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The study on credit risk measurement based on the combined models

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ABSTRACT

The innovative point of this paper is to use the GARCH-t Model to fit the actual fluctuation of assets and calculate the volatility of the value of stock rights, and then to build a new model to measure the credit risk in association with option theory−the KMV-GARCH-*t* Model, and finally study the new model's capability to evaluate the credit risk of listed companies in the stock market in China based on 10 ST companies and 10 paired non-ST companies. The results indicate: the distance to default can better measure in Credit Risk Evaluation of Public Companies, this means the KMV-GARCH-t models has some applicability in China.

KEYWORDS

Credit risk; KMV; Distance to default; GARCH-t model; Measurement.

INTRODUCTION

In the wake of the transformation in international finance, as well as the incessant release of financial derivatives, competition in financial industry has intensified, and moreover, more attention has been given to credit risk by banks, investors and financial communities all over the world. Despite the boom of the financial market in our country, the financing method dominated by bank loan still takes hold, so credit risk has become one of the major risks confronted by the financial market in our country.

The KMV Model is a kind of default model which connects credit risk with expected default rate (EDF), and calculates credit risk via EDF. The KMV Model, which reflects the change of enterprise credit level by using real-time stock price, and is of dynamic nature and perspectiveness[1], is gaining extensive attention and application. At present, research on the KMV Model is focused on its applicability, that is, to distinguish the credit default risk degree of different companies, thus telling "good companies" from "bad companies" [2,3]. In most cases in the past, to measure the credit risk by using the KMV Model is based on the assumption that the fluctuation of stock rights is of normality. However, much empirical research shows that the fluctuation of financial assets is characterized by sharp peak and heavy tail as well as conditional hetero skedasticity, and that the calculation of the risk value of the stock market based on normal distribution, which fails to reflect the actual fluctuation risk of assets, will underrate the actual risk value, and cannot explain the heavy-tail phenomenon in distribution, thus overlooking or underrating the occurrence of extreme events[4,5]. The GARCH Model, which is the most frequently used fluctuation model to reflect the time-variation characteristic of the market, can effectively capture the phenomenon of cluster and heteroskedasticity in the fluctuation of return on assets[6,8]. The KMV Model makes a timely dynamic response to the enterprise credit level, while the GARCH Model can accurately reflect the actual fluctuation of assets, so it is applicable to combine the two models to measure the credit risk.

The innovative point of this paper is to use the GARCH-t Model to fit the actual fluctuation of assets and calculate the volatility of the value of stock rights, and then to build a new model to measure the credit risk in association with option theory–the KMV-GARCH-*t* Model, and finally study the new model's capability to evaluate the credit risk of listed companies in the stock market in China based on 10 ST companies and 10 paired non-ST companies in the stock market in China.

SPECIFICATION AND PARAMETER SETTING OF THE MODEL

Principles and basic approach of the KMV model

In the KMV Model, the market value of stock rights of enterprises is priced according to Black-Scholes-Merton Option Pricing Model, so the stock rights value of the company, V_E is:

$$V_E = V_A N(d_1) - e^{-r\tau} D N(d_2) \tag{1}$$

And thereinto, $d_1 = \frac{\ln(V_A / D) + (r + 0.5\sigma_A^2)\tau}{\sigma_A \sqrt{\tau}}$, $d_2 = d_1 - \sigma_A\sqrt{\tau}$, V_E is the stock rights value of the company, V_A is the asset value, r is the risk-free return rate, D is the debt value of the company, τ is the deadline of the debt repayment, $N(\cdot)$ is the standard normal cumulative distribution function, σ_A is the volatility of the asset value. First take the derivative of both sides of equation (1), then take the expectation, and we can see the relationship between the volatility of company stocks and the volatility of assets as follows:

$$\sigma_E = \frac{V_A}{V_E} N(d_1)\sigma_A \tag{2}$$

So the two unknown variables V_A and σ_A in the KMV Model can be obtained by solving the non-linear equations via iterative programming in simultaneous equations (1) and (2), and meanwhile, DD, the default distance of the enterprise debt can also be obtained, its computational formula is as follows:

$$DD = \frac{E(V_A) - DPT}{E(V_A)\sigma_A} \tag{3}$$

And thereinto, $E(V_A)$ is the expected value of the asset value, DPT is the default point, which can be obtained from the balance sheet of the company. Suppose the asset value of the company is subject to normal distribution, we can calculate EDF, the expected default frequency, according to the default distance. See as follows:

$$EDF = p(E(V_A) < DPT) = N\left[\frac{DPT - E(V_A)}{E(V_A)\sigma_A}\right] = N(-DD) \tag{4}$$

In fact, the asset value of the enterprise is seldom subject to normal distribution, so the KMV Company makes use of its extensive historical default database to convert DD to experienced EDF of a company, thus constructing the enterprise credit risk evaluation system based on experienced EDF. At present, the historical database concerning the enterprise default incidents has not been built in our country, so data is not sufficient. In view of this, this paper uses DD, default distance, as the basis to evaluate the credit change of a company. The bigger the value, the less likely the company will break a contract; Vice versa.

Parameter design and the introduction of the GARCH model

(1) The Determination of the Value of the Enterprise Stock Rights

The market value of stock rights is the product of the closing price and the total shares. In our stock market, besides tradable shares, there are non-tradable shares, which have no market price. Therefore, the stock rights value cannot be calculated via full circulation patterns. This paper uses the product of the net asset value per share and the number of non-tradable shares as the value of non-tradable shares, and if the net asset value per share is less than zero, the value of the net asset value per share is zero. Thus we have:

The stock rights value of listed companies = the value of tradable shares + the value of non-tradable shares = the average closing price of tradable shares × the number of tradable shares + the net asset value per share × the number of non-tradable shares **(5)**

(2) The Determination of the Volatility of Stock Rights Based on the GARCH Model

In order to get the value of enterprise assets as well as its fluctuation in a condition of appropriate share options, it is important to determine a comparatively accurate fluctuation of the stock rights value, which will have an immediate influence on the size of DD in the KMV Model. The traditional method to calculate the volatility is to suppose that the stock return satisfy normal distribution or lognormal distribution, so if the volatility per day and the number of trading days can be obtained, the volatility per year can also be solved. However, substantial empirical research has shown that the financial time series, such as the share return, is rarely characterized by normal distribution, but is apt to have distinctive volatility cluster effect, with characteristics of conditional hetero skedasticity as well as sharp peak and heavy tail. Hence, in order to improve the accuracy of calculating the volatility of the stock rights value, this paper adopts the type of GARCH models which can capture conditional hetero skedasticity and supposes that its random disturbance item is subject to *t* distribution to depict the tail features of its fluctuation, that is, the GARCH-t Model. Specifically use the GARCH(1-1)-*t* Model as follows:

$$\begin{cases} r_t = \mu + \varepsilon_t \\ \varepsilon_t = \sigma_t \eta_t \\ \sigma_t^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \beta_1 \sigma_{t-1}^2 \end{cases} \tag{6}$$

And thereinto, r_t is the earning sequence, μ is the unconditional expected value, σ_t is the conditional variance, ε_t is the residual item; $\alpha_0 > 0$, $\alpha_1 > 0$, $\beta_1 \geq 0$; $\eta_t \sim t(0,1,v)$, v is the variance of *t* distribution; the necessary and sufficient condition for this sequence's being stationary process is $\alpha_1 + \beta_1 < 1$. For every step length *j*, use the known GARCH Model to predict the volatility of its instantaneous step forward *j*, that is the volatility σ_{i+j} of return r_{i+j}, and then calculate the annual volatility of stock return according to the $\sigma_{i+j}^2 (i, j = 1, 2 \cdots, n)$.

(3) The determination of the Face Value of Debt, Debt maturity, Risk-free Interest Rate and Default Point

The face value of the company's debt is the total debt at face value in the annual financial report of the company. In view of the restriction of data and workload, we define that the calculating time of DD is one year. Risk-free interest rate refers to the one-year fixed-term deposit rate published by People's Bank of China. According to the extensive empirical analysis by the KMV Company, it's found that the critical point where default frequently occurs is the value of floating debt plus half of the book value of long-term debts, so this paper uses it as the value of default point.

RESULT AND DISSCUSS

Sample selection

Now in our country, when there is something wrong with the finance or other affairs in listed companies, for example, if listed companies operate at loss in two consecutive years, the exchange of the company stocks will be under special treatment (ST), for the sake of keeping listed companies under strict supervision. The research samples this paper chooses are 10 listed companies which were under ST in 2012, and at the same time, in order to make comparisons, 10 non-ST companies were also chosen to pair them, therefore, we have the market and financial data in 2012 of the 20 listed companies (data come from Great Wisdom Trading Site). In view of the comparability between the sample companies, and in order to avoid farthest the disturbance on the empirical findings due to choosing different companies, this paper chooses the paired non-ST company according to the following conditions: ① to be in the same stock exchange with the paired ST company; ② to be in the same industry with the paired ST company; ③ to have the similar total size of assets with the paired St company.

Data analysis

First, use the GARCH Model to model the sequence of share index returns of various companies. Make Pt the closing index, and use percentage to show the log return of Shanghai Composite Index, Xt：Xt=100*(lnPt-lnPt-1). By testing various share index returns, it's found that the different return is distinctly characterized by sharp peak and heavy tail; J-B normality test also indicates the return is markedly different from normal distribution; the ADF test of the time sequence of the return shows various data comply with the stationary process; seen from the correlation test on the sequence, sequence does not have distinct autocorrelation or partial correlation; the ARCH-LM test results suggest that there exists obvious t heteroskedasticity in the return sequence, so the type of GARCH models can be used for modeling. And then use the software, EVIEWS6.0, to estimate the parameters of the GARCH Model for various return sequences (see Table1). The test results of R^2 show that it is reasonable for various sequences to use the GARCH Model. In the estimation result of the variance υ of the t distribution in the random disturbing terms in the table, "One" means its value is huge, that is, there is extreme peak in the random disturbing terms, and companies of this kind are all ST listed companies. Judged from the market performance of the several companies, almost every stock experienced serial fall staying or daily limit, thus giving rise to the extreme peak of various disturbing terms, whose extreme peak is just captured and reflected. This shows the GARCH(1,1)-t Model makes a reasonable description of the fluctuation of the stock index of various listed companies.

Analysis of the empirical findings

First, determine the default point, the stock rights value and the volatility of the stock rights value of various listed companies, according to their financial data and market data. And then make use of the optimization software, 1stOpt, as well as simultaneous equations (1) and (2) to get the asset value and its volatility. And finally get the default distance (DD) of listed companies through a combination of equation (3).

TABLE 1 : GARCH (1,1) -t parameter estimation in model

	μ	α_0	α_1	β	υ	R^2 ▪ ▪
002145	-0.169	1.02	0.136	0.820	−	0.001
002125	0.035	2.924	0.16	0.681	8.75	0.001
000676	-0.004	5.494	0.219	0.512	4.79	0.003
000967	0.013	1.56	0.124	0.793	7.33	0.004
600217	-0.045	2.972	0.153	0.568	−	0
600318	-0.102	0.108	0.065	0.93	12.66	0
600538	-0.081	1.427	0.083	0.855	−	0
600796	-0.013	0.247	0.071	0.917	22.16	0
600757	-0.022	1.069	0.107	0.797	−	0
600689	-0.089	0.351	0.098	0.889	8.81	0.002
600490	-0.011	1.758	0.115	0.798	9.43	0.001
600146	0.249	7.329	0.133	0.513	250.49	0.002
600868	-0.123	0.487	0.133	0.847	12.3	0.002
600116	-0.057	1.157	0.148	0.79	5.15	0.004
000908	-0.041	2.771	0.108	0.768	−	0.001
000519	0.142	8.665	0.196	0.353	5.15	0
600084	-0.052	1.035	0.15	0.75	−	0.001
600059	-0.033	0.18	0.152	0.731	5.21	0
600860	-0.071	1.133	0.099	0.85	17.26	0.001
600843	0.071	1.35	1.1	0.834	7.19	0.002

TABLE 2 : The default distance

ST company code	DD	Non-ST company code	DD
002145	0.9385	002125	1.7543
600490	1.8341	600146	1.6139
600868	1.6237	600116	2.4135
000676	0.1643	000967	2.2105
000908	-1.8526	000519	2.9048
600217	-0.7528	600318	1.8725
600084	0.7526	600059	1.8254
600538	0.7626	600796	2.7675
600860	1.2860	600843	2.4238
600757	-2.6453	600689	2.0237

Make analysis of the DD characteristics of sample companies, and we can see form TABLE 2 that the average DD values of ST companies as well as their reference companies are respectively 0.21111and 2.18099–the maximum values are 1.8341and 2.9048; the minimum values are -2.4653and 1.6139. Thus it van be seen that no matter what the average values, the maximum values, and the minimum values are, the DD in ST companies is less than that of the non-ST companies. In order to make an intuitive comparison, we make the DD of the two types of companies into a line chart and that's fig1. It can be seen from fig.1 that there are distinct differences in the credit status between the ST companies and the paired companies. In the 10 St companies, there is only one whose DD is greater than that of the paired companies, and the DD of other ST companies are all less than that of their paired companies. This suggests that the KMV Model, whose parameters have been modulated, can better discern the real credit status of the two groups of listed companies. According to *Listing Rules*, the audit results of the two latest accounting years show if the net profit of a listed company is a negative value, or the net asset per share is below the face value of stocks, or the past accounting year is at loss, but if the ownership interest in the past years is less than its registered capital, then the listed company will be specially treated, that is ST. if the company continues to be in a deficit state in the following year, the company shares will be suspended being listed for transaction, and will be most probably terminated for good. So comparatively speaking, ST companies undergo higher credit risk than other normal listed companies. Based on the result of the above DD, it's very easy for us to test this argument.

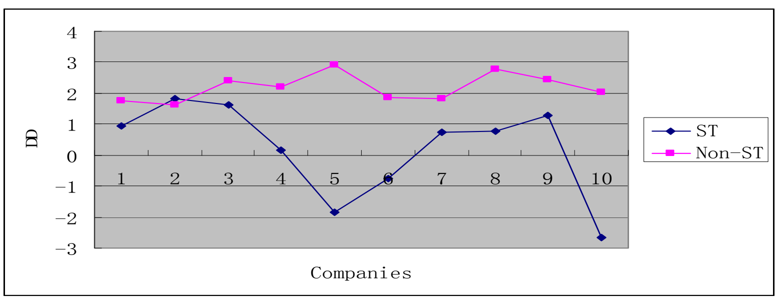

Figure 1 : The distance to default comparison chart

TABLE 3 : The distance to default test

Mean			T test	Wilcoxon
Non-ST companies	ST companies	Mean difference	Value of t	Value of Z
0.21111	2.18099	1.96988	4.65（0.000）	5.71（0.00002）

Note: The numbers in brackets represent the probability correlation test value p

As two types of companies with different credit quality, ST companies and non-ST companies need to be compared to see if the DD of the two groups of samples is distinctly different, in order to verify the effectiveness of the argument. We use T Test and Wileoxon Test of the two paired samples to investigate how well the KMV Model can discern the overall credit risk of the listed companies. T Test is based on whether there is distinct difference in the average value of the two paired samples, while Wileoxon Test refers to a kind of non-parameter test of the paired samples to test if their value is distinctly different. The result of T Test indicates the probability value *p* of the statistics *t* is 0.000. The null hypothesis can be denied if a=0.05, on the basis of which a conclusion can be made that there exists obvious difference in the DD of ST companies and non-ST companies. The result of Wileoxon Test indicates the probability value *p* of the statistics *t* is 0.00002. The null hypothesis can be denied if a=0.05, on the basis of which a conclusion can be made that there exists obvious difference in the mid-value of ST companies and non-ST companies. Therefore, it can be seen from the above test results that the modified KMV Model can tell the credit quality difference between ST companies and non-ST companies, and can also truly reflect the credit risk status of listed companies in China. The test result can be seen in TABLE 3.

CONCLUSIONS

In view of the result of the empirical analysis of the credit status of the listed companies in our country, DD can better measure the degree of the credit status of listed companies, and moreover have better credit warning ability, which demonstrates this model is applicable in our country. However, in consideration of the low efficiency of the present capital market in our country, the defective stock market mechanism, and the massive fluctuation in the market price of stock, it's hard to measure the exact stock value of listed companies. Therefore, we cannot mechanically apply the KMV Model in the same way it is used in foreign countries. Taking into account the real situation of the stock market in our country, we should revise and perfect the KMV Model to add to its accuracy.

In addition, when estimating the parameters of the KMV-GRACH-t Model, we use the GRACH-t Model to estimate the volatility of stock rights and estimate other parameters via traditional and simple methods, which will probably have some impact on the accuracy of DD, but have little influence on the conclusion of this paper. Meanwhile, the application extensiveness of the GARCH-t fluctuation model used in the KMV calculation needs to be further verified.

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