Turkish Journal of Computer and Mathematics Education Vol.12 No. 11 (2021),4184- 4192
Research Article

Credit Risk Measurement of Credit Bonds of Chinese Listed Companies Based on KMV Model

Han-Hsing Yu[1*] , Xiaochun Zhang [1, 2]

1. International College, Krirk University, Bangkok, Thailand
2. Weifang University of Science and Technology, Weifang 262700, China

E-mail:hanhsing.yu@gmail.com

Article History: Received: 11 January 2021; Revised: 12 February 2021; Accepted: 27 March 2021; Published online: 10 May 2021

Abstract: The sudden attack of COVID-19 has brought more unstable factors to the economic development of China and even the world. The risk fluctuation in the market has attracted the attention of all parties in the risk game.In this paper, the KMV model is used to measure credit risk. Taking the listed companies that issued A-shares and issued credit bonds in Shanghai and Shenzhen Stock Exchange as samples from 2016 to 2020, the validity of the model is verified at first.It is found that the average DD of the companies listed in Shanghai Stock Exchange is slightly higher than that of the companies listed in Shenzhen Stock Exchange from 2016 to 2020.In 2017, the overall default risk of the sample increased year by year after the minimum;Through the fluctuation of DD mean value in recent 3 years, it is found that the credit risk course of the whole industry is rising, which is related to the impact of the epidemic in 2020 on the industry economy.

Keywords: credit risk measurement; KMV model; default distance; Chinese Listed Companies

1. Research background

Basel agreement II allows banks, with regulatory approval, to use their own models to estimate the probability of default and calculate the amount of capital they should set aside.Our country also follows the requirement of Basel agreement ,so explore the credit risk measurement model, which will help our financial institutions to identify the credit risk.The statistical results of China Central Depository & Clearing Co., Ltd.(CCDC), by the end of January 2021, The total custodian amount of China's bond market is 115 trillion yuan, and the credit bonds are 39.08 trillion yuan, accounting for 33.98% of the total. This paper takes the credit bonds as the research object.

2. Literature discussion

Professors Scholes and Black (1973) of Stanford University put forward B-S option pricing theory, which laid the foundation of modern option theory.KMV model is based on B-S model, through the equity value and its volatility inverse to calculate the value and volatility of the company.KMV, as the model's promoter, first made empirical predictions on IBM, Bank of Thailand, WorldCom, etc., which proved the effectiveness of the model.Michel, Dan and Robert (2000) respectively used the KMV model to test the credit risks of companies and found that the assessment results of the KMV model for credit risks were in line with the reality.In terms of parameter correction, Carey and Hrycay (2001) redefined the parameters of the KMV model, and the study showed that the prediction effect of the modified KMV model was significantly improved.Lee (2009) proposed a new algorithm of the default point in KMV model, and substituted GA-KMV, QR-KMV and KMV into three models to calculate the default distance respectively, and found that the accuracy of GA-KMV model was better than the other two models.In terms of the comparison between modern credit models, Boris, Lvana and Anna (2015) pointed out that the analysis of KMV model included multiple types of liabilities and forms of default, which was more consistent with the actual situation.Weissova, Kollar and Siekelova (2015) studied the KMV model, CreditMetrics and CreditRisk+ model, and the Credit Portfolio View model found that the KMV model

was most suitable for listed companies.Dai (2020) chose ST and *ST stocks of Shanghai and Shenzhen listed companies as the research objects of the high-risk group, and used KMV to calculate the ratings of DD and EDF compared with Standard & Poor's and Moody's on the samples, reflecting that KMV could correctly reflect the default probability of listed companies.

3. KMV model

3.1 Theoretical basis: Merton's (1973) model is based on assets = liabilities + owners' equity. It is assumed that there are only two capital structures of the company: stocks and homogeneous zero-coupon discounted bonds with face value of D and maturity time of T. On the maturity date of the debt, the asset value is greater than the bond value and there is no default. Otherwise, it is a breach of contract; The difference between assets and bonds is the equity value; Here describes a European call option, taking the equity value as the option price, the asset value as the underlying asset price, and the bond value as the strike price; On this basis, KMV model puts forward the concept of default distance (DD), which is used to evaluate the level of credit risk of a company. Finally, we calculate the empirical EDF value according to the relationship between the default distance and the expected default rate. This paper conducts empirical analysis only by DD value, that is, the greater the DD value, the smaller the default risk. The smaller the DD value, the greater the risk of default.

3.2 calculate the default distance DD

3.2.1 Equity value volatility

This paper uses the historical volatility method to estimate the volatility of the stock market value of listed companies in the next year.Assuming that the stock price of the listed company satisfies lognormal distribution, then the daily return rate of the stock, u, is shown in the formula：

$$u_i = \ln(p_i / p_{i-1}) \qquad 3\text{-}1$$

p_i is closing price of the stock in the day i.

The standard deviation is estimated as

$$s = \sqrt{\frac{1}{n\text{-}1}\sum_{i=1}^{n}(u_i\text{-}\bar{u})^2} \qquad 3\text{-}2$$

3.2.**2 Estimate the company's asset value and the volatility of its asset value**

Under the above assumptions, apply the B-S option pricing model to construct the relationship between asset value and equity value:

$$E = V_A N(d_1) - DPTe^{-rT} N(d_2) \qquad 3\text{-}3$$

$$d_1 = \frac{\ln(\frac{V_A}{DPT}) + (r + \frac{\sigma_A^{\ 2}}{2})T}{\sigma_A\sqrt{T}} \qquad 3\text{-}4$$

$$d_2 = d_1 - \sigma_A\sqrt{T} \qquad 3\text{-}5$$

According to formula (4-1), the following relationship between the volatility of the company's equity value and the volatility of the asset value can be deduced

$$\sigma_E = \frac{V_A}{E} N(d_1)\sigma_A \qquad 3\text{-}6$$

By combining the above formulas (3-3), (3-4), (3-5), (3-6), the company’s assets can be obtained through the value of equity and its volatility, value, volatility and other deterministic parameters.

3.2.**3 Calculate the default distance (DD).**

Default distance refers to the relative distance of the company's asset value from the current level to the default point (DPT) within the risk period, that is, the degree of deviation between the unit asset and the default point (DPT) within the risk period. The formula:

$$DD = \frac{V_A - DPT}{V_A.\sigma_A\sqrt{T}} \qquad 3\text{-}7$$

3.2.**4 Expected probability of default (EDF)**

The calculation of EDF is divided into theoretical EDF and empirical EDF. The theoretical calculation method is as follows:

$$EDF = P[V_A^t \le DPT \mid V_A^0 = V_0] = P[\ln V_A^t \le \ln DPT \mid V_A^0 = V_0]$$

$$EDF = N[-\frac{\ln\frac{V_A}{DPT_t} + (\mu - \frac{\sigma_A^2}{2})t}{\sigma_A\sqrt{t}}] = N[-DD] \qquad 3\text{-}8$$

4. The empirical analysis

Sample source: query from wind financial plate terminal bonds issued in 2016-2020 issued by the credit debt, corporate bonds, corporate bonds, medium-term notes, short-term financing bonds) for a total of 5496, after screening the distribution companies a total of 503 samples of company of issue overseas, Hong Kong shares, B shares after 50 enterprises, a total of 453 sample enterprises, elimination of sample data is not complete five companies a total of 448 samples, 2020, in the same way to find sample companies from 2016 to 2019.

Table 1 List of sample companies (partial)

Shenyi industry	Security code	abbreviation	Security code	abbreviation	Security code	abbreviation
Excavation	601011.SH	Baotelon	000968.SZ	Blue flame Holdings	600157.SH	STYongtai
	601969.SH	Hainan mining	601699.SH	Lu'an Huanneng		
	⋮	⋮	⋮	⋮		
media industry	002292.SZ	Aofei Entertainment	300182.SZ	Jebsen	002354.SZ	*STTianyu
	600136.SH	Contemporary style	002425.SZ	Caesar culture	002445.SZ	*STZhongnan
	300251.SZ	Ray media	300418.SZ	Kunlun wanwei		
	⋮	⋮	⋮	⋮		

Source: wind

4.1 Calculate the equity volatility.

The stock closing price of the sample company from January 1, 2016 to December 31, 2020.was extracted from the market index of the wind financial terminal, and the annual trading days n was checked to calculate the equity volatility.

Table 2 Summary of trading days on stock exchanges

year	2016	2017	2018	2019	2020
Transaction days	244	244	243	244	243

Source: Compiled by this research.

Table3 Summary of stock volatility calculations in 2020 (part)

Security code	abbreviation	Shenwan industry	close 2020-1-2	close 2020-1-3	…	close 2020-12-31	Stock Volatility
000937.SZ	Jizhong energy	Excavation	3.68	3.68		4.16	0.362
000968.SZ	Blue flame Holdings	Excavation	10.35	10.4		8.11	0.328
000665.SZ	Hubei Radio	media industry	5.46	5.42		4.44	0.45
000793.SZ	Huawen group	media industry	3.58	3.58		2.55	0.492

Source: Compiled by this research.

4.2 Risk free interest rate R: the weighted average of one-year fixed deposit interest rate published by the people's Bank of China is adopted, and the average annual rate from 2016 to 2020 is 1.5%, then r = 1.5%;

4.3 Debt maturity T:T=1.

4.4 Default point DPT ： DPT=STD+0.5*LTD

4.5 To find the value of equity

E = value of tradable shares + value of non-tradable shares

= closing price × tradable shares + net per share Assets × non-tradable shares restricted stocks

4.6 Obtain asset volatility and asset value through the B-S formula:

Table 4 Summary of asset volatility and asset value calculations in 2020 (partial)

Security code	abbreviation	Shenwan industry	Asset volatility	Asset value
000937.SZ	Jizhong energy	Excavation	0.135	32,335,862,629.58
000968.SZ	Blue flame Holdings	Excavation	0.234	11,009,030,174.56
000665.SZ	Hubei Radio	media industry	0.232	8,460,070,977.32
000793.SZ	Huawen group	media industry	0.236	10,430,128,847.03
⋮	⋮	⋮	⋮	⋮

Source: Compiled by this research.

4.7 Find the default distance DD

Table5 Summary of the calculation of default distance from 2016 to 2020 (partial)

Security code	abbreviation	Shenwan industry	2016 DD	2017 DD	2018 DD	2019 DD	2020 DD
000937.SZ	Jizhong energy	Excavation	1.962	2.611	3.404	4.002	2.695
000968.SZ	Blue flame Holdings	Excavation	4.387	2.567	2.063	2.918	3.030
000665.SZ	Hubei Radio	media industry	2.424	5.582	2.639	1.846	2.190
000793.SZ	Huawen group	media industry	2.093	4.370	2.072	2.024	1.994
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮

Source: Compiled by this research.

The empirical results are analyzed

In the process of data calculation, the data of 3 samples were abnormal. In the analysis of empirical results, a total of 445 samples in 2020 were excluded.

ST stock: The "ST" is appended to the abbreviation of the security of a listed company whose financial or other conditions are unusual, so the stock is usually classified as a high-risk group;

EPS (earnings per share) is the profit after tax/the total share capital. It is one of the important financial indicators to evaluate the investment risk of enterprises..

1. According to whether they have been ST, the sample enterprises are divided into high-risk group and low-risk group:

In the selected sample, there are 31 high-risk groups, and other enterprises are regarded as low-risk groups.In order to accurately depict the changing process of the mean DD of the high-risk group, this paper searched the time when the enterprise in the high-risk group was identified as ST from the Wind data terminal, as shown in Table 6.

Table 6 High risk enterprises are ST time

time	2016	2017	2018	2019	2020	2021
number	0	1	2	12	15	1

Source:wind

Table 7 Comparison of DD mean values between high-risk group and low-risk group

category	N	2016	2017	2018	2019	2020
High risk group	31	2.068	3.263	2.242	1.787	2.145
Low risk group	414	2.154	3.379	2.612	2.714	2.375
disparity		0.086	0.116	0.371	0.927	0.23

Source: Compiled by this research.

Table8 Comparison of EPS mean between high risk group and low risk group

category	N	2016	2017	2018	2019	2020
High risk group	31	0.416	0.283	-1.073	-1.753	-0.369
Low risk group	414	0.394	0.45	0.327	0.318	0.289
disparity		-0.023	0.167	1.4	2.071	0.658

Source: Compiled by this research.

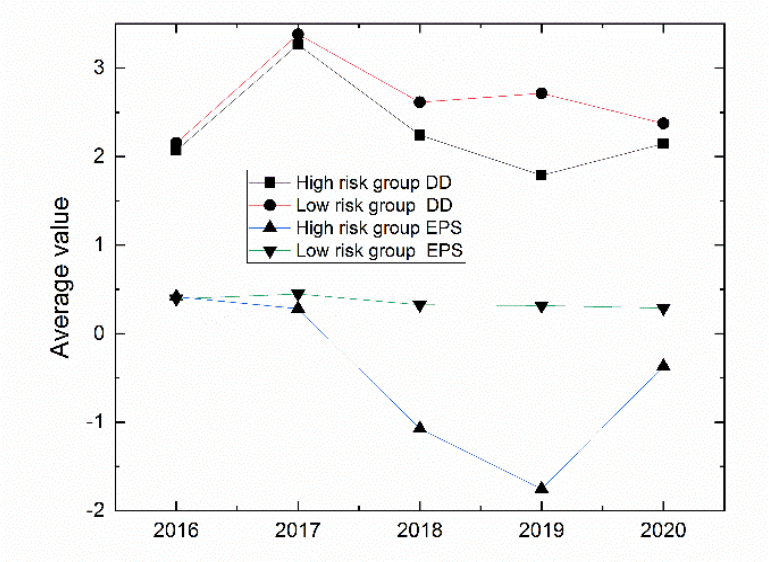

Figure 1 Comparison of DD and EPS between high risk group and low risk group

As can be seen from the figure, in 2016, 2017, and 2018, the difference between the mean values of DD of the two groups of enterprises gradually becomes larger, and the difference is the largest in 2019 and becomes smaller in 2020.The variation trend of EPS mean value of the two groups of enterprises is consistent with that of DD mean value. Combined with the ST time of enterprises in the high-risk group, it is proved that the KMV model is effective in measuring enterprise credit risk.

2. Shenzhen Stock Exchange listed companies and Shanghai Stock Exchange listed companies grouping: The comparison of DD mean values of sample companies after grouping is as follows:

Table 9 DD mean value table of the overall sample company

year	2016	2017	2018	2019	2020
N	426	429	441	442	445
average value	2.148	3.371	2.586	2.649	2.359
standard deviation	0.64	1.207	0.764	0.826	0.707

Source: Compiled by this research.

Table10 SZSE sample company DD mean table

year	2016	2017	2018	2019	2020
N	245	248	253	254	255
average value	2.015	3.205	2.407	2.483	2.203
standard deviation	0.662	1.142	0.645	0.725	0.599

Source: Compiled by this research.

Table 11 DD average table of sample companies on the Shanghai Stock Exchange

year	2016	2017	2018	2019	2020
N	181	181	188	188	190
average value	2.329	3.599	2.827	2.873	2.569
standard deviation	0.561	1.256	0.841	0.898	0.782

Source: Compiled by this research.

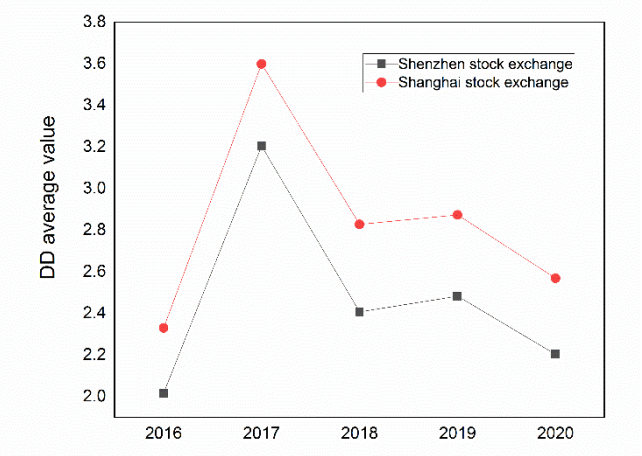

Figure 2 Comparison of DD mean value between Shanghai Stock Exchange and Shenzhen Stock Exchange

We can see from the figure: first, the average DD value of Shanghai Stock Exchange is larger than that of Shenzhen Stock Exchange, that is, the credit risk of listed companies of credit bonds issued by Shanghai Stock Exchange is lower than that of Shenzhen Stock Exchange; second, the default distance is the largest and the default risk is the smallest in 2017.

3. Sample enterprises are grouped by industry and industry

The comparison of DD mean values of sample companies after grouping is as follows:

Table 12 2016-2020 average table of company DD by industry sector

	industry/year	2016	2017	2018	2019	2020
primary industry	Agriculture, forestry, animal husbandry and fishery	2.19	3.775	2.83	2.297	2.025
the secondary industry	public utility	2.591	4.096	3.378	3.378	3.023
	Architectural decoration	1.997	2.95	2.526	2.882	2.588
	real estate	2.188	3.448	2.547	2.805	2.543
	Textile clothing	2.259	3.956	3.031	3.08	2.003
	Steel, non ferrous metals, mining	2.149	2.701	2.624	2.905	2.48
	Electronics, automobile, mechanical equipment, medicine, etc	2.053	3.398	2.456	2.392	2.125
the tertiary industry	Communication, commercial trade, home appliances, media, etc	1.995	3.321	2.276	2.198	2.089
	Transportation	2.557	3.502	2.804	3.158	2.877

Source: Compiled by this research.

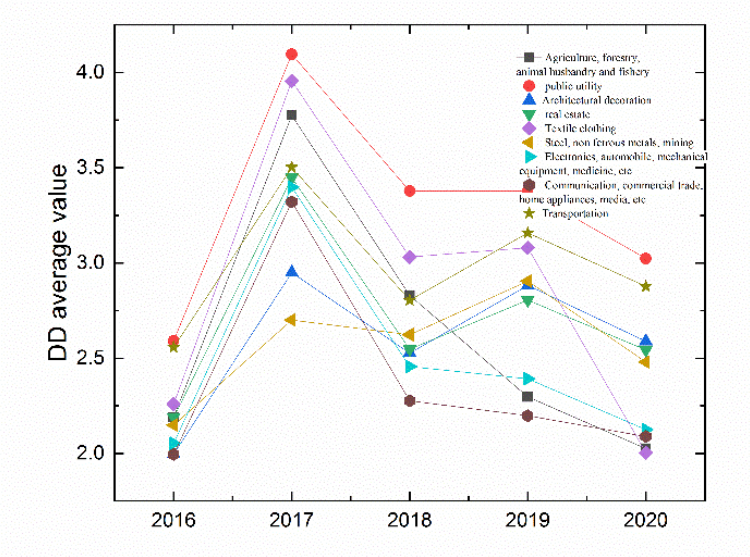

Figure 3 Comparison of DD mean value among different industries

It can be seen from the figure that the public utility industry has the largest default risk, that is, the minimum default risk; the average DD of textile and garment industry has a straight decline from 2019 to 2020; the default risk of the primary industry is medium.

4. The industry risk types of sample enterprises in recent three years are as follows:

Table 13 2016-2020 Corporate Risk Types by Industry Sector

	industry/year	2018	2019	2020	Risk type
primary industry	Agriculture, forestry, animal husbandry and fishery	2.83	2.297	2.025	↗
the secondary industry	public utility	3.378	3.378	3.023	↗
	Architectural decoration	2.526	2.882	2.588	∪
	real estate	2.547	2.805	2.543	∪
	Textile clothing	3.031	3.08	2.003	∪
	Steel, non ferrous metals, mining	2.624	2.905	2.48	∪
	Electronics, automobile, mechanical equipment, medicine, etc	2.456	2.392	2.125	∪
the tertiary industry	Communication, commercial trade, home appliances, media, etc	2.276	2.198	2.089	↗
	Transportation	2.804	3.158	2.877	∪

Note 1: “∪” type: credit risk first decreases and then increases; “∩” type: credit risk first increases and then decreases; “↗” type: credit risk is always on the rise.

It can be seen in the table that about 1 / 3 of the credit risk of the industry is accounted for“ ↗” About 2 / 3 of the industry's credit risk is "type", that is, first decline and then rise; no see type, that is, first rise and then decline; it directly shows that the risk of China's listed companies will increase under the impact of the epidemic in 2020.

5.deficiencies and Prospects

In this study, the empirical research is mainly based on the default distance DD, and there is no in-depth empirical analysis on the parameter correction, and the final default probability EDF is not calculated. In the future research, the following aspects can continue to be discussed: first, further relax the model assumptions to better

simulate the default phenomenon. Secondly, the default database in China is established to lay the data foundation for the mapping relationship between default distance and expected default rate. Thirdly, the model parameters are revised according to industry and empirical analysis is made.

Reference

1. Black, F., & Scholes, M. S. (1973). The Pricing of Options and Corporate Liabilities. Journal of Political Economy, 81(3), 637-654.
2. Crouhy, Michel, Galai, Dan, Mark, & Robert. (2000). A comparative analysis of current credit risk models. Journal of Banking & Finance, 24（1-2）, 59-117.
3. Carey, M., & Hrycay, M. (2001). Parameterizing Credit Risk Models With Rating Data. Social Science Electronic Publishing, 25(1), 197-270.
4. Wo-Chiang, & Lee. (2009). Redefinition of the KMV model's optimal default point based on genetic algorithms – Evidence from Taiwan. Expert Systems with Applications, 38(8), 10107-10113.
5. Boris, K., Ivana, W., & Anna, S. (2015). Quantification of Credit Risk with the Use of CreditMetrics. Procedia Economics and Finance, 26, 311-316.
6. Weissova, I.， Kollar, B. & Siekelova, A. (2015). Rating as a useful tool for credit risk measurement. Procedia Economics & Finance, 26, 278-285.
7. Dai, K. (2020). Risk of credit assessment of Chinese bank of commerce based on KMW model and its empirical research. MS&E, 768(5), 052122.
8. Merton, & Robert, C. (1974). On the Pricing of Corporate Debt: the Risk Structure of Interest Rates.The Journal of Finance, 29(2), 449-470.