Research on Data-driven Enterprise Credit Evaluation and Application

Lan Sun *, Wenqi Jiang

Nanjing University of Science and Technology (NUST), China

Abstract. Enterprise credit evaluation is an important indicator in the process of enterprise development, which has an important impact on enterprises' access to external financing and reputation. This paper fully considered the existing credit evaluation index system, combined with the data-driven environment, designed the enterprise credit evaluation index system with three dimensions of financial, social and moral; Secondly, the combination weighting method is used to design the weights and the VIKOR method is used for evaluation; Finally, a case illustrates the application effectiveness of the method.

Keywords: Data-driven; Enterprise Credit; Evaluate.

1. Introduction

After years of development, the United States, Japan, Europe and other countries have established relatively complete credit systems. Enterprise credit is an important content in the development of enterprises, and has a significant impact on enterprise loans, listing, daily operation, etc. Domestic and foreign rating companies carry out credit evaluation on listed enterprises, which affects the performance of enterprises and the market value of stocks. Due to different perspectives of evaluation, the dimensions and indicator systems of enterprise credit evaluation constructed by them are also different. How to design an effective enterprise credit evaluation system and implement the evaluation is particularly necessary.

At present, the design of credit evaluation indicators at home and abroad is still focused on the financial aspect. For example, Guo Tingwei (2016) established an enterprise credit evaluation indicator system that includes financial indicators [1]. Wu Jinju (2018) evaluated the credit of small and medium-sized enterprises from the aspects of basic business status, business ability, profitability, growth ability and law-abiding operation [2]. Han Qin (2019) built a credit evaluation index system for small and medium-sized enterprises including the macro environment, financing enterprise status, core enterprise reputation and supply chain cooperation [3]. In terms of weight design: Lai et al. (2016) built a credit rating model based on rough set theory and analysis of exploratory factors [4]. Zhu Qingxiang et al. (2017) determined the index weight based on the entropy weight-AHP method [5]. Jiang Manman (2017) used the principal component analysis method to determine the index weight [6], and Zhao Lili et al. (2018) determined the weight of the credit evaluation index based on the maximum accuracy [7]. In terms of credit evaluation methods: Xiao Binqing et al. (2016) rated the credit of small and micro enterprises based on fuzzy neural network [8]. Li Tiantian (2017) built a set of enterprise credit evaluation model based on the data association analysis method [9], Shi Baofeng and others (2017) combined the PROMETHEE-II and cluster analysis method to build a merchant microfinance credit model [10], and Zhang Ke and others (2018) proposed a comprehensive weight model based on the weighting of cause degree and the weighting of group decision network analytic hierarchy process [11]. Meng Bin et al. (2019) constructed a credit evaluation model for small construction enterprises that can significantly distinguish default and non-default customers [12].

The above documents have achieved good results in the design of credit evaluation indicators and evaluation models, but most of their credit evaluation indicators take into account financial indicators, and the indicators of inaccurate data sources are not considered much. Therefore, this paper considers the characteristics of credit evaluation under the data environment, designs the corresponding evaluation index system, and uses subjective weights to implement credit evaluation.

2. Enterprise Credit Evaluation Index Design

The existing enterprise credit evaluation system considers the enterprise financial indicators, operation scale and management system. Under the Internet environment, data information becomes more comprehensive and reliable. Based on the demand of credit evaluation, this paper will construct the enterprise credit evaluation index system from the financial, social and moral aspects.

(1) Financial dimension. In the credit evaluation index system, financial indicators mainly include debt repayment ability, profitability, operation ability, development ability and other indicators. Debt repayment ability can judge the ability of an enterprise to repay its debts. Main indicators include asset-liability ratio, quick ratio and EBITDA margin. Profitability mainly reflects the profitability of an enterprise and is related to its ability to repay loans, which is an important part of credit evaluation. The main indicators include the return on total assets and the cash recovery rate of all assets. Operating ability is the ability to make profits with various funds. The main indicators include the turnover rate of accounts receivable and the cash cycle. Enterprises with high development ability are good at using funds reasonably to expand the industrial scale and repay debts on time, which has become an important basis for credit evaluation. The main indicators include the growth rate of operating revenue, the turnover rate of total assets and the growth rate of retained earnings.

(2) Social dimension. Social responsibility is not only manifested in profit distribution and shareholders' rights and interests, but also requires enterprises to undertake corresponding public obligations, reduce the impact on public safety, and maximize their contribution to society, which is a high manifestation of corporate responsibility. The main indicators include social responsibility development index, income tax contribution rate, per capita income growth rate of employees, tax rating and environmental protection investment proportion.

(3) Moral dimension. Credit ethics is an important indicator to measure the integrity of an enterprise in the industry. It mainly depends on whether the information disclosed by the enterprise is accurate and timely, and the credibility of the enterprise manager. Good credit ethics construction also helps enterprises to plan, organize, command, coordinate and control relevant business activities. The main indicators include the integrity of the audit report and the social reputation.

3. Design of Enterprise Credit Evaluation Model

Suppose there are q weight vectors, in order to take into account, the advantages of subjective and objective weights, it is necessary to integrate subjective and objective weights. Suppose the combined weight vector is $(w_1, w_2, \ldots w_m)$,if the number of decision makers is large, it is considered that the weight vector integration result will be close to the vector $(w_1, w_2, \ldots w_m)$. Considering the role of subjective weight and objective weight in combination weighting, their relative importance is α and β respectively. Assume that l samples and $q-l$ samples are selected from the subjective weight and objective weight sets respectively. For each attribute $G_j (1 \le j \le m)$, there are q samples, for $w_j (1 \le j \le m)$, the smaller the deviation from w_j and the q subjective and objective weights, the better. It can reflect that the combination weight fully considers the role of subjective weight and objective weight. To this end, the following optimization model is constructed:

$$\begin{cases} \min H(w_j) = \alpha \sum_{k=1}^{l} (w_j - w_{kj}^s)^2 + \beta \sum_{p=l+1}^{q} (w_j - w_{pj}^s)^2 \\ 0 \le w_j \le 1, (1 \le j \le m) \end{cases} \tag{1}$$

The q samples are from two different populations. According to the basic idea of moment estimation in probability theory and mathematical statistics, for each attribute $G_j (1 \le j \le m)$, calculate

its expected value: $E(w_{kj}^s)=\frac{\sum_{k=1}^{l} w_{kj}^s}{l}, 1\le j\le m$, for each attribute $G_j(1\le j\le m)$, there is $\alpha_j=\frac{E(w_{kj}^s)}{E(w_{kj}^s)+E(w_{pj}^s)}$.

For the enterprise credit evaluation index system, it can be seen as taking m samples from two different populations, and using the basic idea of moment estimation, we can get:

$$\alpha=\frac{\sum_{j=1}^{m}\alpha_j}{\sum_{j=1}^{m}\alpha_j+\sum_{j=1}^{m}\beta_j}=\frac{\sum_{j=1}^{m}\alpha_j}{m};\beta=\frac{\sum_{j=1}^{m}\beta_j}{\sum_{j=1}^{m}\alpha_j+\sum_{j=1}^{m}\beta_j}=\frac{\sum_{j=1}^{m}\beta_j}{m} \tag{2}$$

For each attribute $G_j(1\le j\le m)$, the smaller $H(w_j)$ the better. For this reason, the above model can be expressed as the following nonlinear programming model

$$\begin{cases}\min H=(H(w_1),H(w_2),\ldots H(w_m))\\ s.t:\sum_{j=1}^{m} w_j=1\\ 0\le w_j\le 1,(1\le j\le m)\end{cases} \tag{3}$$

The above planning model is adjusted to the following planning model by using the equal weight linear weighting method, namely:

$$\begin{cases}\min H=\sum_{j=1}^{m}\sum_{k=1}^{l}\alpha(w_j-w_{kj}^s)^2+\sum_{j=1}^{m}\sum_{p=l+1}^{q}\beta(w_j-w_{pj}^s)^2\\ s.t:\sum_{j=1}^{m} w_j=1\\ 0\le w_j\le 1,(1\le j\le m)\end{cases} \tag{4}$$

Without considering the constraint conditions $0\le w_j\le 1$, establish the Lagrange function:

$$l=\sum_{j=1}^{m}\sum_{k=1}^{l}\alpha(w_j-w_{kj}^s)^2+\sum_{j=1}^{m}\sum_{p=l+1}^{q}\beta(w_j-w_{pj}^s)^2+q\lambda(\sum_{j=1}^{m} w_j-1) \tag{5}$$

Joint constraints $\sum_{j=1}^{m} w_j=1$ can be obtained:

$$w_j=\frac{\alpha\sum_{k=1}^{l} w_{kj}^s+\beta\sum_{p=l+1}^{q} w_{pj}^s}{q}-\frac{1}{m}\times(\frac{\sum_{j=i}^{m}(\alpha\sum_{k=1}^{l} w_{kj}^s+\beta\sum_{p=l+1}^{q} w_{pj}^s)}{q}-1) \tag{6}$$

Through the above process, the combined weight result of enterprise credit evaluation is finally obtained, which lays a good foundation for the subsequent enterprise credit evaluation.

Combined with the above weight results, the implementation of comprehensive evaluation of enterprise credit needs to adopt relevant comprehensive evaluation models. This paper designs an evaluation model based on the advantages of VIKOR method.

First, standardize the data of enterprise credit evaluation indicators, and select the positive and negative ideal points PIS (y_j^+) and NIS (y_j^-) under each indicator.

$$y_j^+=\left\{\max y_{i1},\max y_{i2},\cdots,\max y_{i,10}\middle|i\in(1,2,\cdots,m)\right\} \tag{7}$$

$$y_j^-=\left\{\min y_{i1},\min y_{i2},\cdots,\min y_{i,10}\middle|i\in(1,2,\cdots,m)\right\} \tag{8}$$

Then, the corresponding group utility value and individual regret value are calculated, and the credit evaluation results of each object to be evaluated can be obtained according to the evaluation process of VIKOR.

$$S_i = \sum^{10} w_j D(y_j^+, y_{ij}) / D(y_j^+, y_j^-) \tag{9}$$

$$R_i = \max_j \left\{ w_j D(y_j^+, y_{ij}) / D(y_j^+, y_j^-) \right\}, j \in (1,2,\cdots,10) \tag{10}$$

$$Q_i = v(S_i - S^-)/(S^+ - S^-) + (1-v)(R_i - R^-)/(R^+ - R^-) \tag{11}$$

Therefore, according to the evaluation rules in the VIKOR model, the final comprehensive credit evaluation results of the enterprises to be evaluated can be formed, and corresponding countermeasures and suggestions are put forward based on the difference value of the results.

4. Case Study

In this paper, four listed enterprises in the steel industry are selected for evaluation. The specific data are shown in the table below.

Table 1. Original data of enterprise credit evaluation indicators

evaluating indicator	A	B	C	D
Asset-liability ratio	0.581	0.674	0.469	0.56
Quick ratio	1.056	0.927	0.874	1.10
EBITDA margin	0.242	0.124	0.090	0.11
Return on total assets	0.330	0.130	0.370	0.250
Cash recovery rate of all assets	0.200	0.478	0.480	0.49
Turnover speed of accounts receivable	5.000	7.300	8.420	5.23
Cash cycle	0.505	0.495	0.503	0.50
Operating revenue growth rate	0.197	0.023	0.099	0.15
Total asset growth rate	0.268	0.117	0.230	0.23
Growth rate of retained earnings	0.518	0.549	0.507	0.51
Social responsibility development index	3.000	5.000	5.000	4.00
Income tax contribution rate	0.038	0.047	0.023	0.04
Growth rate of per capita income of employees	0.026	0.0468	0.0375	0.030
Tax rating	1.000	1.000	1.000	1.000
Proportion of environmental protection investment	0.150	0.170	0.250	0.180
Integrity of audit report	1.000	1.000	1.000	1.000
Social reputation	0.600	0.200	0.600	0.400

Assume that the judgment matrix of solvency and development ability under the financial dimension is:

$$A = \begin{bmatrix} 1 & 9 & 1/7 \\ 1/9 & 1 & 5 \\ 7 & 1/5 & 1 \end{bmatrix}, B = \begin{bmatrix} 1 & 4 & 1/7 \\ 1/4 & 1 & 1/5 \\ 7 & 5 & 1 \end{bmatrix}$$

The order relationship between the attributes or schemes formed by the triangular matrix on the matrix is $C_3^2 = 3$.

(1) In the consistency judgment matrix under solvency, from the first level, for example, in the $\{a_1, a_2, a_3\}$, $a_{31} > 1, a_{12} > 1$,should have $a_{32} > 1$, but $a_{32} = 1/5$, the above does not meet the order consistency; in the $\{a_3, a_2, a_1\}$, $a_{23} = 5, a_{13} = 1/7$, $a_{23} > a_{13}$,therefore $a_{21} > 1$ .However, the above result $a_{21} = 1/9$ does not meet the strong order consistency.

According to the above adjustment steps, the directed graph of the calculation example is shown as follows:

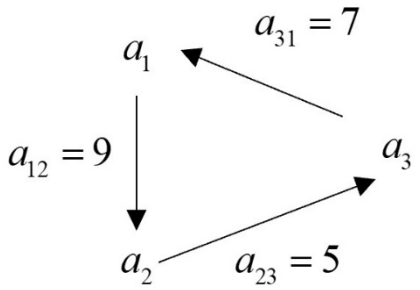


Fig 1. Directed graph representation of judgment matrix

The adjustment process is as follows:

1. $B_{fgh}=\{a_1,a_2,a_3\}$
2. $S_{cde}=\{a_2,a_3,a_1\}$
3. $T_{31}=T_{12}=T_{32}=T_{23}=T_{13}=1$

4. The above times are all 1, a_{32} shall be adjusted first according to principle 1 and modified a_3 to be better than a_2. According to the modification principle provided by Principle 2, if considered $\{a_1,a_2,a_3\}$, $a_{32}=7\times9=63$. The importance value above 5 should be compared separately, and the lowest value of CI should be taken as the final value.

For $\{a_3,a_2,a_1\}$, The priority between a_2 and a_1 needs to be modified, modify it to $a_{21}=2$, and it can also be a scale value above 2.

5. Calculated the value of CI, if $a_{32}=7$, $CI=0.063201$; $a_{32}=6$, $CI=0.060235$; $a_{32}=8$, $CI=0.065425$; $a_{32}=9$, $CI=0.072521$. Therefore, we choose $a_{32}=6$ to satisfy the order consistency and strong order consistency. The judgment matrix obtained is:

$$A=\begin{bmatrix}1 & 1/2 & 1/7\\ 2 & 1 & 1/6\\ 7 & 6 & 1\end{bmatrix}$$

The weight is: $(0.2848,0.3303,0.3849)$.

Based on the credit evaluation index data of the above enterprises, this paper uses the objective weighting method to calculate the weights: 0.0543,0.0585, 0.0624, 0.0610, 0.0869, 0.0563, 0.0848, 0.0617, 0.0300,0.0735,0.0634,0.0491,0.0458,0.0378,0.0341,0.0652,0.0752.

Combining the above weight results and specific indicator data, the VIKOR model is used for comprehensive evaluation, and the evaluation results are as follows:

Table 2. Comprehensive evaluation results of case enterprises

enterprise	Group utility value	Individual regret value	Value of Q
Enterprise A	0.5945	0.0848	0.6687
Enterprise B	0.5426	0.0811	0.0000
Enterprise C	0.6168	0.0817	0.5517
Enterprise D	0.6064	0.0869	0.9299

Since the above calculation results meet the conditions 1 and 2, the credit of the four enterprises can be ranked according to the result of Q value. Based on the above ranking results, listed company B is the best credit company. For the other three enterprises, the credit enhancement project can be carried out separately based on the differences between the specific data of 17 indicators and that of enterprise B. In the process of credit improvement, other enterprises can analyze the difference between them and enterprise B, further strengthen the positive difference value, sort the negative

difference value, and adjust it according to the size of the weight value and in combination with their own resource value.

References

[1] Liu Jie, Guo Tingwei. Research on credit evaluation of scientific and technological start-ups based on BP neural network [J] Modern Commerce and Trade Industry, 2015, 36 (23): 62-64.

[2] Wu Jinju.Construction of credit evaluation index system for small and medium-sized enterprises based on tax information [J] Journal of Social Sciences of Harbin Normal University, 2018, 9 (2): 86-89.

[3] Han Qin.Construction of SME credit risk evaluation index system from the perspective of supply chain finance [J] Times Finance, 2019, No. 727 (9): 177-178.

[4] Lai X, Liu J, Georgiev G. Low carbon technology integration innovation assessment index review based on rough set theory --An evidence from construction industry in China[J]. Journal of Cleaner Production, 2016, 126: 88-96.

[5] Zhu Qingxiang, Xu Nan, Liu Tingyu.Research on the membership vector discrimination of dynamic indicators of credit evaluation of agriculture-related enterprises [J] Practice and Understanding of Mathematics, 2017, 47 (9): 57-63.

[6] Jiang Manman. Research on enterprise credit risk evaluation from the perspective of supply chain finance [J] Operation and Management, 2017 (2): 140-142.

[7] Zhao Lili, Wang Xueqing, Chen Chao.Supervision engineer credit evaluation under interval intuitionistic fuzzy information [J] Operations Research and Management, 2018, 27 (1): 125-131.

[8] Xiao Binqing, Yang Yang, Li Xindan, Li Haohua. Research on credit rating of small and micro enterprises based on fuzzy neural network [J]. Journal of Management Science, 2016,19 (11): 114-126.

[9] Li Tiantian.Research on enterprise science and technology credit rating method based on data association analysis [J] Science and Education Guide, 2017 (1): 175-176.

[10] Shi Baofeng, Liu Feng, Wang Jianjun, Chi Guotai. Credit rating model and empirical analysis of merchant microloans based on PROMETHEE-II [J]. Operation Research and Management, 2017,26 (9): 137-147.

[11] Zhang Ke, Liang Yuqin, Xue Song, Hu Leichuang. Calculation of credit evaluation weight of construction enterprises from the perspective of cross-correlation [J]. Statistics and Decision, 2018,34 (10): 178-182.

[12] Meng Bin, Yang Yue, Diao Shujie. Research on credit evaluation model of small construction enterprises based on distinguishing two types of customers [J]. System Engineering Theory and Practice, 2019, 39 (2): 346-359.