

Empirical Study on Credit Risk of Our Listed Company Based on KMV Model

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Abstract

KMV model is one of the most important credit risk evaluation models in the world. It uses B-S option pricing and Morton formula based on the market value and volatility of the company's equity, debt maturities, risk-free interest rates and the book value of liabilities to estimate the market value of the company's assets and the volatility of the asset value. In this paper, based on the theory of KMV model, we can derive the listed company's default rate, and assess credit risk. And the result is reasonable.

Keywords

KMV Model, Credit Risk, Default Point

1. Introduction

With the development of the world market economic globalization, financial globalization has swept through. Credit risk management draws more and more concern and attention of international financial institutions and other market participants. There are a lot of research about the identification, measurement, prediction and prevention of the credit risk internationally and the mature econometric models were established. Credit risk measurement methods are mainly two: the traditional measurement methods and modern measurement model. The traditional risk measurement approach focuses on qualitative analysis and modern metrics focus on quantitative analysis. With the post-crisis development of financial storm in 2008, credit risk is more complicated and the modern credit risk measurement model is more suitable for depicting the level of risk.

Chen Kai [1] corrects the Default Point of the classical KMV model and researches the four major insurance companies in our country, combined with the characteristics of the insurance industry and the liability reserve funds to set the default point. Default point on the basis of the original model plus 0.8 times the liability reserve funds. Upon testing, the adjusted KMV model can be used to measure credit risk status of the insurance compa-

ny.

Yang [2] combines the qualitative analysis with quantitative analysis in the process of research on credit risk measurement model, uses the GARCH (1, 1) model to explore in the calculation of the fluctuate rate of stock values, and uses the improved KMV model to conduct an empirical analysis for the data of 40 listed companies in our country. Finally, they test the results of the model and find that KMV model in our listed company's credit risk measurement is effective.

Zeng and Wang [3] select 42 manufacturing listed companies in Shanghai and Shenzhen to study the applicability of the KMV model in our country. Through the empirical research, they think KMV can be applied to measure the credit risk of listed companies, and on the selection of the value of the default point, the original model is not applicable to our country economy. They are based on industry characteristics and the situation of the securities market in our country to modify the default point and improve the accuracy of the KMV model.

Peng [4] uses KMV model to conduct empirical research on the situation of the credit risk of 11 small- and medium-sized listed companies in China. They find that no matter how overvalued or undervalued the company's assets value will produce deviation to the company's default distance. So the estimate of company's assets value has the uncertainty influence on the default distance.

In this paper, at first, we respectively introduce the B-S optional pricing model, Merton model and KMV model. And then combining with the actual situation of China securities market, we conduct empirical study on credit risk of our listed company based on KMV model.

2. B-S Option Pricing Model

B-S model [5] see the value of equity as a call option, the basic assumptions of the model are:

- 1) There is no friction in capital market, that is to say no transaction costs and taxes;
- 2) It has the risk-free interest rate;
- 3) The stock without dividends;
- 4) Share price follow normal distribution;
- 5) There is no risk-free arbitrage in the market;

Based on the above assumptions, there is

$$dS = \left(\mu + \frac{1}{2}\sigma^2 \right) Sdt + \sigma Sdz \quad (1)$$

where S is stock price; $\mu + \frac{1}{2}\sigma^2$ is stock prices drift rate; σ is Stock Price Volatility; dz is a wiener process,

in which the expected value is 0 and the variance is 1.

B-S differential variance is derived by ITO lemma

$$\frac{\partial f}{\partial t} + rS \frac{\partial f}{\partial S} + \frac{1}{2}\sigma^2 S^2 \frac{\partial^2 f}{\partial S^2} = rf \quad (2)$$

Then we can get

$$c = SN(d_1) - Xe^{-r(T-t)}N(d_2) \quad (3)$$

$$d_1 = \frac{\ln(S/X) + (r + \sigma^2/2)(T-t)}{\sigma\sqrt{T-t}} \quad (4)$$

$$d_2 = d_1 - \sigma\sqrt{T-t} \quad (5)$$

where c is now option prices; S is the stock prices; r is the risk-free interest rate; T is the due time; t is the current time; X is executive price; $N(d_1), N(d_2)$ are normal distribution function.

3. Merton Model

Merton [6] created the share price jump-diffusion behavior model in 1976. Jumping process of the model obey Poisson process showed discontinuous volatility of share price. And model assumes that the size of the jump

follow lognormal distribution. Diffusion process of the Model obeys Brownian motion expressed as continuous fluctuations of stock prices.

First, it assume that the company’s assets value is follows geometric Brownian motion

$$dV_A = \mu_A V_A dt + \sigma_A V_A dz. \tag{6}$$

The model presents the company’s equity value as the calls which set the company’s asset as subject matter (Figure 1). And the company’s debt is viewed as the puts which set the company’s asset as subject matter.

Based on the above assumptions, T is the due date and D is the book value of debt. The call option value of the Debt maturity is

$$V_E = \max(V_A - D, 0). \tag{7}$$

According to B-S model, at time t , the rights and interests of the company is

$$V_E = V_A N(d_1) - e^{-r\tau} DN(d_2) \tag{8}$$

where V_E is the market value of the rights and interests; $\tau = T - t$ is the debt due time.

In the model, $N(d_2)$ is the probability without default, and $1 - N(d_2) = -N(d_2)$ is the default probability.

4. KMV Model

The basic computing theory of the KMV model are on the base of Morton and B-S option pricing these two models and then according to the company’s share price information to analysis the company credit. Model assumes that when the market value of company assets is higher than the matured liability means not default behavior, on the contrary, if the asset value is lower than the amount of debt due payments, the company will choose to default. The main analysis tools of KMV model is expected default frequency (EDP), so it is also called EDP model.

4.1. The Assumptions of KMV Model

1) Model is complying with the basic hypothesis of Merton option pricing model. That is to say, the stock prices of listed companies to obey random process and the trading is frictionless. And the value of listed companies change Process subject Ito Process.

2) It assumes that when the value of the assets of the listed company less than a certain level, the listed companies choose to default to its shareholders and creditors.

3) It assumes that the return on investment is fixed and known.

4.2. Computation Steps of KMV

1) The market value of the assets and the value volatility

The value of the asset of company is assumed to subject to stochastic process:

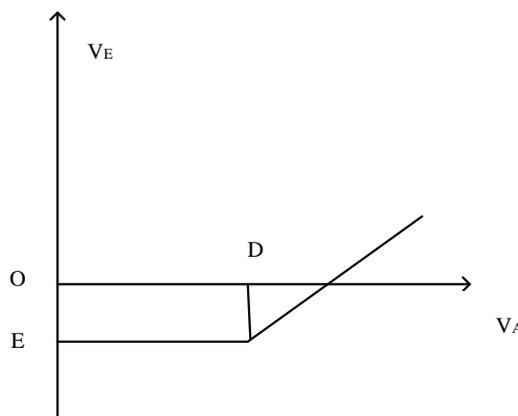


Figure 1. The company’s equity value.

$$dV_A = \mu_A V_A dt + \sigma_A V_A dz \quad (9)$$

where V_A and dV_A are asset value and its changes; μ_A and σ_A are drift rate and volatility dz is Wiener process.

The relationship between the company equity value and the market value of assets can be expressed as [1]:

$$V_E = V_A N(d_1) - e^{-rT} DN(d_2). \quad (10)$$

The relationship between the volatility of equity value and the volatility of asset market value is:

$$\sigma_E = \frac{V_A N(d_1)}{V_E} \sigma_A \quad (11)$$

$$d_1 = \frac{\ln\left(\frac{V_A}{D}\right) + \left(r + \frac{1}{2}\sigma_A^2\right)}{\sigma_A \sqrt{T}} \quad (11)$$

$$d_2 = d_1 - \sigma_A \sqrt{T} \quad (12)$$

where V_E is the market value of equity; V_A is the market value of assets of the company; $N(*)$ is cumulative normal distribution function; D is the market value of the debt; r is the risk-free interest rate; T is the maturity of the debt; σ_A is the volatility of assets value of the company. By the formula (10)-(12), V_A and σ_A can be calculated.

2) Distance to default DD

The default point is usually determined by short-term debt and 1/2 of long-term liabilities. Its mathematical definition is as follows:

It is known that the short-term debt of the company is STD and the long-term debt is LTD. So we define the default point as:

$$DPT = STD + \frac{1}{2} LTD. \quad (13)$$

The calculation of the default distance can be expressed as **Figure 2**. The distance to default DD is the relative distance between the company's future assets value and the default triggers. Because the amplitude of the company's asset value is different, relative distance is more scientific than absolute distance. The formula is

$$DD = \frac{V_A - DPT}{V_A \sigma_A}. \quad (14)$$

According to the standardized indicators of distance to default, different companies can be compared by the index, and the index can be used to measure the stand or fall of company's credit situation. Therefore, distance to default can be used to as an indicator in the evaluation of company credit status.

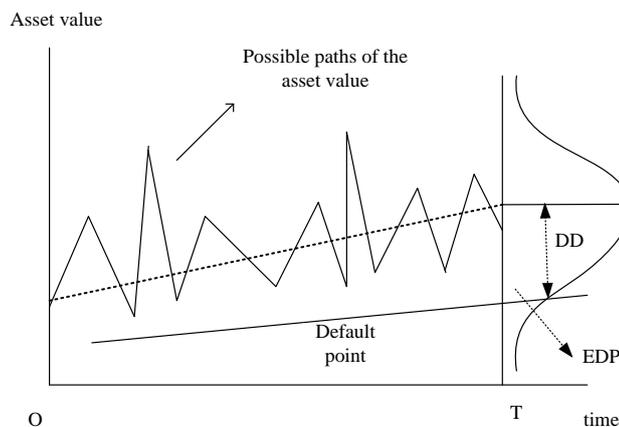


Figure 2. Calculation of the default distance.

3) Expected default frequency

The theoretical value of expected default frequency is concluded from the assumption that the market value of the assets follows the normal distribution. But it is unpractical obviously. So we observe some companies who have the same distance to default and record the actual number of defaults one year later. Expected default frequency is equal to the total number of companies who have the same distance to default divided by the number of companies who actual default. Formula is expressed as

$$\text{EDF} = N\left(-\frac{\ln(V_A/D) + (\mu - 0.5\sigma_A^2)T}{\sigma_A T}\right) = N(-DD). \quad (15)$$

Figure 3 is the corresponding relation between the distance to default and the experience probability of default researched by KMV Company. Our country is lack of huge historical default data to establish an effective database, so we directly use the distance to default (DD) to describe the level of credit risk of listed companies in the empirical part. We use the calculation method of the foreign default probability to calculate the default probability of the sample as a reference. By the above figure, we see that the greater the distance to default (DD) shows that the greater the probability of listed companies due to repay the debt and the smaller is the possibility of default, also illustrates the credit status of listed companies is better. On the contrary, the smaller the distance to default, explain the probability of listed companies due to repay the debt is smaller, the greater the chance of default, the credibility of the company is worse.

5. The Demonstration of the KMV Model

5.1. Parameters Setting

The model estimation need to set a few parameters, most can directly get from the company's financial statements or various trading software and a small number of parameters obtained by computing data. This article is based on data obtained from sina finance and economics website and everbright securities trading software.

1) The setting of the parameter E standing for the market value of Equity

The estimation method of the company equity value set by Traditional KMV model is not applicable to the listed company of our country. In view of the experience of forefathers' research, this paper set the value of the company equity as the sum of the market value of the circulation stock and non-tradable shares. That is to say: $E = E1 + E2$.

The market value of circulation stock ($E1$) = the number of shares of circulation stock \times the annual average closing price.

The market value of non-tradable shares ($E2$) = the number of shares of non-tradable shares \times Net assets per share.

2) The setting of the parameter D standing for the Book value of debt

The Book value of debt is the sum of the Current Liabilities and the noncurrent liability.

3) The setting of the parameters standing for the volatility of equity value

There is more mature method to calculate the stock price volatility At home and abroad. This article uses the

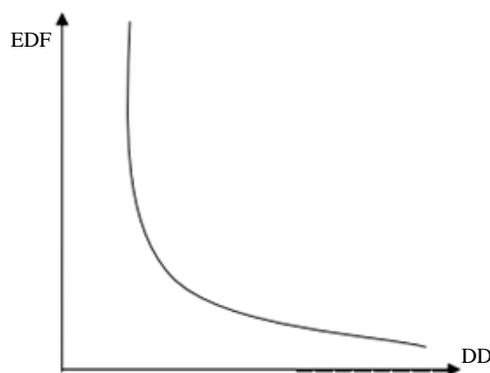


Figure 3. The relationship between EDF and DD.

historical volatility method to conduct calculation:

$$\mu_i = \ln\left(\frac{S_i}{S_{i-1}}\right), \quad i = 1, 2, \dots, n \quad (16)$$

$$\sigma_B = \sqrt{\frac{1}{n-1} \sum_{i=1}^n (\mu_i - \bar{\mu})^2} \quad (17)$$

$$\sigma_E = \sqrt{n} \times \sigma_B \quad (18)$$

where μ_i is log-return of stock of the listed company; $\bar{\mu}$ is the mean of μ_i ; S_i is the stock's closing price after day trading; $\frac{S_i}{S_{i-1}}$ is the day relative price of the stock, that is also the day relative yield; n is the trading days of stock market in a year; σ_B is the day volatility of the stock; σ_E is the annual volatility of the stock.

4) The setting of the parameters r standing for interest rate

Traditional model mainly choose the interest rates whose default risk is low, such as the one-year deposit rate and Treasury rates. Western countries usually use Treasury rates to replace the risk-free interest rate. But The Treasury bond market is not perfect in our country and the interest rate market is just open. Therefore in this section, we set the one-year deposit interest rate by the end of 2012 year as the risk-free interest rate, so $r = 3\%$.

5) The setting of the parameters T standing for the debt maturity

In this section, we select a year for debt maturity.

6) The setting of the parameters DPT standing for default point

The classic formula of default point is: $DPT = \text{Current Liabilities} + 0.5 \times \text{Long-term Liabilities}$. But the market value of the assets of our country is not consistent with them. The domestic most of the credit risk researchers on the selection of parameters are directly quoted all parameters of the original model, it reduce application accuracy of the KMV model in our country's listed companies to a certain extent. we will set 10 different default points in This section and calculated to obtain the default point of KMV risk measurement model which accord with the situation of listed companies in our country. So the default point can be expressed as

$$DPT = \text{STD} + a \times \text{LTD} \quad (19)$$

where STD are current liabilities and LTD are long-term liabilities. And $0 < a < 1$, it can choose 0.1, 0.2 and so on.

5.2. Empirical Research

This paper randomly select real estate, biopharmaceutical, ceramic industry, food industry, hotel tourism, agriculture & farming, coal profession, transportation, cement industry and automobile production, etc., based on the sina finance and economics stocks in Shanghai and Shenzhen. We select a non-ST company and a ST company every industry. There are 20 companies in all. (<http://finance.sina.com.cn/stock/>. Description: ST company operate deficit two consecutive years and *ST company operate deficit three consecutive years). We collect capital stock, long-term liabilities, short-term liabilities, net assets per share and other financial data from different listed company. And after data processing, we calculate the market value of the liabilities, equity market value and equity value volatility of the following 20 listed companies. As shown in **Table 1**.

We can see from the **Table 1** that in addition to the fact that equity annual volatility of the Saatchi & Saatchi PLC is slightly larger than the *ST Shangkong's in the ceramic industry, the equity annual volatility of other industries' non-ST company is smaller than corresponding industries' ST company. This generally conforms to the actual situation.

We get the market of debt and equity and the equity annual volatility. Then we put them into the formulas (10)-(12). We can calculate each listed company's asset market value and the volatility of asset value by using the MATLAB software. It was expressed as **Table 2**.

We can see from the **Table 2** that the non-ST companies' assets value fluctuation of ceramic industry, food industry and hotel tourism, the three industries are bigger than the ST's. It indicates that the ranges of asset value of the three industries are very small.

Table 1. The liabilities, equity value and equity annual volatility of listed companies.

Industry	Stock code	Listed company	The market value of the liabilities (yuan)	Equity value (yuan)	Equity annual volatility
Real estate	000024	Merchants Property	79,758,000,000	30,071,264,223	0.3434
	000056	*ST Guoshang	2,411,513,000	3,217,479,672	0.4067
Biopharmaceutical	000538	Yunnan Baiyao	3,636,674,000	39,734,773,517	0.2692
	600421	*ST Guoyao	220,412,000	913,533,500	0.3965
Ceramic industry	300089	Saatchi & Saatchi PLC	252,823,000	1,169,612,479	0.5774
	002162	*ST Shangkong	1,345,741,900	2,918,366,186	0.5585
Food industry	000895	Shuanghui Development	4,141,016,000	43,368,603,527	0.2593
	000972	*ST Zhongji	3,508,537,600	1,688,277,765	0.4241
Hotel tourism	601888	CITS	2,736,546,490	24,367,274,576	0.3095
	600358	*ST Lianhe	709,132,000	1,767,704,564	0.3239
Agriculture & Farming	600251	Guannon fruit	1,629,518,000	6,881,060,577	0.3557
	600265	*ST Jinggu	456,412,900	910,666,983	0.4450
Coal profession	601088	China Shenhua Energy	150,460,000,000	479,712,161,052	0.2265
	600381	*ST Xiancheng	1,899,580,000	7,165,719,403	0.7436
Transportation	600009	ShangHai airport	3,356,014,000	20,397,263,346	0.1550
	600087	*ST Changyou	15,861,330,000	5,306,963,483	0.6455
Cement industry	600585	Anhui Conch Cement	36,347,400,000	85,584,174,626	0.3412
	600539	ST Shitou	125,449,950	965,149,215	0.3835
Automobile production	601633	Great Wall Motors	20,926,060,000	33,667,439,375	0.3433
	600760	*ST Heibao	2,316,713,000	2,100,841,298	0.4588

Table 2. The market value of the asset and its volatility.

Industry	Stock code	Listed company	The market value of asset (yuan)	Volatility of asset value (yuan)
Real estate	000024	Merchants Property	110,400,000,000	0.0961
	000056	*ST Guoshang	5,646,200,000	0.2355
Biopharmaceutical	000538	Yunnan Baiyao	43,397,000,000	0.2472
	600421	*ST Guoyao	1,135,500,000	0.3213
Ceramic industry	300089	Saatchi & Saatchi PLC	1,424,300,000	0.4773
	002162	*ST Shangkong	4,275,900,000	0.3861
Food industry	000895	Shuanghui Development	47,539,000,000	0.2373
	000972	*ST Zhongji	5,226,200,000	0.1407
Hotel tourism	601888	CITS	27,123,000,000	0.2791
	600358	*ST Lianhe	2,481,800,000	0.2331
Agriculture & Farming	600251	Guannon fruit	8,522,000,000	0.2892
	600265	*ST Jinggu	1,370,300,000	0.2994
Coal profession	601088	China Shenhua Energy	631,230,000,000	0.1736
	600381	*ST Xiancheng	9,091,300,000	0.5925
Transportation	600009	ShangHai airport	23,777,000,000	0.1337
	600087	*ST Changyou	21,659,000,000	0.1688
Cement industry	600585	Anhui Conch Cement	122,190,000,000	0.2416
	600539	ST Shitou	1,091,500,000	0.3405
Automobile production	601633	Great Wall Motors	54,740,000,000	0.2141
	600760	*ST Heibao	4,437,100,000	0.2218

We put the formulas from the table above to calculate default distance and default probability of ST and non-ST companies in all industry. We choose $a = 0.1, 0.2, \dots, 0.9, 1$ as default point to research. The default point is $a = 0.5$ in the classical KMV model. But after empirical research we consider $a = 0.8$ is better point. We compare the default distances when $a = 0.5$ and $a = 0.8$ and the result is shown in **Table 3**.

From the graph 3 we can see that the distance to default of each listed company falls in range (1, 7). Default distance is smaller, the listed company is closer to the default point, namely, the greater the probability of default is, and credit is bad. It generally accords with the calculation results of KMV model.

We first make transverse comparison. The default distance when $a = 0.8$ is less than the default distance when $a = 0.5$ to all listed companies. For the same industry, the change range of default distance of ST and non-ST companies is different. Most of the change range of non-ST companies' default distance is smaller than ST companies'. This can well distinguish default companies and non-default and is more sensitive. When $a = 0.8$, the identifiability of the KMV model is stronger.

Then, we make vertical comparison. Non-ST companies' default distance is mainly bigger than the ST in the same industry. But the default distance of ceramic industry and hotel tourism's non-ST companies is smaller than the ST companies in the same industry when $a = 0.5$. That shows $a = 0.5$ has some limitations to the calculation of default distance. The default distance of the two industries' ST and non-ST companies are revised when $a = 0.8$, CITS's default distance is bigger than *ST Lianhe and the default distance of Saatchi & Saatchi PLC still slightly smaller than *ST Shangkong.

Finally, we compare the non-ST and ST companies. We sort the default distance in two columns and find that part of the non-ST companies' default distance is smaller than the other industries' ST companies', such as, the default distance of Saatchi & Saatchi PLC is smaller than *ST Guoyao, *ST Jinggu companies. And the default distance of *ST Lianhe is bigger than Anhui Conch Cement and Guannon fruit.

We put the default distance when default point is $a = 0.5$ into the default probability formula to calculate. The result is shown in **Table 4**.

Distance to default is inversely proportional to default frequency. The smaller the default distance is, the

Table 3. The comparison of the two default distance.

Industry	Stock code	Listed company	DD ($a = 0.5$)	DD ($a = 0.8$)
Real estate	000024	Merchants Property	3.57195573	3.1616919
	000056	*ST Guoshang	3.105545462	2.7018266
Biopharmaceutical	000538	Yunnan Baiyao	3.714754827	3.709688
	600421	*ST Guoyao	2.509312742	2.5086549
Ceramic industry	300089	Saatchi & Saatchi PLC	1.723222521	1.7232221
	002162	*ST Shangkong	1.800229609	1.7850068
Food industry	000895	Shuanghui Development	3.85827	3.8515058
	000972	*ST Zhongji	2.380985292	2.3539452
Hotel tourism	601888	CITS	3.221639017	3.2215242
	600358	*ST Lianhe	3.392640076	3.1955813
Agriculture & Farming	600251	Guannon fruit	2.853072821	2.8192103
	600265	*ST Jinggu	2.252185048	2.2373967
Coal profession	601088	China Shenhua Energy	4.592211016	4.4692806
	600381	*ST Xiancheng	1.37685396	1.3518101
Transportation	600009	ShangHai airport	6.816059743	6.5806705
	600087	*ST Changyou	2.966850027	2.1382074
Cement industry	600585	Anhui Conch Cement	3.277507847	3.0557062
	600539	ST Shitou	2.603262629	2.6008935
Automobile production	601633	Great Wall Motors	2.953742348	2.9126105
	600760	*ST Heibao	2.297882745	2.2118765

Table 4. Default probability of the listed companies.

Industry	Stock code	Listed company	Non-ST company's EDP	Stock code	Listed company	ST company's EDP
Real estate	000024	Merchants Property	0.0784%	000056	*ST Guoshang	0.3400%
Biopharmaceutical	000538	Yunnan Baiyao	0.0104%	600421	*ST Guoyao	0.6100%
Ceramic industry	300089	Saatchi & Saatchi PLC	4.2400%	002162	*ST Shangkong	4.3200%
Food industry	000895	Shuanghui Development	0.0059%	000972	*ST Zhongji	0.9300%
Hotel tourism	601888	CITS	0.0638%	600358	*ST Lianhe	0.0698%
Agriculture & Farming	600251	Guannon fruit	0.2400%	600265	*ST Jinggu	1.2600%
Coal profession	601088	China Shenhua Energy	0.0004%	600381	*ST Xiancheng	8.8200%
Transportation	600009	ShangHai airport	0.0000%	600087	*ST Changyou	1.6200%
Cement industry	600585	Anhui Conch Cement	0.1100%	600539	ST Shitou	0.4600%
Automobile production	601633	Great Wall Motors	0.1800%	600760	*ST Heibao	1.3500%

greater the default frequency is. The worse the listed company's credit is, the higher the level of risk is. We can see from the **Table 4**, the default frequency of *ST Xiancheng is 8.82% whose default frequency is the largest in the listed companies and who is most likely to default in the sample. According to the announcement of listed companies, *ST Xiancheng suspended its shares from trading on July 18, 2013. Until launching the restructuring plans, it could apply for resumption through Shanghai stock exchange. The reason is that the company has formed a debt hole and is unable to repay matured debts. So the default happened. This also shows that KMV has strong predictability.

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