Impact of Macroeconomic Changes on Corporate Credit Risk in the 5G Industrial Chain: Evidence From China

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Abstract: This study investigates the impact of various macroeconomic factors on the credit risk of listed firms in the 5G industrial chain in China using the KMV model, with a regression analysis of the financial data of 20 A-share listed companies in China's 5G industrial chain from the construction period to the application period, from 2011 to 2019. The results show that the money supply, inflation rate, and the exchange rate of RMB against USD have the most substantial impact on the credit risk of China's 5G listed companies. In addition, the results indicate that the Sino-US trade war had a positive impact on China's economic downturn, with a negative impact on the credit risk of firms in China's 5G industrial chain. However, the Sino-US trade war also harmed the exchange rate of RMB to USD, thus benefiting Chinese companies' foreign trade and reducing corporate credit risk. Therefore, the Sino-US trade war's impact on corporate credit risk in China's 5G industrial chain is twofold.

Keywords: China, 5G Industrial Chain, Credit Risk Management, Macroeconomy

1. Introduction

Information and communication technology (ICT) is an indispensable element of modern development. Nasir and Kalirajan[1] stated that ICT narrows geographical distances and connects different cultures. The development of ICT has made different social groups closer. ICT also plays a vital role in social and economic growth. The development of ICT promotes the growth of gross national product (GDP), increase productivity, enhance international financial cooperation, and increase international trade. In the era of economic globalization, the ICT industry makes far-reaching contributions to economic growth. Over time, the ICT industry has largely supported economic growth[2]. In the last few years, 5G, the latest achievement in ICT, has attracted significant attention.

The 5G industry is highly dependent on capital investment and technological development. At the same time, the global supply chain and foreign trade have a substantial impact on the 5G industrial chain. Competition between countries has generated pressure on the development of China's 5G industrial chain. In 2018, the US launched a trade war against China. Zhang employed the time series model proposed by Diebold and found that the US maintains a dominant position in all market, sand the Sino-US trade war had a substantial impact on the development of China's 5G industrial chain[3-4].

MSEA 2023, May 26-28, Nanjing, People's Republic of China

DOI 10.4108/eai.26-5-2023.2334461

Under declining macroeconomic conditions worldwide, risk management is an essential issue, especially corporate credit risk management[5]. Corporate default probability is related to a country's overall economic situation[6-7]. Corporate default probability is more sensitive to changes in stock market conditions and changes in macroeconomic conditions during a financial crisis[8]. Monetary policy adjustments affect the money supply and aggregate demand, among others, thus influencing the interest rate level and corporate default probability [9]. Monetary policy will generate an increase in interest rates, which adversely affects a company's default probability[10-11]. The inflation rate has a significant influence on the purchase price of raw materials thus affecting a company's default probability[12]. Also, a company's innovation capability, debt-to-asset ratio, rate of return, total assets, and return on assets have a significant impact on the company's default risk[13] (Hsu et al., 2015).

Some issues remain open: Will the economic downturn exacerbate corporate defaults in the 5G supply chain? What are the macro factors that affect a company's probability of default? This study contributes to the literature in the following innovative aspects: (1) We will conduct research from the perspective of the entire 5G industrial chain, involving wireless equipment and base station equipment suppliers-construction companies in the operation and maintenance period, and terminal accessories and operators in the application period. (2) We will investigate whether the China's economic decline will exacerbate corporate defaults. (3) We will determine which macro factors affect the corporate default probability, and (4), we will explore the impact of the Sino-US trade war on corporate default probability in China's 5G industrial chain.

The remainder of this paper is organized as follows. Section 2 provides an introduction of China's 5G industrial chain. In Section 3, we describe the data, summarize the selection of macro variables and control variables and summary statistics. Section 4 concludes.

2. Introduction of China's 5G Industrial Chain

China's 5G industrial chain featured a construction period, operation and maintenance period, and an application period. To ensure the accuracy of the regression results this study used companies listed no later than 2011 and data on 20 A-share listed companies. The construction period includes the wireless equipment, transmission equipment, base station equipment, small base station construction, optical communication equipment, and network engineering construction. The operation and maintenance period comprises network optimization and network operation and maintenance, and the application period includes terminal accessories and the construction of the Internet of Things. Wireless equipment comprises radio frequency devices, optical modules, and transmission equipment, including Software Defined Network (SDN), Network Functions Virtualization (NFV), optical modules, and fiber optic cables. The affiliation of each company is shown in Figure 1.

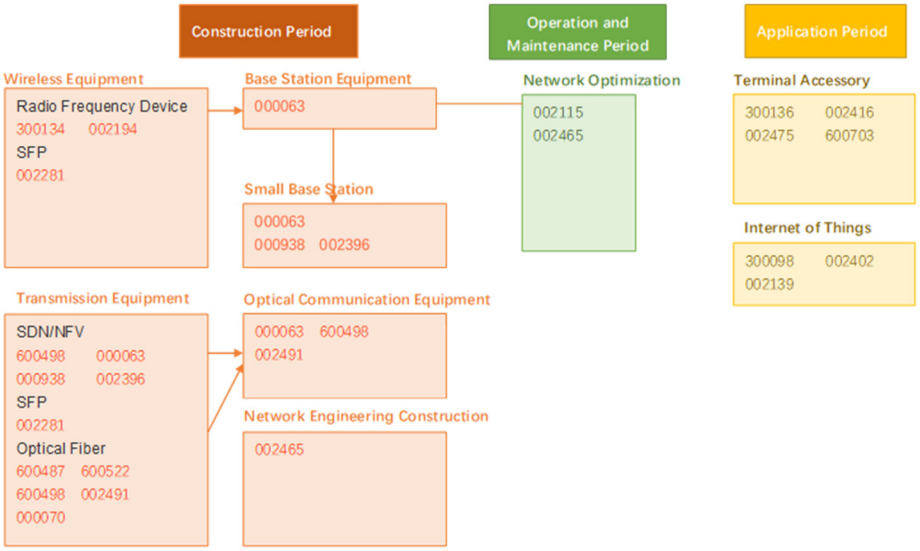

Fig. 1 China's 5G industrial chain

Data source: WIND database.

3. Data analysis and Results

The descriptive statistics of the DD from 2011 to 2019 (Table 1) indicate that the average value of the DD from 2011 to 2014 shows an overall upward trend, suggesting that corporate credit risk is reduced, and the probability of default decreases. The DD dropped significantly in 2015, from 2.3188 to 1.3045, indicating that corporate credit risk rose sharply in 2015, and the probability of default increased rapidly. This result reflects the outbreak of the manufacturing crisis in 2015, the frequent bankruptcy of manufacturing companies, the sharp rise in the bad debt rate of banks, and the worsening of the economic situation, which affected the companies in the communication industry. From 2016 to 2019, the DD showed an alternating rising and falling trend. Only in 2017, the market began recovering after the 2015 crisis. However, macroeconomic factors such as the Sino-US trade war and the global economic downturn began affecting the economy in 2018. The Chinese market has been hit, and companies in the communications industry have also been affected. The maximum and minimum values in Table 1 indicate that the difference between the maximum and minimum DD remained approximately equal to 2. The maximum value exceeded 4 in 2017, indicating large differences in the management level of companies in the industry.

Table 1 Descriptive statistics of DD from 2011 to 2019

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019
Average	2.2368	2.3357	2.0076	2.3188	1.3045	2.0109	2.7693	2.0436	2.2323
Maximum	3.4619	3.4940	2.4783	3.6449	1.9970	3.6819	4.8993	2.5143	3.1418

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019
Minimum	1.1548	1.1161	0.5899	1.2079	0.7124	0.9422	0.7867	1.4859	1.4239
Medium	2.5293	2.5350	2.1085	2.1088	1.3319	2.0010	2.9459	2.0935	2.1956

DD is the dependent variable. The larger the value of the DD, the smaller the credit risk of the company, and the smaller the probability of default.

Macroeconomic factors are the independent variables in the proposed model. GDP reflects the overall economic development of a country. When the economic situation is sound, the external environment of the company's operation improves, the company's capital demand can be met, and financing is more convenient, thus reducing the company's credit risk. M2 is the money supply. When the government adopts a loose monetary policy, the money supply is large; however, this may lead to inflation. The inflation rate calculated by consumer price index data directly describes the market inflation situation, explaining the relationship between the inflation rate and a company's credit risk. The beta coefficient describes the volatility of a stock relative to the market and is typically used to evaluate systemic risk. This study uses this index to represent the level of systemic risk and observe the impact of systemic risk on corporate credit risk. The Sino-US trade war started in 2018, influencing China's economy and international trade. The exchange rate of RMB to USD was greatly affected by the trade war and increased sharply from 6.4 in 2011 to 6.7 in 2018. An upward trend was observed from 2018 to 2019. The specific trend of change is shown in Figure 2. Therefore, this study uses the exchange rate of RMB to USD as an indicator of whether the Sino-US trade war had an impact on companies in the 5G industrial chain, and the direction of the impact is also analyzed. To improve the robustness of its conclusions, this study also employs a dummy variable to conduct a second test of the Sino-US trade war’s impact. The year of the trade war is marked as 1, and 0 otherwise.

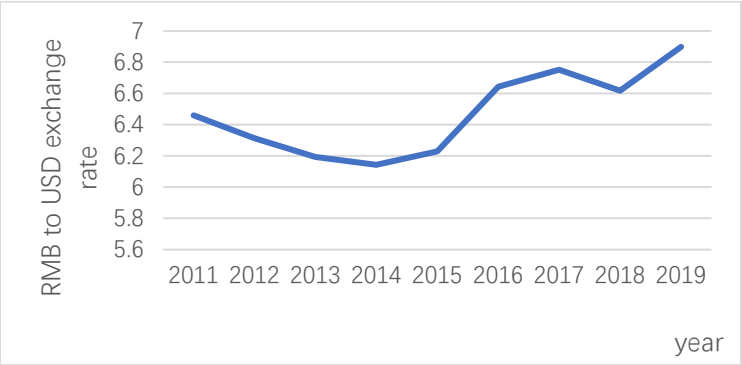

Fig. 2 Upward trend of the exchange rate of RMB to USD from 2011 to 2019

Since a company’s credit risk is not only affected by external macroeconomic factors but also by the company’s microeconomic considerations, to ensure that the regression results are effective, this study adds control variables to reflect the company’s operating conditions. The control variables include the total assets, debt-to-assets ratio, return on net assets, account receivable turnover rate, profit margin, and R&D investment. The variable symbol description and data source description are reported in Table 2.

Table 2 Variable symbol description and data source description

	Symbol	Meaning	Data source
Dependent Variable	DD	Distance to Default	KMV
Independent Variable	lnGDP	Natural logarithm of GDP	National Statistics Bureau
	RtD	Exchange rate of RMB to USD	National Statistics Bureau
	lnM2	Natural logarithm of money supply	National Statistics Bureau
	inflation	Inflation rate	National Statistics Bureau
	beta	Beta coefficient	iFinD
Control Variable	DA	Debt-to-Asset	iFinD
	lnAsset	Natural logarithm of Asset	iFinD
	ROE	Return on Equity	iFinD
	TAR	Turnover of Account Receivable	iFinD
	Profit	Profit	iFinD
	R&D	Research and Development Cost	iFinD
Dummy Variable	dummy	The year of the trade war is marked as 1, others are marked as 0.	

The regression equation reads as follows:

$$DD = \beta_0 + \beta_1 lnGDP + \beta_2 RtD + \beta_3 lnM2 + \beta_4 inflation + \beta_5 beta + \beta_6 DA + \beta_7 lnAsset + \beta_8 ROE + \beta_9 TAR + \beta_{10} Profit + \beta_{11} R\&D \quad (1)$$

The descriptive statistics in Table 3 show that the DD of listed companies in the 5G industrial chain is approximately 2, and the average asset-liability ratio is 41.998%, indicating that ICT companies have a relatively high level of debt. The average profit rate is 11.19%, but the 25% quintile and 75% quantile are 4.79% and 13.21%, respectively, showing a large gap. The 75% quantile and the 25% quantile of the Return on Equity (ROE) value are also characterized by a large gap. The above indicators show that the operating capabilities of listed companies in the 5G industrial chain are quite different. China's GDP has shown an overall slow-growth trend, and its growth rate has gradually declined over the sample period. The exchange rate of RMB to USD, and the money supply showed a slow upward trend, and the inflation rate indicates that China has continued to maintain a slight inflation level.

Table 3 Data description

	Average	Standard Deviation	P25	P50	P75
DD	2.1313	0.6981	1.667	2.0919	2.5576
lnGDP	4.2450	0.2274	4.0826	4.2325	4.4213
RtD	6.4717	0.2549	6.2284	6.4588	6.6423

	Average	Standard Deviation	P25	P50	P75
lnM2	14.1159	0.2753	14.1464	14.1465	14.3404
inflation	0.0251	0.0112	0.02	0.021	0.026
beta	0.9205	0.5419	0.6393	0.9226	1.2699
DA	41.9980	16.1361	30.933	41.5561	54.6167
lnAsset	13.4061	1.2016	12.4942	13.3351	14.0108
ROE	4.2737	8.2201	0	0.7841	9.687
TAR	3.0297	6.1167	0	2.1157	3.8248
Profit	11.1873	18.6344	4.7906	8.4299	13.2055
R&D	27088.63	124226.4	0	0	0
dummy	0.2222	0.4169	0	0	0

The Hausman test results indicate that at the 5% significance level, the p-value is 0.6809 greater than 0.05; therefore, we accept the null hypothesis that the panel data present random effects, and random effects regression should be used. The regression results are reported in Table 4.

Table 4 Regression results

	(1)	(2)
C	87.48886***	143.84800***
	(4.06000)	(5.56000)
	[0.00000]	[0.00000]
lnGDP	9.38237***	22.34977***
	(3.68000)	(5.80000)
	[0.00000]	[0.00000]
beta	0.04630	0.02248
	(0.45000)	(0.23000)
	[0.65000]	[0.81900]
RtD	1.64646***	
	(3.56000)	
	[0.00000]	
dummy		-1.60709***
		(-4.85000)
		[0.00000]
inflation	-31.90716**	2.87195
	(-2.97000)	(0.38000)
	[0.00300]	[0.70100]
DA	0.00174	0.00118
	(0.43000)	(0.29000)
	[0.67000]	[0.77000]

	(1)	(2)
lnAsset	0.09889*	0.10337*
	(1.67000)	(1.77000)
	[0.09500]	[0.07600]
ROE	-0.00307	-0.00723
	(-0.42000)	(-1.05000)
	[0.67400]	[0.29200]
TAR	-0.00480	-0.00598
	(-0.54000)	(-0.70000)
	[0.58700]	[0.48700]
profit	-0.00158	-0.00168
	(-0.47000)	(-0.51000)
	[0.63900]	[0.61000]
R&D	0.00000	0.00000
	(-1.46000)	(-0.98000)
	[0.14300]	[0.32900]
R-square	0.18430	0.23190

*, **, and *** denote that an estimate is statistically significantly different from zero at the 10%, 5%, and 1% levels, respectively.

The first column reports the results of the model specification in which the exchange rate of RMB to USD is included to represent the impact of the Sino-US trade war on companies in the 5G industrial chain. The second column shows the results of the model specification that includes a dummy variable that represents said impact. In the two regressions, the coefficients on lnGDP, lnM2, the exchange rate of RMB to USD, and the dummy variables were all significant at the 1% confidence level, and the inflation rate was significant at the 5% level in regression Equation (1).

According to the absolute value of the correlation coefficient, the inflation rate in regression Equation (1) has the greatest impact on the DD, and they are negatively correlated, implying that every increase in the inflation rate will cause the DD to decrease by 31.91 units. We contend that this inflation causes an increase in the price of raw materials, increasing the costs and expenses and uncertainty of future costs and strategies. The money supply is negatively correlated with the DD, with a correlation coefficient of 9.66. GDP and the DD are positively correlated, that is, lnGDP changes of one unit will make DD change 9.38 units in the same direction. An increase in GDP indicates that the macroeconomic conditions have improved, thus benefiting the companies' development and reducing the probability of corporate default. In contrast, a reduction in GDP indicates that the level of macroeconomic development has declined. Companies are affected by the external economic environment, and their DD decreases, and the default probability increases. The exchange rate of RMB to USD and DD are positively correlated. Each increase in the exchange rate will increase the DD by 1.65 units. We contend that an increase in the exchange rate of the RMB to USD implies that the US dollar appreciates, and the RMB depreciates, which helps Chinese companies to export. In addition, the export of 4G construction-related business' accounts for a large proportion of the

company's main business income in the 5G industrial chain. Hence, an increase in the exchange rate of RMB to USD is more conducive to the company's export of 4G construction-related business and reduces the credit risk of 5G companies.

In Equation (2), the direction of the correlation between each variable and DD remains unchanged. The coefficient on the dummy variable is significant at the 1% confidence level, indicating that the Sino-US trade war has a significant impact on the companies in the 5G industrial chain. The correlation coefficients of GDP and money supply are 22.35 and –16.84, respectively, which indicates that economic growth and money supply still are the two main factors influencing the default probability of companies. In terms of control variables, the coefficient on the size of corporate assets is significant at the 10% confidence level and has a positive correlation with the company's DD, indicating that the larger the company's capital scale, the greater the DD, the smaller the probability of default. Overall, the results of Equation (2) confirm the robustness of the results of Equation (1).

4. Conclusion

This study selects 20 listed in A-share companies in the 5G industrial chain, covering the three major periods of the chain, which include the construction period, operation and maintenance period, and application period, and uses macroeconomic indicators and corporate financial data from 2011 to 2019. The regression analysis indicates the following conclusions: (1) An increase in money supply, a cause of rising inflation rate, increases the company's probability of default. (2) An increase in GDP, an indication of improvement in the macroeconomic conditions, reduces the probability of corporate default. (3) An increase in exchange rate reduces the corporate default probability. (4) The two regressions' results show that the Sino-US trade war has affected China's companies in 5G industrial chain. Creditors such as banks and corporate bondholders should tightly monitor the macroeconomic conditions and pay close attention to the relationship between such conditions and corporate credit risks to reduce default rates and prevent losses from defaults. Meanwhile, companies in the 5G industrial chain should pay attention to macroeconomic changes and macroeconomic policies to reduce their probability of default and to strengthen their management, formulate strategies for corporate development and adjust their business structure to meet the market demand.

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Appendix

The KMV model calculates the DD based on the leverage ratio, calculated by the ratio of the financial book value to corporate asset market value, the asset value (the corporate market value), and the asset risk (the volatility of corporate assets, which is affected by the industry and macroeconomic environment). The calculation implies three steps: the first is to calculate the company's asset value and the volatility of the asset value using the Black-Scholes Option Pricing Model (BSM) model and the equity value of the listed company and the volatility of the equity value. The second step is to obtain the DD, and the third step calculates the expected default probability.

Because a company's asset value and its volatility cannot be directly observed, the market value of equity is treated as a call option based on the market value of the listed company's stock. The Black-Scholes formula is used to obtain the following expression:

$$E = VN(d_1) - D * e^{-rT}N(d_2) = f(V, \sigma_A, r, D, T), \quad (1)$$

$$d_1 = \frac{\ln(V/D)+(r+\sigma_A^2/2)T}{\sigma_A\sqrt{T}},$$

$$d_2 = d_1 - \sigma_A\sqrt{T}.$$

where E is the market value of equity, D is the book value of the liability, V is the market value of the company's assets, T is the expiration time, r is the risk-free interest rate, N is the immediate probability function of the normal distribution based on d_1 and d_2, and σ_A and is the volatility of the asset value.

Using the Black-Scholes formula, we calculate the expectation after deriving the two sides of the equal sign of Equation(1) and obtain the expression to calculate the asset value volatility σ_E:

$$\sigma_E = \frac{N(d_1)V\sigma_A}{E} = g(V, \sigma_A, r, D, T). \quad (2)$$

This expression comprises known variables such as the market value of equity, volatility of equity value, book value of liabilities and maturity time, and unknown variables, such as the asset value and asset value volatility of companies. Using Equation 2, we solve for the unknown variables, completing the first step of the KMV model.

The calculation of the default point (DPT) and DD of the company can be obtained by determining the expected value of the company's assets and the book value of liabilities. In line with the theoretical hypothesis of the KMV model, when the market value of a company falls below a certain level, the company defaults. Generally, when the market value of the company's assets drops below the total face value of its debt, the company will default. However, the book value of the company's debt consists of long-term debt and short-term debt, in which the former often relieves the pressure on the company to repay the debt, thus allowing to avoid default. In line with the characteristics of China's listed companies, this paper revises the default point setting coefficient according to the literature. The best strategy seems to be to set the default point in China as short-term debt plus 75% long-term debt. The default point is set as follows:

$$DPT = STD + 75\% * LTD \quad (3)$$

STD is short-term debt; LTD is long-term debt.

$$DD = \frac{E(V_A) - DPT}{E(V_A)\sigma_A} \quad (4)$$

Under the assumption that the value of the asset follows a normal distribution or a logarithmic distribution, the expected default probability (EDF) can be calculated by the DD. In other words, the mapping relationship between the DD and the default probability can be established. Assuming that the asset value follows a normal distribution, the theoretical calculation of the expected probability of default is as follows:

$$EDF = \Pr(E(V_A) < DPT) = N\left(\frac{DPT - E(V_A)}{E(V_A)\sigma_A}\right) = N(-DD). \quad (5)$$

This expression implies that the default probability of a company with a DD of 4 standard deviations is approximately zero. However, in practice, many companies with a DD of 4 standard deviations default. The KMV model uses its large historical default database to map the DD calculated by each company with its actual default probability, thus constructing a corporate credit evaluation system based on an empirical EDF. Hence, the KMV model calculates the DD and default probability through the historical financial data and stock price of the company through a dynamic approach, thus improving the lag problem affecting the previous model. At the same time, the default probability rates of different types of companies are comparable.