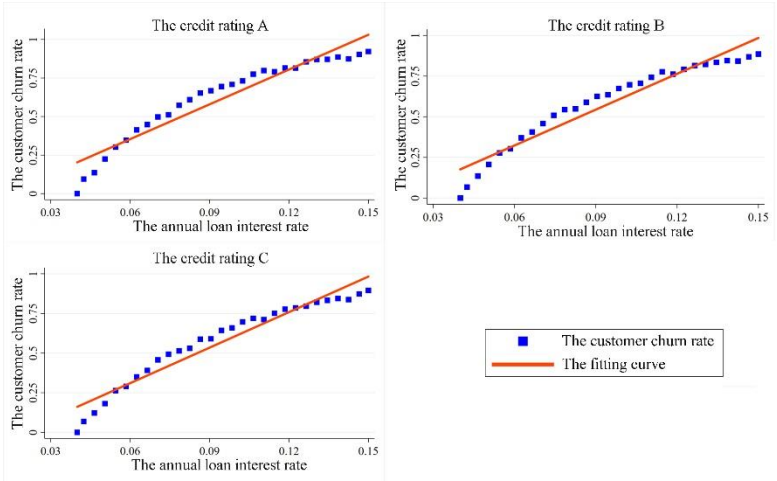

Figure 1. The goodness of fit curve between the annual loan interest rate and the customer churn rate of each credit grade

Secondly, the linear relationship expression and goodness of fit R^2 between the annual loan interest rate and the customer churn rate of class A, B and C credit rating enterprises are shown in Tab. 4.

Table 4 Linear expression of loan annual interest rate and customer churn rate and its goodness of fit

Level	Linear expression	Goodness of fit
A	y = 7.5241x - 0.0979	0.9111
B	y = 7.3511x - 0.1178	0.9256
C	y = 7.4684x - 0.1379	0.9353

Thirdly, according to the risk coefficient z value, 123 data are divided into 10 groups (there are 7 groups of 12 data; the remaining 3 groups contain 13 groups of data), and the default rate of each enterprise is obtained, as shown in Tab. 5.

Table 5 The default rate of each enterprise

Group number	Enterprise number	Default rate
G1	E87, E29, E88, E109, E74, E63	5/12
G2	E82, E92, E79, E88, E99, E83	5/12
…	…	…
G10	E11, E20, E19, E7, E14, E23, E27	0

Finally, by calculating (12), it is obtained that when the total annual loan limit $\sum_{i=1}^{m}\alpha_i$ is 10 million, the optimal solution of the objective function expression is solved, and the results are shown in Tab. 6. (enterprises with the credit rating of D will not give loans directly)

Table 6 Bank to enterprise credit strategy (fixed total annual credit)

Enterprise number	Annual interest rate	Enterprise	Annual interest rate
E1	7.2959%	E2	7.6029%
E3	7.6029%	E4	7.2959%
E5	7.2959%	E6	7.2959%
…	…	…	…
E97	7.6181%	E98	7.6029%
E99	7.2959%		

As can be seen from Tab. 6, when the total amount of bank loans $\sum_{i=1}^{m}\alpha_i$ is a fixed value, the greater the loan amount to each enterprise, the greater the bank income; The enterprise's risk coefficient and household turnover rate will affect the annual interest rate, which is basically about 7%. At this time, the bank income will reach the maximum.

Similarly, when we set the $\sum_{i=1}^{m}\alpha_i$ to 30 million, 50 million, 70 million and 90 million, we can calculate the corresponding optimal credit decision. When the total annual credit is 30 million, the loan limit begins to differ, no longer a single 1 million, and the annual interest rate has been maintained at about 7%. It can be seen that the total bank loan limit has no significant impact on the annual interest rate.

4 CONCLUSIONS

By constructing the decision-making model of bank credit, this paper comprehensively considers various factors affecting the enterprise risk coefficient. The results show that the credit risk coefficients of most enterprises are densely distributed between 0.4-0.6, and the average

profit has the greatest impact on the risk coefficient; The stability of upstream enterprises has the least impact on z value. By solving the optimal solution, it is found that when the total amount of bank loans is a fixed value, the larger the loan amount to each enterprise, the greater the bank income; The enterprise's risk coefficient and customer churn rate will affect the annual interest rate, which is basically about 7%. At this time, the bank's income will reach the maximum.

In addition, the credit decision-making model of banks constructed in this paper has certain popularization, which can measure the credit strategies that banks make to maximize the bank's income in the face of different enterprises and different situations. It is of great significance to judge the bank's credit decision from a quantitative point of view.

REFERENCES

[1] Kreps, David M. and Wilson, Robert B.. Reputation and imperfect information. Journal of Economic Theory, 1982,27(2), pp. 253-279.

[2] Winfred Agbeibor. Pro-poor economic growth: Role of small and medium sized enterprises. Journal of Asian Economics, 2006, 17(1), pp. 35-40.

[3] Liu,H.Y.,Gu,H.B.,Wang,R.X.,Zhong,T.Z.,Liu,S.M.. Research and application of banking credit scoring technology in China (Zhejiang) free trade zone -- An Empirical Analysis Based on credit availability of small and medium-sized enterprises. Credit Reference, 2019,37(02):50-56.

[4] Fu,W.Z.,Chu,L.P.. Research on high quality development evaluation of manufacturing industry from the perspective of integration of Yangtze River Delta -- TOPSIS evaluation model based on improved critical entropy weight method and combined weight. Journal of Industrial Technological Economics,2020,39(09):145-152.

[5] Ma,M.Y.. Discussion on membership function of partial large Cauchy distribution. Modern Vocational Education,2019(10):122-123.

[6] Xu,F.. Research on the innovation of real estate financing credit model of small, medium and micro enterprises -- from the perspective of financial sustainable development. Northern Economy and Trade, 2020(09):104-1.