Ann Oper Res (2015) 234:3–15
DOI 10.1007/s10479-014-1727-y

Discovering the impact of systemic and idiosyncratic risk factors on credit spread of corporate bond within the framework of intelligent knowledge management

Rongda Chen · Liu Yang · Weijin Wang · Ling Tang

Published online: 19 September 2014

Abstract This paper exploits the implied information of data collected from credit spreads of Chinese corporate bonds and systemic and idiosyncratic risk factors. We compute contribution of risk factors to credit spreads of Chinese corporate bonds by establishing the unbalanced panel data model, identify the key factors impacting the size of credit spreads of corporate bonds. Knowledge extracted by data mining is helpful to investors for reasonable pricing of bonds and making rational investment decisions. When selecting variables, the unbalanced panel data model is used to calculate the Zero-volatility credit spreads, which are more accurate. We use term structure adjusted return of bond index as the systemic risk factor of corporate bond market, the three Fama/French systemic factors as the systemic risk factors of stock markets and idiosyncratic stock/bond volatility and idiosyncratic bond value-at-risk as the idiosyncratic risk factors. Empirical analysis of corporate bonds sampling China's listing Corporation issued and traded on Shanghai Stock Exchange from 2008 to 2011 shows that the size of credit spreads is mainly determined by the systemic risk factors

R. Chen (✉) · L. Yang · W. Wang · L. Tang
School of Finance, Zhejiang University of Finance and Economics, No. 18 Xueyuan Street, Xiasha Higher Education Zone, Hangzhou 310018, People's Republic of China
e-mail: rongdachen@163.com

R. Chen
Collaborative Innovation Center of Wealth Management and Quantitative Investment, Zhejiang University of Finance and Economics, Hangzhou 310018, People's Republic of China

R. Chen
Government Regulation and Public Policy Research Center of Zhejiang Province, Hangzhou 310018, People's Republic of China

L. Yang
Business School, University of International Business and Economics, Beijing 100029, People's Republic of China

L. Tang
School of Economics and Management, Beijing University of Chemical Technology, Beijing 100029, People's Republic of China

of bond market, i.e. risk factors of stock market make very little contribution to the spread; the idiosyncratic risk factors also contribute. An interesting phenomenon is that we find that the relationship between idiosyncratic stock volatility and credit spread is negative, which is contrary to extant research while the relationship is positive and mainly focuses on impact of risk factors on credit spread of corporate bond.

Keywords Intelligent knowledge management · Corporate bond · Credit spread · Systematic risk factor · Idiosyncratic risk factor · Unbalanced panel data model

1 Introduction

Credit spread, which is an important indicator of the credit quality of corporate bond, is helpful both in managing credit risk of corporate bond and in making investment decisions. There is a lot of relevant research on credit spread abroad, while research on credit spread of corporate bond is rare in China due to the short history of the corporate bond market. Therefore, research on factors that have impact on credit spread is meaningful both in theory and in practice. Considering the huge amount of financial data available because of development of information technology, it has become important and feasible to examine major problems such as dynamic features of the financial system and risk, by integrating intelligent knowledge management in the finance discipline.

This paper tries to develop a data mining method to discover useful information about contribution of risk factors to credit spreads of Chinese corporate bonds by exploiting those data which is collected from credit spreads of Chinese corporate bonds, systematic risk factors, and idiosyncratic risk factors. Namely, we develop a statistical analysis technique and establish a unbalanced panel data model integrated with data mining and intelligent knowledge management to identify the key factors impacting the size of credit spreads of corporate bonds. Knowledge achieved through data mining is helpful to price bonds reasonably and to improve decision-making of investors.

Credit spread reflects the credit risk and can be used to observe the change of credit risk (Kiesel et al. 2001; Saunders et al. 2007). Though credit spread is essentially the premium paid for credit risk, the relationship between credit spread and credit risk is still not known adequately. Actually, credit spreads are much larger than what is justified by expected loss from default (Elton et al. 2001). By using option adjusted spread (OAS), Eom et al. (2004) suggested that expected default loss is only a small part of credit spread. This is known as "the credit spread puzzle". Using a hand-collected data set of cover pool information, Prokopczuk et al. (2013) find that the credit quality of the cover assets is an important determinant of covered bond yield spreads.

Many researchers have been trying to decompose credit spread to identify factors that affect it. Initial research mainly focused on factors related to credit quality, such as distress cost, tax, asset value and so on (Jones et al. 1984; Lonstaf and Schwartz 1995). Then some researchers took account of the impact of risk premium, liquidity risk and market risk (Delianedis and Geske 2001; Driessen 2005; Huang and Huang 2012). Besides, the evolution of credit derivatives has inspired some researchers to study the behaviour of credit spreads (Elkhodiry et al. 2011; Castellano and D'Ecclesia 2013).

In recent years, researchers have tried to decompose credit spread into systemic and idiosyncratic risk factors, which seems to be more meaningful both theoretically and practically than simple decomposition. Gemmill and Keswani (2011) find that systemic risk factors have a strong linear relationship with credit spread but with small contribution to its size, and credit spreads are mainly determined by idiosyncratic risk factors—idiosyncratic stock volatility, idiosyncratic bond volatility and idiosyncratic bond VaR, among which idiosyncratic bond VaR makes the biggest contribution.

In China too decomposition has been used for examining credit spread (Ren and Li 2006; Chen 2008; Liu and Yang 2010) but the Chinese bond market is still evolving and, therefore, factors that impact credit spread are different from those in developed markets. What's more, selection of factors in these researches is discretionary and there is no available data of credit spreads.

Credit spreads of corporate bonds are calculated after taking into account term structure of interest rate. Then factors that impact credit spreads from the perspective of systemic and idiosyncratic risk factors are analyzed and contribution of each factor is determined to identify the key factors. Firstly, this is very useful for enterprise-wide risk management (ERM), which includes both credit risk and market risk. Secondly, the credit spreads we calculated imply whether the prices of corporate bonds are appropriate for investors to make investment decisions. Thirdly, credit spread, which is a credit risk factor that reflects the quality of credit, is helpful in bond valuation. Lastly, for supervisors, credit spreads can be used to judge whether the prices of bonds are appropriate and whether the bond market is reasonably priced.

2 Analytical framework and methods

Systemic and idiosyncratic factors that impact credit spreads are analyzed to determine which of them are the key factors. The empirical process includes defining the sample corporate bonds, calculating the credit spreads, defining the risk factors and determining the regression approach. The data sources include RESSET, WIND and the website of the Shanghai Stock Exchange (SSE).

2.1 Define the sample bonds

Sample corporate bonds should meet all of the following standards: (1) Issued by listed companies and traded on the SSE.; (2) With no option, that is neither callable nor puttable; (3) Fixed-rate, and pay coupon once a year. RESSET provides 46 bonds that meet all these standards from January 4, 2008 to September 30, 2011. As there are 205 trading week among this period, we have 2,157 effective observations which all are the Friday trading prices of each bond.

2.2 Calculate the Zero-volatility credit spreads

2.2.1 Zero-volatility credit spread

Since data of credit spreads is not available, at least publicly, we had to first calculate the credit spreads. Most domestic researchers have chosen the nominal credit spread, which is simply the difference between the yield-to-maturity of corporate bond and Treasury bond with the same maturity (Tan 2010). Nominal credit spread doesn't consider the effect of term structure while the Zero-volatility credit spread takes the effect of term structure into account and is, therefore, more accurate (Amato and Remolona 2005). The calculation is based on the spot rate of Treasury bonds, not yield-to-maturity. The calculation formula is as per Eq. (1):

$$P_{market} = \sum_{i=1}^{n} \frac{CF_i}{(1 + R_{T_i} + Z)^{T_i}} \tag{1}$$

where R_{T_i} is the spot rate of a T_i-years Treasury bond, Z is the Zero-volatility credit spread. After the consideration of Z, all the discount rates are same and the volatility of discount rates is zero, so it is called the Zero-volatility credit spread.

2.2.2 Fitting the yield curve of Treasury bond

We should fit the yield curve of Treasury bond before calculating the Zero-volatility credit spread. We choose the NSS model (Svensson 1994 proposed an extension of the Nelson–Siegel model) to fit the yield curve. Equation (2) shows the NSS model:

$$\begin{aligned} R(0,t) = \beta_0 + \beta_1 \left[\frac{1 - \exp\left(-\frac{t}{\tau_1}\right)}{\frac{t}{\tau_1}} \right] + \beta_2 \left[\frac{1 - \exp\left(-\frac{t}{\tau_1}\right)}{\frac{t}{\tau_1}} - \exp\left(-\frac{t}{\tau_1}\right) \right] \\ + \beta_3 \left[\frac{1 - \exp\left(-\frac{t}{\tau_2}\right)}{\frac{t}{\tau_2}} - \exp\left(-\frac{t}{\tau_2}\right) \right] \end{aligned} \tag{2}$$

2.2.3 Calculation method

In order to calculate the Zero-volatility credit spreads of a corporate bond on a particular day, we should know the price, maturity and the coupon rate of the bond, as well as the structure of yield curve of Treasury bond on that day. The data of price, maturity and coupon rate are provided by RESSET, and yield curve can be fitted as explained in Sect. 2.2.2.

For a particular corporate bond, with data of its price, maturity, coupon and the series of estimated parameters of NSS model, we can get the series of Zero-volatility credit spreads by using the fsolve function in Matlab7.6, to solve non-linear equation. But when using the fsolve function, the algorithm should be set as the "Levenberg-Marquard" algorithm, which can improve both the calculation speed and the accuracy.

Figure 1 shows the Zero-volatility credit spread series of Changdian bond for the period 4th January 2008 to 30th December 2011; frequency is weekly and the figures are for all the 52 weeks.

2.3 Calculate the series of risk factors

2.3.1 Systemic risk factors

(1) Bond market

We use the term structure adjusted yield of bond index as the systemic risk factor of the bond market, as Eq. (3) shows, which is selected by reference to Capital Asset Pricing Model (CAPM) of the stock:

$$ARB_{it} = \alpha_i + \beta_i AROBI_{it} + \varepsilon_{it} \tag{3}$$

where *ARB* is the term structure adjusted yield-to-maturity of corporate bond, i.e. the difference between the yield-to-maturity of the corporate bond and the appropriate risk-free

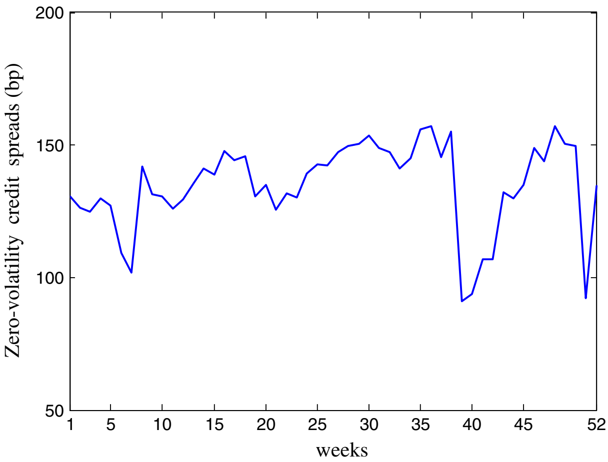

Fig. 1 Weekly credit spread series in 2008 of 07 Changdian bond

interest rate based on the duration of the bond. *AROBI* is the term structure adjusted yield-to-maturity of the bond index, which is the yield-to-maturity of the bond index minus the appropriate risk-free rate based on the duration.

The yield-to-maturity of bond should be adjusted by term structure because unlike stock yield, which is a spot yield, it is not affected by term structure whereas yield-to-maturity of bond is affected by term structure. If the duration of the bond and the bond index are different, term structure has different effects on the bond and the bond index and therefore the term structure effect should be deducted from the yield-to-maturity.

The sample bonds are corporate bonds traded on SSE, so the corresponding bond index is Hu maket index corporate bond (000022). Since data of yield-to-maturity and duration of this bond index are not available, we have to choose another bond. WIND provides data of the Zhongzhai-Fixed-rate Corporate Bond Index, which includes yield-to-maturity and duration, so we choose it as the reference bond index.

(2) Stock market

Stock market has correlation with bond market, especially in developed markets, so some relevant literature on credit spread, which related to systemic risk factors, often take the effect of the stock market into account. Elton et al. (2001) found that the Fama–French factors of stock market, i.e. market risk premium, SMB and HML, can explain some of the credit spreads. The Fama–French three-factor model is:

$$RS_{it} - rf_{it} = \alpha_i + \beta_i\,(RM_{it} - rf_{it}) + s_i SMB_t + h_i HML_t + \varepsilon_{it} \tag{4}$$

where RS is the stock yield of the listed company. $(RM - rf)$ is the market risk premium (labeled as Rmrf), usually represented as the yield of stock index minus the risk-free rate. SMB is the market value factor, which is the difference between the yield of a small-cap stock and that of a big-cap stock. HML is the ratio of book-to-market factor, which is the difference between the yield of a high book-to-market stock and that of a low book-to-market stock.

RESSET is a Database which provides daily statistical data of the three factors—(Rmrf, SMB and HML) for SSE, Shenzhen Stock Exchange and both the two stock exchanges. The issuing companies of the 46 corporate bonds in the sample are all listed on SSE, except one company, so we choose the data of SSE.

2.3.2 Idiosyncratic risk factors

With reference to the related extant research focusing on impact of risk factors on credit spread of corporate bond, we choose idiosyncratic stock volatility, bond volatility and bond VaR as the idiosyncratic risk factors that affect credit spreads.

(1) Idiosyncratic stock volatility

Since stock volatility is composed of the stock market volatility and idiosyncratic stock volatility, idiosyncratic stock volatility is stock volatility less the effect of systemic risk. Because of inadequate availability of data, we approximate it:

$$IEV_{it} = EV_{it} - \beta_i SZV_{it} \tag{5}$$

where IEV is idiosyncratic stock volatility, EV is stock volatility, β is Beta of stock and SZV is volatility of the Shanghai Composite Index (000001).

RESSET provides daily stock volatility (includes 20-days moving average volatility, 60-days moving average volatility, GARCH (1, 1) volatility and EWMA volatility) and yearly Beta before 2011. So we need to calculate daily stock volatility and Beta for 2011 and daily volatility of stock index from 2008 to 2011. To simplify the calculation, we choose GARCH (1, 1) volatility. Calculation of Beta is by regressing daily stock yield with daily yield of the Shanghai Composite Index. The calculated daily volatility should be annualized by multiplying the daily volatility by the square root of trading days in a year (240 days).

(2) Idiosyncratic bond volatility

In Eq. (3), β is the measure of systemic risk of the corporate bond. So the standard deviation of the residual in Eq. (3) is the idiosyncratic bond volatility (marked as IBV). To calculate the weekly idiosyncratic bond volatility, we regress the term structure adjusted yield-to-maturity on the last trading day of each of the past 13 weeks (including the base week) with its corresponding term structure adjusted yield-to-maturity of bond index and the residual is the idiosyncratic bond volatility. Since the data is large, we use Matlab7.6 to complete the regression. Since missing bond prices for some weeks can lead to inaccurate idiosyncratic bond volatility, the regression should be constrained. Similarly, the calculated idiosyncratic bond volatility should also be annualized as idiosyncratic stock volatility.

(3) Idiosyncratic bond VaR

Idiosyncratic bond VaR is the remaining part of bond VaR that is not caused by changes of bond index. Similarly, idiosyncratic bond VaR can be approximated as:

$$IVaR_{it} = VaR_{it} - \beta_i MVaR_{it} \tag{6}$$

where $IVaR$ is the idiosyncratic bond VaR, VaR is VaR of the bond, β is the Beta of the bond and $MVaR$ is VaR of the bond index (VaR of the Zhongzhai-Fixed-rate Corporate Bond Index).

Beta can be calculated using Eq. (3). Though there is no upper or lower limit in Chinese bond market, we eliminate the outliers to increase the R-square of the regression. This can be completed by SPSS.

We use the method proposed by [8] to calculate the VaR of the bond. For a particular week, first calculate the weekly percentage yield of the past 13 weeks (including the base week). Then, choose the minimal yield after adjusting for simple moving average to be VaR of the base week. The degree of confidence of the calculated VaR is 92.3 % (1-1/13).

2.4 Fixed-effect model

The main factors that influence credit spreads of the 46 sample corporate bonds during 4th January 2008 to 30th December 2011 are analyzed from the perspective of systemic and idiosyncratic risk (weekly data) and their contributions are calculated. In all, there are 205 weeks. The panel data comprises 46 sample bonds and 205 weeks. The difference between fixed effect model and random effect model is that whether its explanatory variables are random. In statistics, a fixed effects model is a statistical model whose explanatory variables are treated as if the variables were non-random. This is contrary to random effects models in which all of the explanatory variables are treated as if they arise from random causes. However, as the time span is relatively long, there is little difference between using fixed-effect model and random-effect model. What's more, we analyze the corporate bond market as a whole, so we choose to establish the fixed-effect model.

2.4.1 Systemic risk factors

Establish the following two fixed-effect models:

$$spread_{it} = \alpha_{it} + \beta_1 AROBI_{it} + \varepsilon_{it} \tag{7}$$

$$spread_{it} = \alpha_{it} + \beta_1 Rmrf_{it} + \beta_2 SMB_{it} + \beta_3 HML_{it} + \varepsilon_{it} \tag{8}$$

where, i represents the 46 sample bonds, t represents the 205 weeks. Equation (7) is the fixed-effect model for systemic risk factors of the bond market and Eq. (8) is the fixed-effect model for systemic risk factors of the stock market.

2.4.2 Idiosyncratic risk factors

Volatility of the Shanghai Composite Stock Index (marked as SZV) is compared with idiosyncratic volatility factors of corporate bonds and the following 4 fixed-effect models are formulated:

$$spread_{it} = \alpha_{it} + \beta_1 SZV_{it} + \beta_2 IEV_{it} + \varepsilon_{it} \tag{9}$$

$$spread_{it} = \alpha_{it} + \beta_1 SZV_{it} + \beta_2 IBV_{it} + \varepsilon_{it} \tag{10}$$

$$spread_{it} = \alpha_{it} + \beta_1 SZV_{it} + \beta_2 IEV_{it} + \beta_3 IBV_{it} + \varepsilon_{it} \tag{11}$$

$$spread_{it} = \alpha_{it} + \beta_1 SZV_{it} + \beta_2 IVaR_{it} + \varepsilon_{it} \tag{12}$$

where i represents the 46 sample bonds and t represents the 205 weeks.

After establishing the previous six fixed-effect models, we analyze whether there is a significant linear relationship between each risk factor and the credit spreads and then calculate its contribution to the size of the credit spreads. Contributions are calculated as coefficient times the range for a factor between its median and its minimum (or zero, whichever is greater). In addition, we should test whether the six fixed-effect models are better than random-effect model, whether serial correlation exists and whether heteroscedasticity exists.

Table 1 Statistical description of the bond

	Mean	Minimum	Maximum
Face value (million)	1,894	3	110
Coupon rate (%)	6.76	3.75	9
Maturity (years)	5.28	1	9.8
Duration (years)	4.42	0.9	8.1

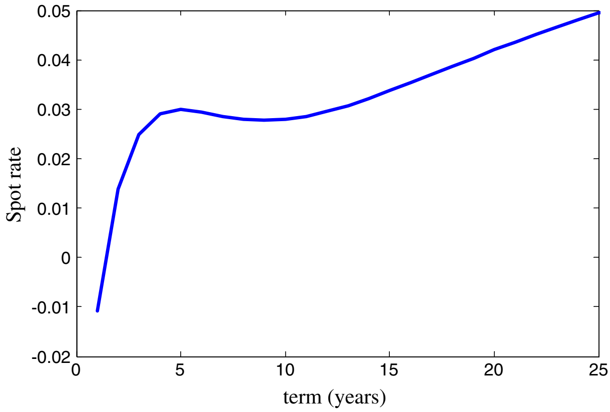

Fig. 2 SSE Treasury bond yield curve

3 Results and analysis

3.1 Statistical description of the panel

3.1.1 Description of sample

There are 2,157 effective bond-week observations in the panel (excluding bonds due to expire in <1 year, whose liquidity is low). This is an unbalanced panel. Table 1 shows the statistical description of the bond-week observations.

We can see from Table 1 that the average face value of the 2,157 observations is 1,894 million RMB, average maturity is 5.28 years and the average duration is 4.42 years.

3.1.2 Selection of yield curve

RESSET provides daily estimates of parameters of the NSS model, so we can fit the yield curve by using Matlab7.6. Comparison of the fitted yield curve of Treasury bonds traded in the SSE with that of the inter-bank market for Treasuries shows that the second is more reasonable. Figures 2 and 3 show the yield curve of SSE and inter-bank market, respectively.

In Fig. 2, short-term (<1 year) spot rate is obviously negative, which is quite different from the reality. What's more, the 7-year and 8-year spot rates have an obviously declining trend, while the structure of the yield curve in Fig. 3 is more reasonable. This is mainly because the types, trading volumes and liquidity of Treasury bonds in SSE are all inferior than in the inter-bank market. So we choose the yield curve of the inter-bank market to calculate the Zero-volatility credit spreads.

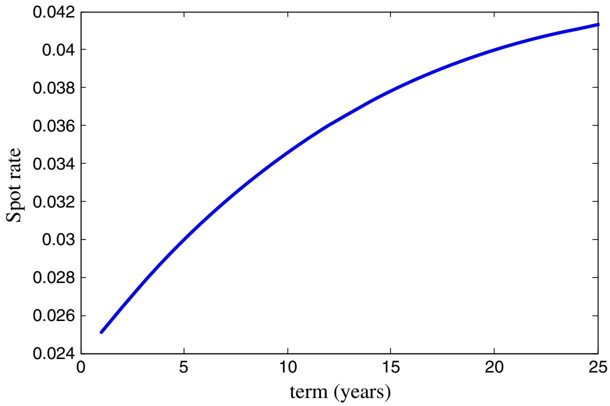

Fig. 3 Inter-bank market Treasury bond yield curve

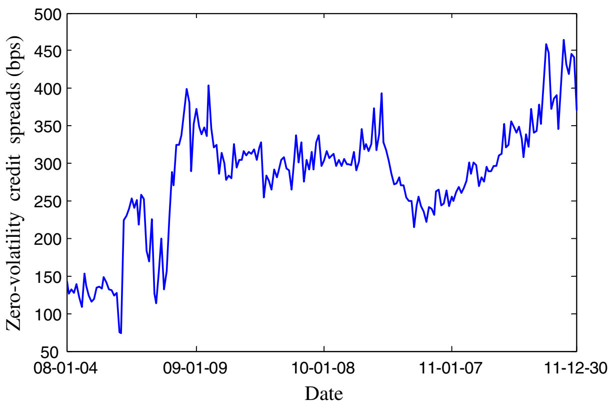

Fig. 4 Weekly trend of Zero-volatility credit spread series of 205 weeks

3.1.3 Credit spread of sample and statistical descriptions of its risk factors

Of the 2,157 bond-week credit spreads, the average is 310 bps, the minimum is 13 bps and the maximum is 117 bps. Figure 4 gives the weekly average credit spread of the sample corporate bonds: there are 205 weeks and the average is 281 bps, the minimum is 74 bps and the maximum is 464 bps.

For the 2,157 observations of each risk factor, Table 2 gives their statistical descriptions.

3.2 Systemic risk factors and the contribution

Table 3 shows the results of the two fixed-effect models of the systemic risk factors with confidence level of 95 % and contribution to the size of credit spreads.

In Table 3, N is the number of observations. Model (I), which corresponds to Eq. (7), is the regression of the credit spreads and the systemic risk factors of the bond market. We can see from Model (I) that AROBI has a significant positive relationship with credit spreads and its contribution to the average credit spread is 101 bps. The average credit spread is 310 bps, so AROBI explains 33 % of the spread. Model (II) corresponds to Eq. (8), which is the fixed-

Table 2 Statistic description of risk factors

Risk factors	Mean	Maximum	Minimum	Range
AROBI	0.0188	0.0081	0.0278	0.0107
Rmrf	0.0011	−0.0618	0.0992	0.0011
SMB	−0.0003	−0.0265	0.0139	−0.0003
HML	−0.0003	−0.0202	0.0177	−0.0003
SZV	24.31	16.39	51.74	7.92
IEV	15.12	0	73.59	15.12
IBV	3.35	0.35	20.5	3
IvaR	−0.00684	−0.14035	0.00627	−0.00684

Table 3 Regression results of systemic risk factors and the contribution

Model	Coefficient	t-Statistic	Coefficient	t-Statistic	Contribution (bps)	
	(I)		(II)		(I)	(II)
AROBI	9,443.8	15.53			101	
Rmrf			−105.5	−0.75		0
SMB			218.8	0.57		0
HML			506.5	2.78		0
N	2,157		2,157			
F-Statistic	61.93		60.27			
R-squared	0.1026		0.0049			

Table 4 Results of test of serial correlation and heteroscedasticity of Models (I) and (II)

Model	F statistics	Prob.	Chi-square statistics	Prob.
(I)	320.226	0	48,471.52	0
(II)	313.318	0	1,300,000	0

effect model for systemic risk factors of the stock market. In Model (II), both Rmrf and SMB have no significant relationship with credit spreads; HML has significant relationship with credit spreads but its contribution is nearly 0 bps. F-value is the statistic used to judge whether the fixed-effect model is more optimal than the mixed regression model. F-value of both models is zero, which means there is significant fixed effect in the panel and fixed-effect model is more optimal than mixed regression model.

Table 4 shows the results of test of serial correlation and heteroscedasticity of Models (I) and (II).

Table 4 shows that both the F statistic that test the serial correlation and the Chi-square statistic that test heteroscedasticity are zero, so there is no serial correlation or heteroscedasticity in the two models, which confirms the relatively short time period of the panel (4 years).

The two models imply that systemic risk factor of bond market has strong explanatory power for the size of credit spreads while systemic risk factors of stock market have weak explanatory power. Among them, term structure adjusted yield-to-maturity of bond index (AROBI) has significant relationship with credit spreads and can explain 33 % of the average credit spread. The three Fama–French factors, stock market-market risk premium (Rmrf),

Table 5 Regression results of idiosyncratic risk factors and the contributions

Model	Coefficient				t-Statistic				Contribution (bps)			
	(III)	(IV)	(V)	(VI)	(III)	(IV)	(V)	(VI)	(III)	(IV)	(V)	(VI)
SZV	1.27	0.24	0.39	1.01	3.7	0.73	1.17	3.02	10	2	3	8
IEV	−0.75		−0.53		−3.22		−2.34		−10		−8	
IBV		11.24	11.1			14.05	13.85			34	33	
IVaR				−1,525.3				−6.38				10
N	2,157	2,157	2,157	2,157								
F-statistic	59.86	52.31	52.37	61.16								
R-squared	0.0096	0.0899	0.0922	0.0236								

Table 6 Result of test of serial correlation and heteroscedasticity of Models (III)–(VI)

Model	F-statistics	Prob.	Chi-square statistics	Prob.
(III)	329.209	0	27,213.74	0
(IV)	333.196	0	30,386.37	0
(V)	334.479	0	28,951.02	0
(VI)	314.852	0	35,962.88	0

market value factor (SMB) and book-to-market ratio factor (HML) have almost no explanatory power. This conforms to Liu and Yang (2010) in that the three Fama–French factors have almost no explanatory power for the excess return of the Chinese bond market. This is mainly because the Chinese corporate bond market is still evolving and its correlation with stock market is relatively low.

3.3 Idiosyncratic risk factors and the contribution

Table 5 shows the regression results of the four fixed-effect models for idiosyncratic risk factors and the contributions.

In Table 5, Model (III) corresponds to Eq. (9), which is the regression between credit spreads and volatility of the Shanghai Composite Stock Index (SZV) and the idiosyncratic stock volatility (IEV). In Model (III), SZV and IEV both have significant relationships with credit spreads and their contribution to the average credit spread is 10 and −10 bps, respectively. Model (IV) corresponds to Eq. (10) and is the regression between credit spreads and SZV and idiosyncratic bond volatility (IBV). IBV has significant relationship with credit spreads and its contribution is 34 bps (11 %). Model (V) corresponds to Eq. (11) and the results of the regression are similar to Models (III)and(IV). Model VI corresponds to Eq. (12) and is the regression between credit spreads and SZV and idiosyncratic bond VaR. Model (VI) implies that IVaR has significant negative relationship with credit spreads and its contribution to the average credit spread is 10 bps (3 %). Similar to Models (I) and (II) all these four models' F statistic imply that there is a fixed effect in the panel and the fixed-effect model is more optimal than the mixed regression model.

Then the serial correlation and heteroscedasticity of the four models are tested. Table 6 shows the result of the test.

Table 6 shows that there is no serial correlation or heteroscedasticity in these four models.

In the four fixed-effect models, idiosyncratic stock volatility has a significant correlation with credit spreads and its contribution is 10 bps, which can be offset by the −10 bps contribution of the stock market volatility. This implies that stock volatility has almost no explanatory power for credit spreads. This is in tune with Zhen and Chen (2011) who indicated that the correlation between Chinese stock and bond market is low. One possible explanation of the significant negative relationship between idiosyncratic stock volatility and credit spreads is the high level of speculation in the Chinese stock market. The higher the idiosyncratic stock volatility is, the larger is the trading volume of the stock and this may lead to smaller trading volume of corporate bonds, thus resulting in lower prices of bonds.

Idiosyncratic bond volatility has significant positive relationship with credit spreads and its contribution to the average credit spread is 34 bps (11 %). There are two possible reasons. First, idiosyncratic bond volatility may reflect the credit quality of corporate bonds. High credit quality bonds have lower volatility and thus smaller credit spreads. In reality, most Chinese corporate bonds are AA or AAA, which can not reflect the difference in credit quality of corporate bonds. In addition, idiosyncratic bond volatility may reflect the liquidity risk premium of corporate bonds.

Idiosyncratic bond VaR is negatively related to credit spreads, that is, when VaR is smaller (more negative or larger loss), the credit spread is larger. This implies that the larger the market risk of the corporate bond is, the larger the credit spread will be, since investors will require higher premium for market risk. The contribution of idiosyncratic bond VaR is 10 bps (3 %). Idiosyncratic bond VaR reflects the market risk of the corporate bond; this is in consonance with Delianedis and Geske (2001) who show that credit spreads contain premium because of market risk.

4 Conclusions

By analyzing the six fixed-effect models we established from the perspective of systemic and idiosyncratic risk factors, we draw the following conclusions about the influencing factors of Chinese corporate bond market from 2008 to 2011.

Firstly, systemic risk factor of bond market-term structure adjusted yield-to-maturity of bond index (AROBI) is the decisive factor in determination of credit spreads of Chinese corporate bonds and its degree of contribution to average credit spread is 33 %.

Secondly, systemic risk factors of stock market-risk premium (Rmrf), Market value factor (SMB) and book-to-market ratio factor (HML) have almost no explanatory power, which indicates low correlation between Chinese stock and bond markets.

Thirdly, idiosyncratic bond volatility can explain 11 % of the average credit spread, since it reflects the credit quality of the corporate bond. Most Chinese corporate bonds are AAA and AA, so it implies that credit rating of Chinese corporate bonds should be improved to better reflect the credit quality.

Fourthly, idiosyncratic bond VaR can also explain 3 % of the average credit spread, which indicates that credit spreads of corporate bonds include the effect of market risk and it is coincident with extant research focusing on impact of risk factors on credit spread of corporate bond.

Lastly, we find an interesting result that is contrary to extant research. Idiosyncratic stock volatility has a significant negative correlation with credit spreads, which is mainly because of speculation in stocks.

In all, from 2008 to 2011, term structure adjusted yield-to-maturity of bond index (AROBI) and idiosyncratic bond volatility are the main systemic and idiosyncratic influencing factors of credit spreads of Chinese corporate bonds. Among them, systemic risk factor of bond-market-term-structure-adjusted yield-to-maturity of bond index (AROBI) is the determining factor.

Acknowledgments This research was supported by the program of the National Natural Science Foundation of China (Grant Nos. 71171176, and 71471161), the key program of the National Natural Science Foundation of China (Grant Nos. 71433001, and 71231005), the Program of Humanities and Social Sciences of Ministry of Education of China (Grant Nos. 11YJC790306, and 12YJC910011), the Fundamental Research Funds for the Central Universities in UIBE (No. 14YQ04).

References

Amato, J., & Remolona, E. (2005). The pricing of unexpected credit spreads, Working Paper, Bank for International Settlements.

Castellano, R., & D'Ecclesia, R. L. (2013). CDS volatility: The key signal of credit quality. *Annals of Operations Research*, *205*(1), 89–107.

Chen, S. W. (2008). Empirical analysis on Chinese corporation bond's credit spread. Doctoral Dissertation, Zhejiang University, China (in Chinese).

Delianedis, G., & Geske R. (2001). The components of corporate credit spreads: Default recovery, tax, jumps, liquidity and market factors. SSRN working paper. https://papers.ssrn.com/306479

Driessen, J. (2005). Is default event risk priced in corporate bonds? *Review of Financial Studies*, *18*(1), 165–195.

Elkhodiry, A., Paradi, J., & Seco, L. (2011). Using equity options to imply credit information. *Annals of Operations Research*, *185*(1), 45–73.

Elton, E., Gruber, M., Agrawal, D., & Mann, C. (2001). Explaining the rate spread on corporate bonds. *Journal of Finance*, *56*, 247–277.

Eom, Y., Helwege, J., & Huang, J. (2004). Structural models of corporate bond pricing: An empirical analysis. *Review of Financial Studies*, *17*, 499–504.

Gemmill, G., & Keswani, A. (2011). Downside risk and the size of credit spreads. *Journal of Banking & Finance*, *35*, 2021–2036.

Huang, J., & Huang, M. (2012). How much of the corporate-treasury yield spread is due to credit risk. *Review of Asset Pricing Studies*, *2*(2), 153–202.

Jones, E., Mason, S., & Rosenfield, E. (1984). Contingent claims analysis of corporate capital structures: An empirical investigation. *Journal of Finance*, *39*(3), 611–627.

Kiesel, R., Perraudin W., & Taylor A. (2001). The structure of credit risk: Spread volatility and ratings transitions, Bank of England.

Liu, G. M., & Yang, C. (2010). Application of Fama-French multi-factor model in China's bond market during recent financial crisis. *Journal of Zhejiang University (Science Edition)*, *37*(4), 396–400. (in Chinese).

Lonstaf, F., & Schwartz, E. (1995). A simple approach to valuing risky fixed and floating rate debt. *Journal of Finance*, *50*, 789–819.

Prokopczuk, M., Siewert, J. B., & Vonhoff, V. (2013). Credit risk in covered bonds. *Journal of Empirical Finance*, *21*, 102–120.

Ren, Z. Z., & Li, P. (2006). Impact of liquidity risk on the term structure of credit spreads. *Systems Engineering Theory Methodology Applications*, *15*, 251–255. (in Chinese).

Saunders, D., Xiouros, C., & Zenios, S. A. (2007). Credit risk optimization using factor model. *Annals of Operations Research*, *152*(1), 49–77.

Svensson, L. (1994). Estimating and interpreting forward interest rates: Sweden 1992–1994. NBER working paper. http://www.nber.org/papers/w4871

Tan, S. N. (2010). *The research of factors of credit spread of corporate bonds*. Tianjin: Tianjin University. (in Chinese).

Zhen, Z. L., & Chen, Z. Y. (2011). An analysis of the dynamic correlation of yields between China's stock market and bond market. *Contemporary Finance & Economics*, *2*, 45–53. (in Chinese).