

Ershi Qi  
Jiang Shen  
Runliang Dou *Editors*

# The 19th International Conference on Industrial Engineering and Engineering Management

Engineering Economics Management

 Springer

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Ershi Qi · Jiang Shen · Runliang Dou  
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*Editors*

Ershi Qi  
Jiang Shen  
Industrial Engineering Institution of CME  
Tianjin  
People's Republic of China

Runliang Dou  
College of Management and Economics  
Tianjin University  
Tianjin  
People's Republic of China

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# Chapter 1

## A Study of Research and Application of Credit Scoring Model Based on Probit Model

Da Ren, Maodong Hou and Huan Li

**Abstract** As the main content of the credit risk management, Credit rating has significant research value. China's current use of credit scoring method is too subjective and unable to adapt to the fierce competition in the banking sector. In connection with the weak ability of risk identification of Chinese commercial banks, paper use the Probit regression to build credit scoring models, calculate the probability of default of each customer, divide the customers into two categories, and then test the classification results with ROC curve. The conclusion of the paper shows that the Probit—based credit scoring models can be effective to identify the risk of a manufacturing enterprise, and it is suitable for China's commercial banks to assess corporate lending credit risk.

**Keywords** The management of credit risks · Probit regression · Credit rating · Risk identification

### 1.1 Introduction

As the basis of market economy, credit system impacts on the development of market economy seriously. The financial crises of 2008 make credit risk an urgent problem to the market economy countries. As the most main type, credit risk is being the greatest issue of current financial community. With the development of the economic environment, commercial banks are forced by the fierce market competition to find a fast and accurate credit mechanism to take place of artificial credit. And the credit scoring has been developed in the internal needs of such credit institutions. The CBRC released the China Banking Regulatory Committee Issuing the Guidelines on the Implementation of New Capital Accord provides that

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D. Ren · M. Hou (✉) · H. Li  
School of Management, Tianjin University, Tianjin, People's Republic of China  
e-mail: houmd2012@126.com

large domestic commercial banks should finish the model of credit risk and market risk to measure the credit risk, market risk and the operational risk. Since differences in the business and data of different banks limits the general applicability of the model of credit rating, the banks should build the credit scoring models suited to the development of their business needs based on their own business characters and the data their got. The credit decision is mainly depend on artificial subjective judgments which are complicated, low efficiency, and high cost, and this influences the accuracy and objectivity of credit decisions. Accordingly, the study of the credit scoring model has great theoretical and practical significance.

## 1.2 The Current Research Status

The foreign scholars expanded credit scoring models to the evaluation of small sample and individual consumers, and not only limited to the improvement of the model, but also dedicated to the examination of the perfect combination of technology and model (Thomas and Edelman 2002; Good 2005; Rosenberg and Gleit 1994) Summarized the common credit scoring models and introduced the applications. Marshall and Milne (2010), Potter (2005), Fitzmaurice et al. (2007) builded the the corresponding non-linear regression model and verified the results by permutation test base on the Unbalanced sample data. Vladimir et al. (2002) created the credit evaluation model based on the quadratic utility function. Musto and Souleles (2005) built a portfolio model; Gross and Souleles (2000) built a nonlinear regression method. They also tried to explain that how does the psychology and behavior of consumers influence the results of credit scoring, and the study found that liabilities affect the application of credits greatly. Deyoung et al. (2008) built the scoring models based on the Differences between the loaner and loanee in SME Loan Financial Information and the behavior of loaners, and this model has a higher ability to identify the risk of default of the SME.

The study of the credit scoring system in china is relatively late, and it is at the stage of study and research; some scholars make effort to SME credit scoring models. Hui (2001) and some others studied the new research and development of key technologies of personal credit scoring; Lin (2006), Du (2008), Chen (2005) and so on studied the mature credit scoring system in the U.S., and summed up the development process of credit scoring model; Li (2009) built the a credit scoring system which suit to China based on the summery of credit evaluation index system and method; Dong (2007) proposed small business credit scoring can improve the availability of small-scale loans greatly by reducing information asymmetry effectively. Wu (2005) analyzed the application and impact of credit scoring in the field of SME loans, and provided the advices to solve the difficulty of SME loans and development. Cheng (2003) explored the method to measure the SME credit and set up the evaluation index system preliminary by analyzing the characteristics of High-tech SMEs. Ziyi and Zhao (2005) built the SME credit scoring model based on financial position, and quantification of information of

enterprises and their head, and this provided reference to measure credit risk accurately and low-cost for banks. Guan and Zongxian (2004) built and explored the Default prediction model as sub-scale and sub-regional sample specially for manufacturing industry enterprises based on a massive database of loans to businesses across financial institutions on national. Sun (2007) compared the accuracies of many kinds of default prediction of credit risk models by constructing accuracy ratio and conditional information entropy, and found that Nonlinear models have higher default prediction accuracy at the end. Cheng and Lian (2007) modeled credit scoring system with the ROC curve and the Transformation of Variable array that different with the method used in China before.

With the development of computer technology, artificial intelligence methods began to be used on the commercial banks' credit ratings, but the statistical method is still the core of the credit scoring model. The two main reasons are robustness and transparency. A part of the artificial intelligence methods get bad results when the characteristics of data change totally. What's more, the regulatory agencies require customers to give reasons for refusing customers credit application. But the "black case work" made by artificial intelligence can provide this information. In China, commercial banks started to use statistical methods such as logistic regression, linear regression, linear programming and classification tree. The logistic regression is used the most widely due to many advantages, but its accuracy is relatively low. As a generalized linear model like logistic regression, Probit-regression model has not been used widely until now, so there is no corresponding literature reference about discussion and comparison of this model. Accordingly, this paper introduces probit-regression into credit scoring, and tests its accuracy of prediction.

### 1.3 Index Selection and Data Collection

The Credit Risk Assessing Targets recognized internationally contain "5C", "5P", "LAPP" Pinson (1989), and the targets include the financial credit information such as credit history record, individual accounting recording, and debt intention. All these are developed on long-time accumulation of historical data, and have strong reliability. Whereas commercial banks in China have been built for a short time and the credit system is not perfect and lacks long-time accumulation of historical data, so the choice of credit targets depends on basic personal information more, such as age, gender, occupation, income and other factors. Specific indicators and the number depends on the data collected by banks.

The financial market seems to provide model vast amounts of data, but in fact, it is still hard to get many parts of data, and even the data got are maybe unable to get application. For the credit scoring model studied in this paper, commercial banks may focus more on the data of customers got the loan rather than the data of customers who have not got the loan, and defaulting customers of banks are only a small part on customers. This leads to customer type distribution is extremely

uneven. And serious imbalance of data will affect the accuracy of credit scoring model, which has become a common problem facing by all credit scoring models already. Chinese scholars believe that the ratio of good and bad sample have obvious effect on the estimation and efficiency of Logistic default probability model, and the ratio of 3:1 is more suit to the situation of china. Therefore, the ratio of 3:1 is the focus of this paper.

## 1.4 The Foundation of Model

### 1.4.1 Identification of Bad Sample

The attributes of the customers is the internal secret, and they are affected by a variety of outside factors such as the types of financial products. But it is important to define good and bad customers clearly and to keep accord with banks' credit policy and goal of risk management. Generally, quality customer, good sample, refers to the ones without default or with low risk of default during the observation window period; and the high-risk customer, bad sample, refers to the ones with default or delay and the ones refused by banks when propose a loan; the customers unable to be defined don't be included.

### 1.4.2 Probit Model

Probit-regression is mainly used to process the case that the dependent variable is Binary Choice, that is to say the dependent variable is 0 or 1. In the example of paper, the bad sample with default is defined as  $Y = 1$ , and the good sample without default is defined as  $Y = 0$ . Set  $P_i = p(y_i = 1|x_i)$ , it refers that the probability of  $y_i = 1$  under certain condition  $x_i$ . And  $1 - p_i$  is the probability of  $y_i = 0$  under certain condition  $x_i$ .

To define a continuous explanatory variable  $Y^*$ , set  $y_i^* = \alpha + x_i \beta + \varepsilon_i$ ,  $\varepsilon_i \sim N(0, 1)$  and when  $y_i^* > 0$ ,  $y_i = 1$ . Then  $p(y_i = 1|x_i) = p(y_i^* > 0) = p(\alpha + x_i \beta + \varepsilon_i > 0) = p(-\varepsilon_i > \alpha + x_i \beta) = \Phi(\alpha + x_i \beta) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\alpha+x_i\beta} e^{-\frac{t^2}{2}} dt = p_i$  where  $\Phi$  in the cumulative distribution function of the standard normal distribution, and this transformation is called the probit transformation.

Probit regression model uses maximum likelihood estimation method to calculate the coefficients. Set independent observations as samples, denoted as  $y_1 \dots y_n$ . Then the likelihood function is  $L = \prod_{i=1}^n p_i^{y_i} (1 - p_i)^{1-y_i}$ .

Take logarithm on both sides:

$$\begin{aligned}\ln L &= \ln \left[ \prod_{i=1}^n p_i^{y_i} (1 - p_i)^{1-y_i} \right] \\ &= \sum_{i=1}^n [y_i \ln(p_i) + (1-y_i) \ln(1 - p_i)]\end{aligned}$$

Take  $y_i^* = \alpha + x_i \beta + \varepsilon_i$  into above, then

$$\ln L = \sum_{i=1}^n \left[ y_i \ln \phi \left( \alpha + \sum_{j=1}^m \beta_j x_{ij} \right) + (1 - y_i) \ln \left( 1 - \phi \left( \alpha + \sum_{j=1}^m \beta_j x_{ij} \right) \right) \right].$$

For the log-likelihood function, work out the partial derivatives of  $\alpha$  and  $\beta_j$ , set them to 0, and then calculate the estimated values of the Simultaneous equations by iteration method. We can verify the result of modeling with data external samples.

### 1.4.3 Model Checking

To judge the merits of credit scoring models is the key of modeling. The testing of stability and accuracy of model is based on the performance of the credit scoring model to distinguish good customers and bad customers. In the paper, the ROC curve is used to measure the accuracy of the model.

The ROC, receiver operating characteristic curve, is also named feelings shaped curve.

For a classification problem, each sample two categories and there are Positive and Negative. To credit scoring, P means bad customers and N means good customers. Specificity = True Negative/N, this means the ratio that a good customer is correctly predict as a good customer; Sensitivity = True Positive/P, this means that a bad customer is correctly predict as a bad customer and Sensitivity is marked as TP rate. 1-specificity, marked as FP rate, which means a good customer is predict as a bad customer.

FP rate as X axis, and TP as Y axis, then we can get a ROC curve. On the ROC curve, The origin (0, 0) means that the correct rate of classifying P is 0, and also the rate of classifying N; (1,1) means that the correct rate of classifying P is 1, and also the rate of classifying N. The points on the diagonal means that these point represents right and wrong equal probability, which is random. The point should keep as far as possible from the diagonal. If points are close to the diagonal, it means that the result is better without random assortment, and this makes no sense. To rank the scores of sample as descending order, then set the classification criteria as the scoring after ranking. Then to mobile classification criteria, calculate the classification of samples, update TP and FP continuously until to get several

discrete classification points, and those points are connected together to be an approximate continuous ROC curve. The values of AUC are values represented on the ROC curve, and we can convert the classification result of the ROC curve into a specific value by calculating the size of the area under the ROC curve. The value of QUC is between 0 to 1, and when it is closer to 1, the larger the area under the ROC curve, which indicates that the classification result is better.

## 1.5 Numerical Experiments

### 1.5.1 Data Sources

The purpose of the paper is to verify the application of probit model in credit scoring model. Data sources come from the financial data of a certain manufacturing enterprise collected by a large state-owned commercial bank. After clearing missing data and abnormal data, there are 11922 remaining data. Among these, there are 11855 good samples, 67 bad samples, including 130 variables, marked as  $X_1, \dots, X_{130}$ .

The initial index system is exceptionally complicated, and there is a serious collinearity. Therefore, before modeling we must consider the 130 variables and remove significant correlational variables at first, and then filter the remaining variables. We often use cross tabulation to analyze, and determine the characteristic variables and feature items into the model by Weight of Evidence, WOE and Information Value, IV.

There are two purpose of the experiment in the paper. Firstly, to verify the better judgment ability of model with the ratio of good and bad samples that is 3:1. Secondly, to verify that the WOE value got from Weight of Evidence is better than the value got from the model with original indexes.

### 1.5.2 Full Sample Model

There are 67 “bad” samples in the data, and we selected 201 “good” samples and 67 “bad” randomly to model. The “good” samples remaining are used to verify.

To build the regression model with the 15 variables selected, the non-dominant of some indexes (Table 1.1) need to a further selected. In the paper, a step-by step screening method is used, and removed variables  $X_{105}$ ,  $X_{73}$ ,  $X_{108}$ ,  $X_{16}$ ,  $X_{122}$ ,  $X_{118}$ ,  $X_{62}$ , Sequentially, and the get a better regression model (Table 1.2).

After choosing 201 good samples and 67 bad samples to build the model, we get a model with 8 independent variables (Table 1.3).

The ROC curve of modeling samples is shown in Fig. 1.1 and the area under the ROC curve, AUC value, is 0.9058.

**Table 1.1** The coefficients of a full variable regression model

Parameters	Estimate	Standard error	Z	Sig.	95 % Confidence interval	
					Upper limit	Lower limit
X16	-0.1	0.213	-0.471	0.637	-0.517	0.317
X18	-0.127	0.076	1.687	0.092	-0.276	0.021
X28	-0.531	0.731	-0.727	0.467	1.965	0.902
X54	-3.603	0.363	2.643	0.008	6.274	-0.931
X62	0.08	0.624	0.128	0.898	1.143	1.302
X72	0.016	0.007	0.211	0.027	0.002	0.03
X73	0	0	1.801	0.072	0.001	0
X97	-0.415	0.076	5.437	0	0.565	-0.266
X104	0	0	2.277	0.023	0	0
X105	-0.207	0.581	0.356	0.722	1.345	0.931
X108	-0.009	0.597	0.015	0.988	1.178	1.16
X114	1.216	0.518	0.347	0.019	0.2	2.231
X118	0	0	0.498	0.619	0	0
X122	-0.682	0.788	0.865	0.387	2.226	0.863
X124	-1.344	0.843	1.594	0.111	2.997	0.309
Intercept	4.313	0.821	5.256	0	0.492	5.133

**Table 1.2** The coefficients of stepwise regression model

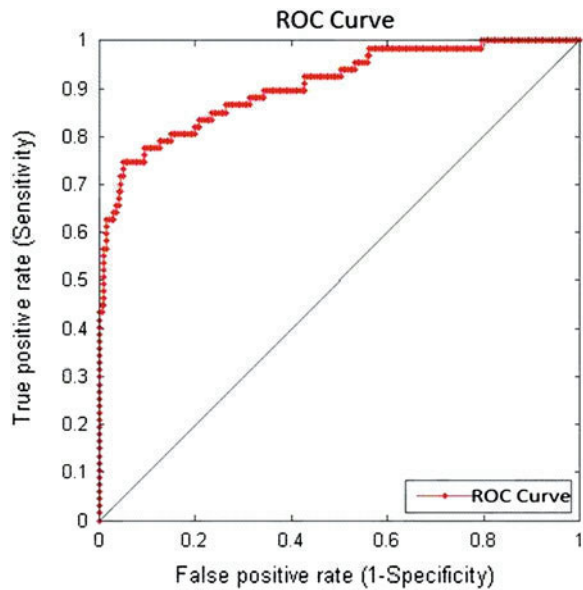
Parameters	Estimate	Standard error	Z	Sig.	95 % Confidence interval	
					Upper limit	Lower limit
X18	-0.145	0.066	-2.178	0.029	-0.275	-0.015
X28	-1.275	0.496	-2.572	0.01	2.247	-0.303
X54	-3.448	0.237	-2.787	0.005	5.872	-1.024
X72	0.02	0.008	2.574	0.01	0.005	0.036
X97	-0.423	0.073	-5.778	0	-0.566	-0.279
X104	0	0	-2.356	0.018	0	0
X114	1.359	0.524	2.594	0.009	0.332	2.387
X124	-1.618	0.645	-2.508	0.012	2.883	-0.354
Intercept	4.543	0.874	5.197	0	3.669	0.417

Analysis of modeling results can be informed that the cut-off point is 0.343, that is to say there are 201 data with calculation results less than 0.343. To verify the results of modeling with 11654 good samples and also taking the 0.343 as the cut-off point, there are 1206 samples are judged as bad samples. The ratio of correct judgment is 89.65 %, and the ratio of fail judgment is 10/35 %. This is an acceptable result. Since the 67 bad samples are all used to model, there is no bad sample used to verify the model.

**Table 1.3** Full sample model

Index	Estimate
The ratio of the net assets of fixed assets	-0.145
The growth rate of tangible assets	-1.275
FFO to total assets	-3.448
Asset turnover number of months	0.02
Logarithm of total assets	-0.423
Three-year average sales growth rate	0.0001
Net profit ratio of fixed assets and inventories	1.359
Long-term return on capital	-1.618
Intercept	4.543

**Fig. 1.1** The ROC curve of full sample model

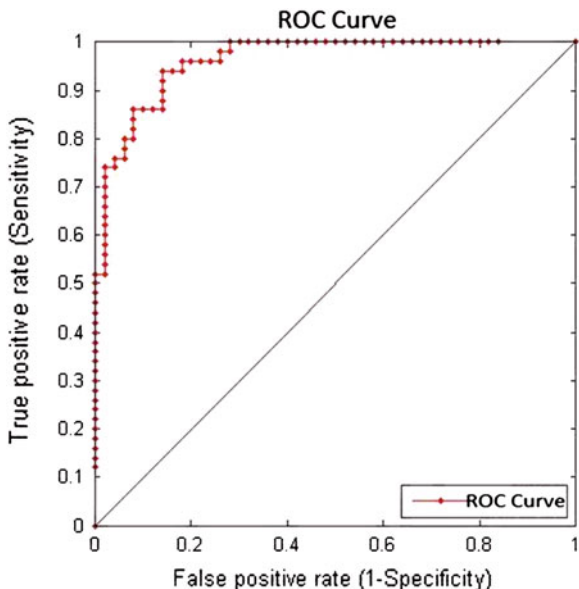


### 1.5.3 Random Sample Model

In the model above, since all the samples used to verify is good and all the bad samples are used to build the model, the performance of the model on the rate of correct judgment is no convincing. Now to model with samples obtained randomly.

At present, the domestic scholars build credit scoring model at the ratio of good or bad samples generally 1:1; 1:2; 1:3. To design three experiments to verify that Probit model can get application efficiently into the credit scoring, and draw a conclusion that it is a better ability of evaluation capacity when the model is built at the ratio of good or bad samples is 3:1.

**Fig. 1.2** The ROC of experiment 1



Experiment 1: To build the model with 50 good samples and 50 bad samples, and to verify the model with the remaining samples. There are 11822 samples, which contain 11805 good samples and 17 bad samples.

Experiment 2: To build the model with 90 good samples and 45 bad samples, and to verify the model with the 11765 good remaining samples and 22 bad remaining samples.

Experiment 3: To build the model with 144 good samples and 49 bad samples, and to verify the model with the remaining 11711 good remaining samples and 19 bad remaining samples Figs. 1.2, 1.3, 1.4, Table 1.4.

Considering the sentenced positive rate, the model is best when the ratio of good or bad is 3:1. However, these data need to be selected by SPSS before modeling.

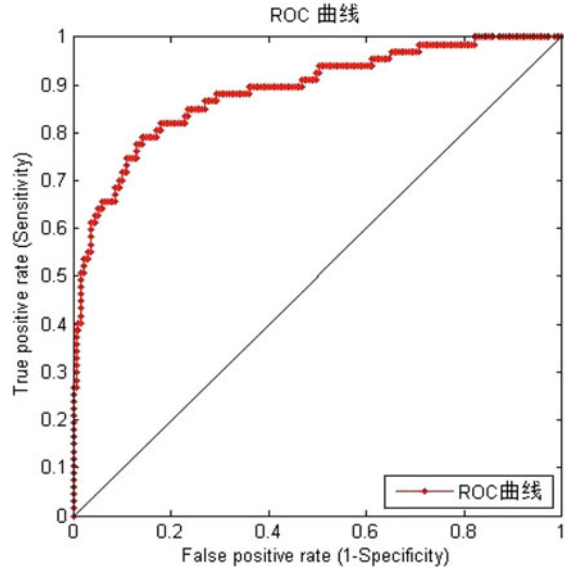
When there is a great imbalance of bad and good samples, the three experiments above may not be able to carry out. Although the model with ratio 3:1 is superior to the models with ratios 2:1 and 1:1, we can't say it superior to all the models. So we build the model at the ratios of 4:1, 5:1, and 10:1.

Experiment 4: To build the model with 168 good samples and 45 bad samples, and to verify the model with the 11687 good remaining samples and 22 bad remaining samples.

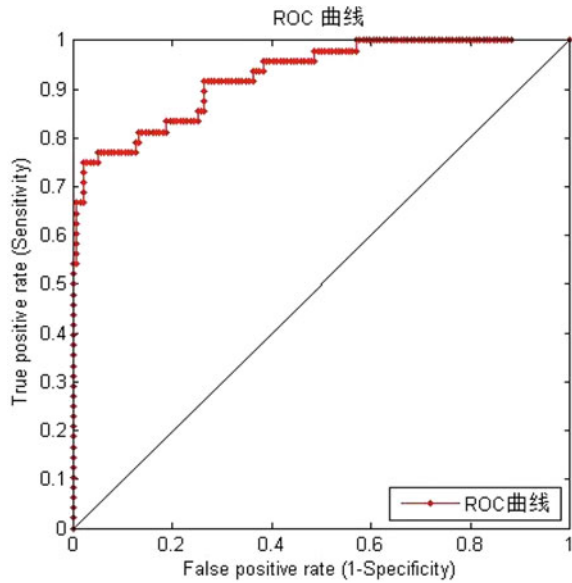
Experiment 5: To build the model with 200 good samples and 40 bad samples, and to verify the model with the 11655 good remaining samples and 27 bad remaining samples.

Experiment 6: To build the model with 300 good samples and 30 bad samples, and to verify the model with the 11555 good remaining samples and 37 bad remaining samples.

**Fig. 1.3** The ROC of experiment 2



**Fig. 1.4** The ROC of experiment 3



**Table 1.4** Testing values of multi-experiments model

	AUC	Found positive rate	
		Predicated good (%)	Predicated bad (%)
Experiment 1	0.962	77.88	64.71
Experiment 2	0.9568	85.23	59.09
Experiment 3	0.928	88.66	73.68

**Table 1.5** Testing values of the experiments

	AUC	Found positive rate	
		Predicated good (%)	Predicated bad (%)
Experiment 1	0.962	77.88	64.71
Experiment 2	0.9568	85.23	59.09
Experiment 3	0.928	88.66	73.68
Experiment 4	0.9012	89.12	65.98
Experiment 5	0.8776	90.01	60.65
Experiment 6	0.8025	92.17	49.04

The values from Table 1.5 show that with the ration increases gradually, AUC value decreases gradually, and this illustrates that the overall sentenced positive rate is getting lower and lower. In the fact, since the amount of good samples increases, the correct judgment of judging good increases and the correct judgment of judging bad decreases at the same time, but the degree of reducing is significantly greater than the degree of the increase of correct judgment of judging good. This demonstrates that at the ratio of 3:1 can get the optimal regression estimation model when the ratio is in a certain range.

### 1.5.4 The WOE Value Model

To calculate with new variable indicators and WOE value. When the ratio of good and bad samples was 1:1, we selected 23 indicators with WOE, and calculated and compared the results got from 23 original value and WOE value separately (Table 1.6).

The analysis shows that the model built with WOE value get the best results when the ratio of good and bad samples is 3:1. And the correct-judgment rate of good samples is 91.66 %, and the correct-judgment rate of bad samples is 73.68 %. The AUC value of validation sample is 0.8711. This result is acceptable.

**Table 1.6** Comparison of testing values of original value model and WOE value model

Matching type	AUC	Found positive rate	
		Predicated good (%)	Predicated bad (%)
1:1	Original value	72.08	64.71
	WOE value	84.06	64.71
2:1	Original value	88.81	63.64
	WOE value	87.71	68.18
3:1	Original value	88.28	63.16
	WOE value	91.66	73.68