

# Research on the Financial Crisis Early Warning of Listed Companies in China—Based on Probit model and Logit model

Kangbo Liu<sup>1</sup>, Wei Liu<sup>2</sup>, Qiqi Xu<sup>3</sup>

1. School of Finance, Anhui University of Finance and Economics, Anhui Bengbu, 233000

2. School of Economics, Anhui University of Finance and Economics, Anhui Bengbu, 233000

3. School of Statistics and Mathematics, Anhui University of Finance and Economics, Anhui Bengbu, 233000

**ABSTRACT.** The article selects 12 financial indicators from the six aspects of listed companies' profitability, operating capacity, solvency, growth capacity, cash flow and capital structure to construct Probit model and Logit model to study the financial difficulties of listed companies in China. The results show that earnings per share, equity ratio, interest protection multiples and inventory turnover ratio have a significant early warning effect on the financial distress of listed companies in China. The Probit model has a prediction accuracy rate of 78.31% for whether the company will fall into financial difficulties, and the Logit model has a prediction accuracy rate of 92.18%. The Logit model's prediction ability is significantly better than the Probit model.

**KEYWORDS:** Listed Company; Financial Distress; Probit Model; Logit Model

## 1. Introduction

With the improvement of China's securities market, the number of listed companies is increasing year by year, which directly promotes the development of China's capital market. At the end of 2013, the IPO restarted for more than a year,

---

1.Kangbo Liu(1999—), male (Han), Huaibei, Anhui, undergraduate student at Anhui University of Finance and Economics, research direction: Finance.

2.Wei Liu(1999—), male (Han), Enshi, Hubei, undergraduate student at Anhui University of Finance and Economics, research direction: Economics.

3.Qiqi Xu(1999—), female (Han), Huaibei, Anhui, undergraduate student at Anhui University of Finance and Economics, research direction: Data Science

and the Chinese stock market once again attracted worldwide attention. As a typical representative of the real economy, a listed company occupies a vital position in the industry. Its financial situation not only involves many stakeholders, but also has a significant impact on the market environment.

In recent years, affected by the macroeconomic environment at home and abroad, the financial situation of Chinese listed companies has deteriorated, and the phenomenon of "polarization" has become significant. In 2019, there were 74 ST companies in Shanghai and Shenzhen, the largest number since the establishment of the ST system in 1998. At the same time, the "Financial Security Evaluation Report of China's Non-financial Listed Companies" shows that China's financial security index has been showing a downward trend. Establishing an effective enterprise financial early warning mechanism for listed companies can detect problems early, move the risk threshold forward, and reserve time windows for company management to make decisions and change strategies. It is not easy for enterprises to fall into financial difficulties. We can mine effective information from complex financial data and establish mathematical models to judge the direction and extent of changes in financial indicators in a timely manner to reduce losses as much as possible. For investors, because the listed company's equity is publicly issued and circulated in the market, it belongs to a major interest entity, and its financial situation affects every stakeholder. At present, China's securities market is in a weak and effective stage. It is particularly important for economic decision-making institutions and investors to establish a prediction mechanism that can effectively determine whether listed companies will fall into financial crisis in the future.

## 2. Literature Review

The development of the stock market in capitalist countries is relatively early. From the Amsterdam Stock Exchange in the early 17th century to the establishment of the New York Stock Exchange in 1903, Western countries have developed relatively mature listing and delisting mechanisms, and have conducted many studies. Fitzpatrick<sup>[1]</sup> selected 19 sample companies for financial early warning analysis in 1932, divided them into a bankruptcy group and a non-bankruptcy group, and then selected a single financial indicator for empirical research. The results show that two financial indicators, Return on Equity (ROE) and Debt-Equity Ratio (CR), can better predict the financial crisis of an enterprise. Altman<sup>[2]</sup> (1968) based on Fitzpatrick's research, expanded a single variable into multiple variables for financial early warning analysis. He first selected five representative financial indicators through principal component analysis, and then separately analyzed these five. Each financial indicator is given different weights, and finally the weighted summary generates a total discriminant value (Z value). By analyzing the Z value, it is judged whether the company will have a financial crisis in the future. With the development of mathematical statistics, Jones and Hensher<sup>[3]</sup> (2004) chose the mixed Logit model for the first time to establish a financial distress early warning model. The goodness of fit and prediction accuracy of the mixed Logit model are higher than the Logit model. Min and Lee<sup>[4]</sup> (2005) used the support vector machine (SM)

method to predict the financial distress of listed companies, and the results obtained were superior to neural network models, multivariate discriminant analysis models, and Logit models.

Reviewing relevant research in China, Wu Shinong and Lu Xianyi<sup>[5]</sup> (2001) used 70 financial crisis companies listed in 1998-2000 and 70 financially sound companies as research samples, and compared Fisher linear discriminant analysis and multiple linear regression analysis. Method and Logit regression analysis method in predicting the performance of the financial crisis, select the Quick-ratio (Acid-test Ratio), Debt to Asset Ratio, Working Capital Ratio, Equity Capital Growth Rate (Equity) 7 financial indicators including capital growth rate, Return on Equity, Accounts Receivable Growth Rate and Total Asset Turnover were empirically studied. Zhang Qingli<sup>[6]</sup> (2018) used DEA method to analyze financial early warning indicators, and then constructed Logistic regression model to analyze the difference in technical efficiency, pure technical efficiency and comprehensive efficiency between financial crisis group and normal financial group. Deng Lichun and Du Weiyong<sup>[7]</sup> (2020) 1409 listed companies on the stock exchange were taken as samples, and a Cox proportional risk model was established to systematically discuss and analyze the occurrence of corporate financial risks.

Based on the above literature, a variety of financial crisis prediction models have been established in academia, but the evaluation performance of prediction models is rarely compared. On the other hand, the Probit model and Logit model constructed in this paper do not require too many assumptions. Compared with neural network models, DEA and other models, the prediction cost is low, the operation is simple, and it is more valuable in application research.

### 3. Research Design

This article defines companies that have been specially dealt with by the Shanghai Stock Exchange and Shenzhen Stock Exchange due to financial anomalies (ST) as listed companies in financial distress. For the status of being ST, all listed companies have only two states of "yes" and "no".

#### 3.1. Utility Model

Through the utility model, a binary selection model can be derived. The utility model is:

$$U_i^1 = X_i B^1 + \varepsilon_i^1 \quad (\text{The utility of the } i\text{-th individual choice 1}) \quad (1)$$

$$U_i^0 = X_i B^0 + \varepsilon_i^0 \quad (\text{The } i\text{-th individual chooses the utility of 0}) \quad (2)$$

Equation 1 minus equation 2:

$$U_i^1 - U_i^0 = X_i(B^1 - B^0) + (\varepsilon_i^1 - \varepsilon_i^0)$$

Assume  $Y_i^* = U_i^1 - U_i^0$ ,  $B = B^1 - B^0$ ,  $\mu_i^* = \varepsilon_i^1 - \varepsilon_i^0$ , Computable:

$$Y_i^* = X_i B + \mu_i^* \tag{3}$$

Equation 3 is a binary selection model, where  $Y_i^*$  is an unobservable variable and is usually called a latent variable. What we can observe are dummy variables:

$$Y = \begin{cases} 1, & \text{if } Y_i^* > 0 \\ 0 & \text{others} \end{cases}$$

So

$$P(Y_i = 1) = P(Y_i^* > 0) = P(\mu_i^* > -X_i B)$$

In order to estimate Equation 3, we assume that the probability distribution of the random error term  $\mu_i^*$  is a standard normal distribution and a logical distribution. The former generates a Probit model and the latter generates a Logit model.

### 3.2. Data Source and Indicator Description

This article will select 124 listed companies that were specially treated (ST) in Shanghai and Shenzhen due to abnormal financial conditions from 2014 to 2019 as the research sample.

For the selection of normal companies, this article randomly selects 248 A-share listed companies according to one ST company in financial difficulty and two companies with normal financial status. When choosing a normal company, it also considers the industry factors between it and ST company to make the comparative study of the two more feasible.

Next, we divided 372 listed companies into two groups. The first group includes 83 ST companies and 166 normal companies from 2014 to 2017; the second group includes 41 ST companies and 82 normal companies from 2018 to 2019. . The first group is used as a training set to estimate the parameters of the Probit model and Logit model; the second group is used as a verification set to test the predictive ability of the Logit model and the Logit model. In the explained variables, this article marks ST companies as 1, and normal companies as 0.

The data of 12 financial indicators (see Table 1) of 124 ST companies and 248 normal companies all come from the Wind financial database. Since China currently has a two-year lag period for ST processing of listed companies, the financial data of the first two years of ST companies are selected, and the corresponding financial indicators of normal companies are also taken from the previous two years.

Table 1 Financial indicators

Index classification	Financial indicator name	
Profitability	Earnings per share(EPS)	Return on assets(ROA)
Solvency	Equity ratio(ER)	Interest coverage ratio(ICR)
Growth-ability	Operating income growth rate(IROBR)	Operating profit growth rate(OPGR)
Operating-capacity	Inventory turnover(ITR)	Accounts receivable turnover ratio(ARTR)
cash flow	Labor service cash payment rate(SCPR)	Net cash flow from operating activities(NCFFO)
Capital Structure	Assets and liabilities(AAL)	Current assets ratio(CAR)

#### 4. Empirical analysis

##### 4.1 Parameter Estimation

In the empirical analysis, because there are many financial indicators that are not significant, the model may have multiple collinearity problems. Therefore, this paper adopts Probit stepwise regression method and Logit stepwise regression method respectively to introduce significant variables into the model one by one, while eliminating insignificant or redundant variables. Finally, the three financial indicators EPS, ER, and ICR are retained in the Probit model, and EPS, ER, and ITR are retained in the Logit model. The empirical results of the Probit model are shown in Table 2.

Table 2. Empirical results of Probit model

Variable	Coefficient	Std	Z	P
C	-0.5601	0.1399	-3.3558	0.0007*
EPS	-3.4736	0.7814	-5.3982	0.0000*
ER	0.0006	0.0007	2.3521	0.0492*
ICR	-0.0263	0.0132	-1.5536	0.0845**
McFaddenR <sup>2</sup> = 0.5569			P=0.0000	
LR=172.3770				

Note: "\*" and "\*\*\*" mean significant at 5% and 10% significance level respectively (same below)

It can be seen from Table 2 that the McFaddenR<sup>2</sup> of the Probit model is 0.5569, and the likelihood ratio P value of 0 is less than the significance level of 5%, indicating that the model fits well. From the point of view of parameter estimates,

the four coefficients reject the null hypothesis at the 10% significance level, and the explanatory variables will have a significant impact on the explained variables.

According to Table 2, the expression of  $y_i$  of the Probit model can be obtained:

$$y_i = -0.5601 - 3.4736EPS_i + 0.0006ER_i - 0.0263DSCR_i \quad (4)$$

In Equation 4, the coefficient of EPS reflecting the profitability of the company and the ICR reflecting the solvency of the company are negative, indicating that the stronger the profitability and solvency of the listed company, the less likely it is to fall into financial distress, which is in line with expectations; and reflects the company The equity ratio of the solvency is positive, indicating that the higher the equity ratio of the listed company, that is, the weaker its solvency, the greater the probability of the company's financial risk, which is also in line with expectations.

Based on Equation 4, the Probit model of financial distress early warning model can be obtained:

$$p_i = \phi(-0.5601 - 3.4736EPS_i + 0.0006ER_i - 0.0263DSCR_i) \quad (5)$$

In the formula,  $\Phi(x)$  indicates that the function follows a normal distribution, and the probability P value can be obtained by solving the normal distribution table or function. The empirical results of the Logit model are shown in Table 3:

Table 3. Logit model empirical results

Variable	Coefficient	Std	Z
C	-0.7484	0.2953	-2.5346*
EPS	-8.8349	1.2857	-6.8716*
ER	0.0025	0.0009	2.7505*
ITR	-0.0775	0.0311	-2.4914*
McFaddenR <sup>2</sup> = 0.5818		P=0.0000	
LR=181.5508			

Table 3 shows that the McFaddenR<sup>2</sup> of the Logit model is equal to 0.5818, and the P value of the likelihood ratio is also less than the significance level of 5%, indicating that the Logit model fits well. At the same time, all four variables can pass the significance test with a significance level of 5%.

From Table 3, the  $y_i$  expression of the Logit model:

$$y_i = -0.7484 - 8.8349EPS_i + 0.0025ER_i - 0.0775ITR_i \quad (6)$$

Equation 6 shows that both the Logit model and the Probit model retain the two financial indicators of EPS and ER, and the coefficient of earnings per share is negative and the coefficient of the equity ratio is positive, indicating that the profitability and solvency of the listed company are stronger. , The less likely it is to cause financial risk; however, the ICR indicator is removed from the Logit model,

and the EPS1 indicator with a negative coefficient is added, which indicates that the higher the inventory turnover rate of the listed company, that is, the stronger its operating ability, the company is in financial trouble The lower the probability.

The financial distress early warning model based on the Logit model is:

$$p_i = F(y_i) = \frac{1}{1 - e^{-y_i}} = \frac{1}{1 + e^{0.7484 + 0.8849EPS_i - 0.0025ER_i + 0.0775ITR_i}} \quad (7)$$

The McFadden $R^2$  of the Logit model is equal to 0.5818 greater than 0.5569 of the Probit model, indicating that the fit of the Logit model is better than the Probit model.

#### 4.2 Comparison of Prediction Effect between Probit Model and Logit Model

Next, the second set of data (N = 123) with fiscal year 2012 to 2013 will be substituted into the estimated Probit model and Logit model, respectively. First calculate the probability that each verification sample company is in financial distress, and then use 0.5 as the cut-off point. When the estimated probability is greater than or equal to 0.5, the company will be considered to be in financial distress, and when the estimated probability is less than 0.5, then Treat the company as a normal company. The statistical results are shown in Table 4.

Table 4. Probit model and Logit model prediction results

Probit Model				Logit Model					
Original classification	Classification		Total	Original classification	Classification		Total		
	1	0	N=123		1	0	N=123		
Count	1	22	19	41	Count	1	35	6	41
	0	10	72	82		0	8	74	82
Percentage	1	49.51%	50.49%	78.31%	Percentage	1	90.57%	9.43%	92.18%
	0	7.85%	92.15%			0	7.29%	92.71%	

Table 4 shows the results of using listed companies' financial data after t-2 years to predict whether they will fall into financial trouble two years later. For the Probit model, the prediction accuracy rate of ST companies is 49.51%, the prediction accuracy rate of normal companies is 92.15%, and the overall prediction accuracy rate is 78.31%. For the Logit model, the accuracy rate of the ST company's prediction is 90.57%, which is much higher than the Probit model's 49.51%. At the same time, the Probit model's prediction accuracy for normal companies is 92.71%, which is in line with the Probit model's prediction results for normal companies. quite. The overall prediction accuracy of the Logit model is 92.18%, which is also much higher than the 78.31% of the Probit model. This shows that the Logit model has an excellent prediction effect on the financial risks of listed companies, and is

far superior to the Probit model.

## 5. Conclusion

This article first uses 83 listed companies and 166 normal listed companies that were specially treated due to abnormal financial conditions in 2014 to 2019 A shares as a research sample to construct a virtual explanatory variable that represents whether the listed company has a financial crisis, and then gradually The regression method selects the main influencing variables from the twelve financial indicators of the listed company's profitability, operating ability, solvency, growth ability, cash flow and capital structure to construct Probit model and Logit model for regression analysis. Finally, the Probit model retains three financial indicators: earnings per share, equity ratio and interest protection multiple. The results show that with the increase in the multiples of earnings per share and interest protection of listed companies, the profitability and solvency of listed companies will also increase, and the probability of the company falling into financial distress will decrease; Stock income, equity ratio and inventory turnover rate. The model not only shows that the improvement of profitability and solvency can reduce the probability of listed companies falling into financial distress, but also shows that the increase in the inventory turnover rate of listed companies, that is, the enhancement of their operating capacity will also reduce the probability of financial risk explosion. The regression results also show that the goodness of fit of the Logit model is higher than that of the Probit model.

Next, in order to compare the financial early warning capabilities of the Probit model and the Logit model, this article substitutes 123 samples composed of 41 ST companies and 82 normal companies from 2018 to 2019 into the Probit model and Logit model obtained above. The results show that the correct rate of Probit model prediction is 78.31%, while the correct rate of Logit model prediction is 92.18%. This shows that the Logit model constructed in this paper has a good predictive ability for the financial distress of listed companies and is much better than the Probit model constructed.

Based on the above empirical research conclusions, the article puts forward three suggestions for listed companies: First, the financial department should focus on the EPS indicator. The prediction results of both the Logit model and the Probit model show that EPS has the greatest marginal impact, which means that when EPS decreases, the company will have a high probability of falling into financial trouble in the future. Second, establish a sense of risk prevention. According to historical experience, the financial departments of many listed companies still only undertake traditional functions such as liquidation, transfer, and dividend payment. However, with the diversification of modern capital instruments and the complexity of the external operating environment, company management must analyze financial issues. 3. Forecast to make timely strategic adjustments. Third, establish an early warning countermeasure database. The above research has shown that there are many reasons for the financial crisis, so governance of this problem should also be "appropriate." Listed companies should make different countermeasures for different financial



indicators and form a financial plan early.

### References

- [1] Fitzpatrick P J. A comparison of ratios of successful industrial enterprises with those of failed firms [J]. *Certified Public Accountant*, 1932, (20) 2: 589—731.
- [2] Altman E. Finance ratios, discriminant analysis and the prediction of corporate bankruptcy [J]. *Journal of Finance*, 1968,23 (4): 589—609.
- [3] Jones S, Hensher D A. Predicting firm financial distress: A mixed logit model [J]. *The Accounting Review*, 2004, 79 (4): 1011—1038.
- [4] Jae H. Min, Young-Chan Lee. Bankruptcy prediction using support vector machine with optimal choice of kernel function parameters [J]. *Expert Systems with Applications*, 2005 (28), 4: 603—614.
- [5] Wu Shinong, Lu Xianyi. Research on the prediction model of financial distress of listed companies in China [J]. *Economic Research*, 2001 (06): 46-55 + 96.
- [6] Zhang Qingli. Research on early warning of financial crisis of Chinese listed companies based on DEA-Logistic regression model [J]. *Modern Business*, 2018 (22): 124-127.
- [7] Deng Lichun, Du Weiyong. Research on financial crisis prediction of listed companies—Based on Cox proportional hazard model [J]. *Friends of Accounting*, 2020 (04): 140-146.