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Research on Financial Risk Early Warning of Listed Companies Based on Stochastic Effect Mode

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Abstract

In the current era, the market competition is becoming increasingly fierce, complicated and unpredictable. Based on the interaction of various factors, the probability of financial risks of listed companies is significantly improved. Because of its unique characteristics, the listed companies' operating status affects the overall operation of China's market economy and occupies a fundamental position in the national economic system. If listed companies have financial risks, it will cause great trauma to our economy. Based on the financial risk evaluation theory of listed companies, this paper analyzes the financial indicators of listed companies through random effect model, and puts forward the risk analysis and prediction index system of listed companies from theoretical and empirical angles, thus constructing a financial risk early warning model based on linear random effect model, and studying the financial risk early warning of listed companies with practical cases. The research results show that the financial risk early warning model of random effect model is feasible and effective, which can help listed companies to carry out financial risk early warning management and improve financial management level.

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1 Introduction

With the continuous development of listed companies in China, the management level of listed companies has been significantly improved. [1,2] At present, China's capital market is still in the emerging capital market, and there are some problems, such as great volatility, strong investment and inadequate supervision, which make the financial risks seriously affect the stable development of listed companies. In the aspect of financial risk early warning indicators, with the continuous development of economy, managers' demand for financial early warning information is increasing day by day. [3] Nowadays, the research on financial risk early warning of listed companies begins to gradually introduce non-financial factors and cash flow factors to improve the selection limitations of traditional financial indicators, so as to establish a more perfect index system and improve the prediction accuracy. [4] In addition, although the categories of selected indicators are becoming more and more perfect, it is still difficult to combine with different characteristics of various industries for analysis. At present, the Exchange has announced that it will make special treatment (ST) for the stock trading of listed companies with abnormal financial status. It is of great significance for the healthy and stable operation and development of the company to analyze the public financial indicators of listed companies through the random effect model to predict the financial risks, take into account the corporate governance, strategy, internal control and other factors, eliminate the limitations, and identify and remedy the problems in financial management in time. [5]

2 Methods

Multivariate linear model refers to a linear model with multiple dependent variables and multiple independent variables. [6] Random effect model refers to the regression coefficient of fixed effect model as a random variable, which is usually assumed to originate from normal distribution and is mainly used to analyze group level effect, individual effect and observation level effect. This time, the random effect model is used to measure the financial risk level of listed companies. [7]

The multivariate equilibrium random effect model is established as follows:

$$Y_{ij} = \mu + X_{ij}\beta + b_i + w_{ij}, i = 1, \dots, n; j = 1, \dots, r \quad (1)$$

Where Y_{ij} is the observation vector of $1 \times p$; μ is the unknown parameter vector of $1 \times p$; b_i is the random effect vector of $1 \times p$; β is an unknown parameter matrix of $q \times p$; X_{ij} is a fixed constant vector of effect vector of $1 \times p$, and w_{ij} is the random error vector of $1 \times p$.

Where, the probability distribution P of response variable Y_{ij} of the model is expressed as follows:

$$\begin{aligned} U_i &\sim N(0, \Sigma) \\ P(y_{ij} | U_i, X, \alpha_{ij}) \end{aligned} \quad (2)$$

Among them, Y_{ij} is the observation value of the second level Observation Units at the i and the j TH observation value of response variable. X is the explanatory variable observation matrix; U_i is the i TH unit random effect vector observed at the second level. α_{ij} is the parameter vector of fixed effect; P is some distribution. In this paper, only binary random effects u_1 and u_2 are considered, namely:

$$\Sigma = \begin{bmatrix} \sigma_1^2 & \rho\sigma_1\sigma_2 \\ \rho\sigma_1\sigma_2 & \sigma_2^2 \end{bmatrix} \quad (3)$$

When the parameter ρ , σ_1 , σ_2 are optimized and fitted into a binary random effect model, ρ is often very close to -1 in the optimization process, which makes it difficult to calculate and finally has to be stopped. In this case, the expression is as follows:

$$\begin{aligned} u_{i1} &\sim N(0, \sigma_1^2), u_{i2} = \tau^* u_1 \\ P(y_{ij} | u_{i1}, u_{i2}, X, \alpha_{ij}) \end{aligned} \quad (4)$$

Although the random effect model is a kind of generalized linear model, it considers the original fixed regression coefficient as random. The model includes error term ε_i and individual internal error u_{ij} . Where, ε_i belongs to the error component of specific observation individuals, and u_{ij} is the synthesis of the error component of time series and the error component of cross section. Therefore, it can also be called error component model (ECM), and its expression is as follows:

$$h(y_{ij}) = \beta_0 + \beta_1 X_{ij1} + \beta_2 X_{ij2} + \cdots \beta_p X_{ijp} + u_{ij} + \varepsilon_i \quad (5)$$

This expression is different from the generalized estimation equation, that is, it is a function of the explanatory variable y_{ij} , and the expression of the synthesis error is set as, then the model can be converted to $w_{ij} = u_{ij} + \varepsilon_i$

$$y_{ij} = \beta_0 + \beta_1 x_{ij1} + \beta_2 x_{ij2} + \cdots \beta_p x_{ijp} + w_{ij}, i = 1, 2, \cdots N; j = 1, 2, \cdots n_i \quad (6)$$

The model assumes the following:

$$\begin{cases} \varepsilon_i \sim N(0, \sigma_\varepsilon^2); \mu_{ij} \sim N(0, \sigma_u^2) \\ E(\varepsilon_i \mu_{ij}) = 0; E(\varepsilon_i \varepsilon_j) = 0 (i \neq j) \\ E(\mu_{ij} \mu_{is}) = E(\mu_{ij} \mu_{kj}) = 0 (j \neq s; i \neq k) \end{cases} \quad (7)$$

That is, the error components are not correlated with each other, which can be obtained from the above assumptions:

$$\text{Cov}(Y_i) = \sigma_\varepsilon^2 I_{n_i} + \sigma_u^2 J_{n_i}, \text{Var}(w_{ij}) = \sigma_\varepsilon^2 + \sigma_u^2 \quad (8)$$

Where, I_{n_i} is the unit matrix of $n_i \times n_i$, and J_{n_i} is the $n_i \times n_i$ square matrix with all elements of 1.

The random effects model can be composed of formulas (6), (7) and (8). If $\sigma_\varepsilon^2 = 0$, then the random effects model is the same as the linear regression model with all the sample data mixed together. If the variance of the error term w_{it} is the same, then the correlation coefficient of the error term can be calculated as follows:

$$\rho = \text{cor}(w_{ij}, w_{is}) = \frac{\sigma_\varepsilon^2}{\sigma_\varepsilon^2 + \sigma_u^2}; j \neq s \quad (9)$$

Logistic regression mainly deals with data in which the response variable is two variables, such as data in which two attributes exist, and usually the response variable is assigned a value of 0 or 1. Assuming that there are P explanatory variables $X_1, X_2, \cdots X_p$, the listed company implementing ST is denoted as response variable Y . When given an explanatory variable, the conditional probability of $Y = 1$ (representing the occurrence of ST implemented) is $P = P\{Y = 1 | X_1, X_2, \cdots X_p\}$, then the logistic regression model is as follows:

$$P = \frac{\exp(\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots \beta_p X_p)}{1 + \exp(\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots \beta_p X_p)} \quad (10)$$

The regression model is transformed by logit, and the linear form is as follows:

$$\log it(P) = \ln\left(\frac{P}{1-P}\right) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots \beta_p X_p \quad (11)$$

The quasi-likelihood method is used for calculation. It is assumed that there are individuals in total, is the observed value of the individual, is covariables, and . The function expression of response variable mean value on explanatory variable is established as follows:

The quasi-likelihood method is used for calculation. It is assumed that there are N individuals in total, Y_i is the observed value of the i ($i = 1, 2, \dots, N$) individual, $X_{i1}, X_{i2}, \dots, X_{ip}$ is p covariables, and $E(Y_i = 1 | X_{i1}, X_{i2}, \dots, X_{ip}) = \mu_i$. The function expression of response variable mean value on explanatory variable is established as follows:

$$h^{-1}(u_i) = \beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2} + \dots + \beta_p X_{ip} \quad (12)$$

The variance of the response variable can be expressed as a mean function:

$$\text{Var}(Y_i) = \phi v(\mu_i) \quad (13)$$

The likelihood score equation obtained from maximum likelihood estimation is as follows:

$$\sum_{i=1}^N \left(\frac{\partial \mu_i}{\partial \beta} \right)' \frac{1}{\phi v(\mu_i)} \{Y_i - \mu_i(\beta)\} = 0 \quad (14)$$

While $\hat{\alpha}$ and $\hat{\phi}$ are estimated by Pearson residual statistic, the constructed statistic is only related to $\hat{\beta}$, and the consistent estimator of the three can be obtained by iterative method.

The distribution of random effect ε_i is usually assumed and estimated by the generalized least squares method or maximum likelihood method.

3 Experiment

In this paper, according to the principle of sample selection, the time period is 2018-2019, and the selected objects are listed companies listed in A shares and specially treated for the first time. In order to verify the validity of the above analysis model and the credibility of the analysis method, the financial evaluation factors of listed companies are summarized in table 1. [8] The historical financial data in the past two years were obtained through the Financial Association, and the selected objects were listed companies listed in A shares and specially treated for the first time, with 56 selected companies. In view of the fact that the model based on longitudinal data needs the financial indicators of all samples in 2 years, it is necessary to clean the sample data. In this paper, missing data is not considered, and this part of samples is eliminated directly. After data cleaning, the final sample size of ST Company is 50pcs. 50pcs samples were randomly selected from healthy listed companies, which were used as matching samples, and the selected samples of listed companies were not displayed.

In the vertical data analysis model, this paper uses the data of ST company and health company in each year from 2018 to 2019, and the sample size changes from 100 to 400. The explanatory variables were selected and the data delayed by two years were used. By forecasting the financial crisis of 2020-2021, the financial ratio data of 2018-2019 is used. Using 30 financial indicators with the same financial evaluation factors of listed companies, we do factor analysis and fit factor scores to generalized estimation equation and random effect model. Finally, we compare the two results. Among them, the model response variable assignment rule is that if the company falls into financial crisis in X year, then:

$$\begin{cases} y_{it} = 1, (i \text{ is a sample of companies with financial crisis, and } t \geq X\text{year}) \\ y_{it} = 0, (i \text{ is a sample of healthy companies or } i \text{ is the sample of companies in financial crisis, and } t < X\text{year}) \end{cases}$$

The financial crisis of an enterprise is a dynamic process, which is usually related to the state of the same company in different years. If the company's financial situation is relatively poor in the previous year, there will be a high probability of financial crisis in the next year. The generalized estimation equation can select a variety of working correlation matrices when estimating coefficients, and in practical application, the correlation matrix

can be selected by criteria. Because the correlation coefficients between different observations of the same individual are fixed in the random effect model in this paper, the generalized estimation equation is chosen to exchange correlation structures. In view of the fact that the corresponding variables are binary variables, the model connection function is logit function, and the estimated results are shown in Table 2. The regression equation of the estimated results is as follows:

$$\log it(p) = -1.417 + 3.075factor1 - 0.925factor2 - 0.312factor3 + 0.344factor4 + 0.525factor5$$

In the model, only the coefficient of factor 3 is not significant. On factor 1, factor 2, factor 3 and factor 5, the symbol of the coefficient estimated by the model is consistent with the symbol of the logistic regression coefficient, and is consistent with the logistic regression interpretation. According to the model, the coefficient of the work correlation matrix is estimated to be 0.203, which shows that the measured values of the same individual at different times are correlated, and the data results show that the response variables at different time points have little correlation. See table 3 for the prediction results obtained by bringing the sample data into the model. From the prediction results, it can be known that the prediction accuracy of financial crisis companies calculated by using the generalized estimation equation reaches 92%. Health companies have no prediction errors. [9–13]

The intercept of each sample in the random effect model is random and different, which means that the number of estimation equations is the same as the number of samples. The random effect model results are divided into three parts, namely, the random influence coefficient of each sample, the estimated intercept term of the model and the variable regression coefficient. The general model fitting results are expressed as follows:

$$\log it(p_{ij}) = \varepsilon_i + \beta_0 + \sum_{j=1}^p \beta_j X_{ij}, \text{ among them } i = 1, 2, \dots, N, m = 1, 2, \dots, p$$

Where, $i = 1, 2, \dots, N; m = 1, 2, \dots, p; j = 1, 2, \dots, n_i$, the fixed effects estimated by the model are shown in the first column of table 4, and the estimated results of the model are shown in table 5. The fixed effect of the random effect model is consistent with the estimation coefficient sign of the generalized estimation equation. Only the coefficient of factor 4 of the model is not significant.

4 Results

The prediction accuracy of financial crisis companies obtained by random effect model is high, and it is 94%. Among them, the prediction accuracy of health companies by random effect model is the same as that by generalized estimation equation, and the prediction of financial crisis is more accurate, that is, both models estimate that the financial crisis of listed companies is positively correlated with factors 1, 4 and 5, and negatively correlated with factors 2 and 3. The results show that the random effect model is more accurate in predicting financial crisis companies. Because the longitudinal data model refers to the time factor, the random effect model can predict the probability of financial crisis in 2018-2019 at the same time, thus expanding the prediction range. According to the characteristics of each sample, the random effect model is modeled separately, and the prediction accuracy of financial crisis companies and healthy companies is 94% and 98%. It can be seen that the calculated accuracy is high. In view of the differences in company size and internal and external environments, it is more meaningful to model each company separately. Therefore, the stochastic effect model is more suitable for predicting the financial crisis of listed companies.

Table 1 Financial evaluation factors of listed companies.

Financial evaluation factors of listed companies
Net cash flow from operating activities
Retained profits
Provision for information loss
Depreciation and amortization
Deferred income tax expense (revenue)
Investment loss (gain)
Investment/asset impairment charges
Amortization of debt and issuance costs
Gain (loss) from business disposal
Stock-based compensation
Accounts receivable
Loans
Inventory
Prepaid expenses
Payables
Income tax payable
Accrued liabilities
Other working capital
Other non-cash items
Other assets and liabilities
Other business activities
Net cash flow from investment activities
Fixed-asset investment
Purchase
Acquisition and disposal
Property and equipment
Purchase of investment assets
Debt/sales investment
Purchase of intangible assets
Other investment activities
Net cash flow from financing activities
Cash flow from financing activities
Long term bond issue
Long term bond repayment
Bond issue
Bond redemption
Common Stock issue
Common stock repurchase
Stock repurchase
Change in short-term borrowing
Dividend payments
Other financial activities
The impact of exchange rate movements
Change in net cash
Operating cash flow
Capital expenditure
Free cash flow
Initial cash flow
Ending cash flow

Table 2 Estimation results of generalized estimation equation.

	Estimate	Std.Error	Wald	Pr(> W)	
(Intercept)	-1.4170	0.2233	40.277	0.0000	***
Factor 1	3.0746	0.6937	19.641	0.0000	***
Factor2	-0.9254	0.3002	9.500	0.0021	**
Factor3	-0.3116	0.2683	1.349	0.2455	
Factor4	0.3442	0.1998	2.966	0.0851	.
Factor5	0.5249	0.2064	6.469	0.0110	*

Table 3 Prediction results of generalized estimation equation.

Actual value	Predicted value		Accuracy rate
	ST	Non ST	
ST	46	4	92%
Non ST	1	49	98%

Table 4 Estimation results of random effect model.

	Estimate	Std.Error	Z value	Pr(> z)	
(Intercept)	-2.714	0.754	-3.60	0.0003	***
Factor1	5.643	1.386	4.07	0.0000	***
Factor2	-2.289	0.883	-2.59	0.0095	**
Factor3	-1.383	0.752	-1.84	0.0661	.
Factor4	0.491	0.465	1.06	0.2908	
Factor5	1.350	0.521	2.59	0.0096	**

Table 5 Prediction results of random effect model.

Actual value	Predicted value		Accuracy rate
	ST	Non ST	
ST	47	3	94%
Non ST	1	49	98%

5 Conclusion

In this paper, a financial risk analysis model of listed companies based on random effect model is proposed, and the financial risk analysis model of listed companies is constructed based on this algorithm. The effectiveness of the method is simulated with a case study. The research results verify the feasibility and effectiveness of the method, which is helpful to the early warning management of financial risks of enterprises and improve the financial management level.

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