Study on Fuzzy Evaluation of Credit Risk of Corporate Bond

Ouyang Jiazhong, Li Min
School of Business and Administration
Jiangxi University of Finance and Economics
Nanchang, 330013, China

JDIM
Journal of Digital Information Management

ABSTRACT: *The credit risk evaluation of corporate bond is one of the difficult and hot research fields in the related research and plays a key role for corporate financing. Based on the fuzzy theory and analytic hierarchy process, a new credit risk evaluation model of corporate bond is presented. First an evaluation indicator system of credit risk of corporate bond is designed through analyzing the characteristics of the evaluation indicator with more details; Second, analytic hierarchy process is used to determine the level of different indicators and multistage comprehensive fuzzy evaluation is used to evaluate the credit risk of corporate bond. Finally, corporate bond of 10 enterprises are taken for examples to evaluate the credit risk and verify the validity and feasibility of the model and the experimental results show that the model can evaluate the credit risk of different corporate bond of different enterprises practically.*

Categories and Subject Descriptors:
I.5 [PATTERN RECOGNITION] Fuzzy set; **K.4.4 Electronic Commerce**

General Terms: Fuzzy Models, Credit evalution, E-commerce

Keywords: Credit Risk Evaluation, Multistage Comprehensive Fuzzy Evaluation, Analytic Hierarchy Process, Evaluation Indicator System

Received: 12 November 2012, Revised 25 December 2012, Accepted 30 December 2012

1. Introduction

Corporate bond is an important means for corporate financing; credit risk is the main risk in corporate bond market. Corporate bond market is an integral part of financial market, the development of which not only broadens company's financing channels, optimizes corporate capital structure, meets diversified investment demands of investors, but also plays an important role in perfecting financial market structure, improving financial market efficiency and facilitating the coordinated development of capital market.But the corporate bond financing has been strictly limited in the developping country that and it has been proved by practice that the strict limitation on corporate bond financing fails to effectively prevent the risk of corporate bond; instead, greatly restrains the normal development of corporate bond market. Therefore, to propel the positive development of corporate bond, correctly and reasonably assessing credit risk of corporate bond is of crucial theoretical significance and practical value [1, 2, 3].

Modern commonly-used analytical methods of credit risk of corporate bond mainly include KMV model method, VaR method, and radial basis function method. (1) KMV model method, the basic concept of the method is that share price of listed company includes investors' anticipation on future profits of enterprise, with foresight, making use of share price to better capture the information of credit risk of enterprise. KMV model, through default distance, combines three core factors (company scale, operation risk and industry risk) for assessing credit risk and demonstrates with a simple formula. The key to realize this operation is that for listed enterprise, creditors holding company's debts is equal to selling a European put option marked by company's assets value; company's debts value is equal to the value of put option [1, 2]. (2) VaR method; VaR is short for "*Value At Risk*", i.e. "*at-risk value*", which means mostly probable losses of certain financial asset or convertible bond combination within certain period in the future under the normal fluctuation of market and given probability level (degree of confidence).

There are three most commonly-used model methods of VaR: parametric method, historical simulation method and montecarlo simulation method. See Literature (1) for details [3, 4]. (3) Radial basis function method is a non-network numerical calculation method with no need for space division, which obtains quasi radial interpolation basis function method through combining quasi interpolation method with radial basis function method. Through this combination, compared with finite difference and finite element methods, radial basis function method occupies a large advantage in calculation efficiency. So all the above methods evaluate the risk with hard judge and had lower evaluation accuracy [5, 6, 7].

Credit risk analysis of corporate bond is a multi-factor and multi-indicator complicated evaluation process, among which lots of indicators have dynamics, fuzziness, subjectivity and intermediate transitivity, resulting in a difficult application of transitional evaluation method. However, fuzzy evaluation is a method that accurately solves inaccurate and incomplete information, the greatest advantage of which is that the fuzziness and initiative of human thinking can be naturally processed by using it. Hence, this paper will design credit risk analysis system of corporate bond, evaluating the credit risk of corporate bond with multi-level fuzzy evaluation method, thus making enterprises convenient to carry out credit risk analysis.

2. Evaluation Index System Design for Credit Risk Analysis of Corporate Bond

Credit risk analysis of corporate bond is the combination of qualitative analysis and quantitative analysis, the unity of historical investigation and future prediction, the integration of individual rating and external support, mainly comprised of two aspects: credit analysis of bond issuing body and credit analysis of debt. The former is the analysis of the capacity for capital and interest repayment and repayment intention on the debts of the issued corporate bond of bond issuer, including the comprehensive analysis of enterprise quality, operation capacity, profitability, debt-paying ability, credit standing, development prospect and other factors. The latter is to carry out rating analysis on corporate bond issued by issuing body, i.e. aiming at the characteristics of corporate bond, for example: analysis on deal structure, term, guarantee or mortgage, reserved liquidity support, and etc. This thesis focuses on the credit analysis of bond issuing body; specific credit risk analysis includes financial risk, credit rating risk, policy factor risk, enterprise management risk, enterprise system and governance risk, and etc [7].

Through the above analyses, the risk evaluation indexes of corporate bond designed in this thesis mainly include such four first-rate indexes as financial risk, credit rating risk, economic cycle risk and enterprise management risk.

(1) Financial risk of corporate bond mainly pays attention to the future debt-paying ability of enterprise; relevant influencing factors include profitability of enterprise (OPR and PDR, i.e. operation profit ratio and asset net profit rate), debt-paying ability (CR and QR, i.e. capital flow ratio and capital quick ratio), funding liquidity (cash flow, total assets of enterprise at the end of period), enterprise operation ability (turnover rate of total assets at the end of period), cash quantity, debt structure and financial flexibility.

(2) Credit rating risk of corporate bond is to quantize default caused by credit risk and study on each factor influencing default rate of corporate bond and obtain final conclusion. Moreover, rating agency shall pay attention to details while carrying out the rating to avoid new risk. The specific evaluation on this is mainly to carry out evaluation on evaluating company. Here only evaluate as first-rate index.

(3) Economic cycle risk of corporate bond, macro economy directly influences the operating performance and profit status of enterprise, thus influencing the credit strength of enterprise and showing on the credit spread of corporate bond. In the phase of economic expansion, enterprise has a favorable operation status and profitability with sufficient cash flow and strong credit strength as well as narrow credit spread; in the phase of economic recession, the contrary is the case. The evaluation indexes on this mainly include inflation, economic growth rate and capital market fluctuation.

(4) Enterprise management risk of corporate bond, credit risk analysis starts from the evaluation of enterprise operation and competition; enterprise management condition analysis is the important content for credit rating. Evaluation indexes on this mainly include enterprise operation and competition (enterprise's competitive advantage, product price, product quality, supply chain, sales channel, product image, product characteristic, before-sale and after-sale service, and etc.), enterprise management strategy (enterprise strategy, risk preference, financing policy, corporate governance, and etc.)

3. Establishment of Multi-hierarchy Fuzzy Evaluation Model

3.1 Steps of Fuzzy Overall Evaluation Method

Fuzzy overall evaluation in this paper is conducted according to the following five steps [6-9].

3.1.1 Establish Evaluation Element Set

Evaluation element set is an ordinary set constituted by all the elements influencing evaluation object; suppose there are n evaluation indicator elements expressed by $u1$, $u2$, $u3$,..., irrespectively, then the set constituted by these n evaluation elements is called evaluation element set, i.e. $U=\{u1, u2, u3,..., un\}$ [8, 9].

3.1.2 Confirm Evaluation Set

Evaluation set is also called judgment set, which is comprised of all the evaluation results of evaluator on evaluation object, is an ordinary set formed by all the possible evaluation results of evaluators on evaluation object. Evaluation results can be divided into m hierarchies according to actual demand of specific cases, which can

be expressed by $v1$, $v2$, $v3$,...,vm respectively, then evaluation set can be constituted as $V = \{v1, v2, v3, ..., vm\}$.

3.1.3 Confirm the weight of evaluation indicator

The reasonable confirmation of indicator weight embodies the different weight relations among all the evaluation indicators in the system, increases the comparability among all the evaluation indicators and the effectiveness of evaluation result. AHP is objective with such merits as practicability, conciseness and systematicness. Thus, this paper adopts AHP to confirm the weights of all the evaluation indicators, obtaining the weight wi of each evaluation indicator ui. The set constituted by each weight wi is called weight set W, as shown in formula 1.

$$W = \{w1, w2, w3, ..., wn\} \sum_{i=1}^{n} w_i = 1 \quad w_i \geq 0 \qquad (1)$$

There are generally the following steps to confirm indicator weight by AHP:

The specific steps to calculate indicator weight by adopting AHP are as follows.

①Construct Judgment Matrix

After building hierarchical structure, the subordination between elements in upper and lower hierarchies is confirmed. Suppose that taking top element U as criterion, the next hierarchical element dominated by it is $u1$, $u2$, $u3$,...,um; corresponding weights $w1$, $w2$, $w3$,...,wn of their relative importance towards U will be obtained through pairwise inter-comparison. Assign the value to indicators' relative importance based on scale table, n compared elements in the lower hierarchy consist of a pairwise inter-comparison judgment matrix $A = (aij)$.

②Calculate the Weights of All the Indicators

This paper adopts root method to calculate weight; steps are as follows steps. First, calculate the product of each line in comparison matrix; *Second*, extract nth root of products obtained in step a;Third, Total all the products obtained in step b; *Finally*, weight wi is obtained through dividing values obtained in step b by values in step c.

③Consistency Check of Judgment Matrix

While building judgment matrix, due to complexity of objective things, there are always errors in judgment matrix. Generally, there may be no complete consistency in judgment matrix, so consistency check of judgment matrix is required. Quantitative indicator used for measuring judgment matrix is called consistency indicator CI, as shown in formula 2.

$$CI = (\lambda\max - n) / n - 1 \qquad (2)$$

In formula 2 [8], $\lambda\max$ is the maximum eigenvalue of judgment matrix, n is the number of comparison indicator. $\lambda\max$ is calculated as follows: respectively multiply elements in each line of judgment matrix by vector component of weight W, then add, obtaining Awi; divide Awi respectively by wi, obtaining value Awi / wi. $\lambda\max$ is the average value of Awi / wi.

In order to confirm the allowed range of inconsistency degree, the corresponding average random consistency indicator RI of n can be looked for the following table.

Order	1	2	3	4	5
RI	0	0	0.58	0.90	1.12

Table 2. Average Random Consistency Indicator

At last, judge whether the matrix is consistent through consistency ratio CR, $CR = CI / RI$. If $CR < 0.1$, the consistency of judgment matrix is acceptable. Whereas, if $CR \geq 0.1$, the consistency of judgment matrix is unacceptable; judgment matrix should be properly amended to keep the consistency of judgment matrix to certain extent.

3.1.4 Single-factor Fuzzy Evaluation

Suppose that evaluation object carries out evaluation according to the ith factor in factor set $U ui$ (i =1, 2, 3, …, n), the subordination of which as to the jth factor in evaluation set $V vj$ (j =1, 2, 3, …, m) is expressed as rij, formula 3 can be used to show the evaluation result of the ith factor ui.

$$R_i = \{ri1, ri2, ri3, ... rim\} \qquad (3)$$

Ri in formula 3 is single-factor evaluation set, so formula 4 can be obtained, i.e. single-factor evaluation set of each factor.

$$R = \begin{bmatrix} R_1 \\ R_2 \\ \vdots \\ R_n \end{bmatrix} = \begin{bmatrix} r_{11} & r_{12} & .... & r_{1m} \\ r_{21} & r_{22} & .... & r_{2m} \\ \vdots & \vdots & \vdots & \vdots \\ r_{n1} & r_{n2} & .... & r_{nm} \end{bmatrix} \qquad (4)$$

R in formula 4 is called single-factor evaluation matrix. R_{ij} can be obtained through experts grading method, subordination function method or other managerial mathematical methods.

3.1.5 Build Evaluation Model to Carry out Fuzzy Overall Evaluation

In consideration of difference importance of each factor, i.e. different indicator weights, it is necessary to combine the weight set W and R of all the evaluation indicators, to carry out overall evaluation, building overall evaluation model formula 5

$$B = W \circ R \circ \begin{bmatrix} r_{11} & r_{12} & .... & r_{1m} \\ r_{21} & r_{22} & .... & r_{2m} \\ \vdots & \vdots & \vdots & \vdots \\ r_{n1} & r_{n2} & .... & r_{nm} \end{bmatrix} = (b_1, b_2, ... b_m) \qquad (5)$$

In formula 5, B is the result set of fuzzy overall evaluation, b_j (j = 1, 2, 3, …, m) is called fuzzy overall evaluation indicator, which judges the indicator subordination of the jth evaluation element in evaluation set while comprehensively considering the impact of all the indicators on evaluation object.

In the above evaluation process, symbol "o" is fuzzy

synthetic operator, also called fuzzy operator, generally having the following four forms:

Model 1 $M(\wedge, \vee)$ —— Major Factor Determining Type, see formula 6

$$b_j = \bigvee_{i=1}^{n} (w_i \wedge r_{ij}) \quad (j = 1, 2, 3, \ldots, m) \qquad (6)$$

"$\vee$" in formula 6 represents large-taking symbol, "$\wedge$" represents small-taking symbol, the model features the focus on major factors, and that other factors have little impact on results. This operation sometimes makes decision result not easy to be distinguished.

Model 2 $M(.\,, \vee)$ —— Major Factor Highlighting Type, see formula 7.

$$b_j = \bigvee_{i=1}^{n} (w_i \,.\, r_{ij}) \quad (j = 1, 2, 3, \ldots, m) \qquad (7)$$

"." in formula 7 represents multiplication, the model first multiply species of attribute by single factor subordination, then get a greater one, the feature of which is to highlight major factor and ignore the role of secondary factor.

Model 3 $M(\wedge, \oplus)$ —— Major Factor Highlighting Type 8.

$$b_j = \otimes \sum_{i=1}^{n} (w_i \wedge r_{ij}) \quad (j = 1, 2, 3, \ldots, m) \qquad (8)$$

"$\oplus$" in formula 8 is bounded sum, i.e. $a \oplus b = \min(1, a + b)$, $\oplus \sum_{1}^{n}$ is to get a sum of n under the operation of $\oplus$, i.e. $b_j = \min\left[1, \sum_{i=1}^{n} (w_i \wedge r_{ij})\right]$,

Model 4 $M(.\,, +)$ —— Weighted Average Type, see formula 9

$$b_j = \otimes \sum_{i=1}^{n} (w_i \,.\, r_{ij}) \quad (j = 1, 2, 3, \ldots, m) \qquad (9)$$

The model first multiplies *wi* by *Rij*, then do the sum operation. The model, according to the weight of indicator factor, evenly gives consideration to all the indicator factors, especially applicable to the situation when multiple factors jointly work. Therefore, the competitiveness evaluation of commercial banks in this paper adopts that model for calculation.

3.2 Confirmation of Subordination Degree

Subordination degree concept is the basic concept of fuzzy mathematics. The key to applying fuzzy mathematics lies in building realistic subordinate function. There are a lot of methods to confirm subordinate function, and this paper adopts fuzzy statistical method to confirm the subordinate function of qualitative indicator. In fuzzy statistical method, carry out fuzzy statistics experiment to confirm the subordination degree of certain element. Divide element into several value grades, like such five grades as "*Excellent*, *Good*, *Medium*, *Poor*, *Worst*", then judge through investigation, carry out frequency count on the basis of investigation judgment and obtain the "*degree subordinating to certain hierarchy*" of the indicator, which is subordination degree.

4. Empirical Study on Risk Evaluation of Corporate Bond

4.1 Sample Data

Study data come from Xenophon China Center for Economic Research (CCER), China Bond Information Website, Securities Market Software of China Merchants Bank and database of Stock Star website, including corporate bond's date of issue, date of expiry, holding period, coupon interest, interest payment frequency, intermediate offer and initial rating of guarantor bank on bond issuing enterprise. In order to reduce measuring error and influence of price fluctuation, we take monthly data as the basic data for study so as to make price fluctuation relatively stable. Raw data include part of bonds issued during September 1985 to December 2010, taking as sample, for convenience's sake, this thesis selects 10 companies as final samples. As to the initial credit level of the 10 companies, the thesis is subject to the credit decision of guarantor bank upon bon issuance. All of 10 companies are AAA level. As to the transfer of company's credit level, we are subject to the credit rating standard of Moody Company.

Code	Date of Issue	Date of Expiry	Period	Rating Result
110606	2006-5-19	2013-5-19	7	A
111024	2004-9-15	2014-9-15	10	AA
111027	2003-10-28	2013-10-28	10	AAA
111030	2005-12-19	2015-12-19	10	AA
111032	2006-7-31	2021-7-31	15	C
120602	2006-3-28	2026-3-28	20	B
120609	2006-9-11	2021-9-11	15	A
120506	2005-12-19	2020-12-19	15	AA
122001	2007-11-9	2017-11-9	10	A
120523	2005-6-10	2015-6-10	10	B

Table 1. The credit risk evaluation results of corporate bond of 10 enterprises

Target Hierarchy	First-grade Indicator	Second-grade Indicator	Third-grade Indicator	Rating Result
Credit Risk Evaluation of Corporate Bond	Financial risk	Profitability of Enterprise	Operation Profit Ratio	A
			Asset Net Profit Ratio	AAA
		Debt-paying ability	Capital flow Ratio	AA
			Capital Quick Ratio	AA
		Funding Liquidity	Cash Flow	AAA
			Total Assets of Enterprise at the End of Period	AA
		Enterprise Operation Ability	Turnover Rate of Total Assets at the End of Period	AA
		Other Financial Risks	Financial risk	A
			Debt Structure	B
			Financial Flexibility.	AA
	Economic cycle risk	Inflation	Inflation	A
		Economic Growth Rate	Economic Growth Rate	AA
		Capital Market Fluctuation.	Capital Market Fluctuation.	A

Table 2. Part of the evaluation results of bond 120506

4.2 Empirical Results and Analysis

The credit risk evaluation results of corporate bond of 10 enterprises are shown in table 1. Taking bond 120506 (Datang bond) enterprise for an example, the specific evaluation indexes are listed in table 2 and only some of evauation results are given because limited page of the paper.

5. Study Conclusion

It can be imagined that once the corporate bond realizes actual marketization, the real credit risk will be definitely shown. This paper, on the basis of the analysis of modern analytical methods, analyzes and builds credit risk evaluation system of corporate bond, makes use of multi-hierarchy fuzzy evaluation method to establish credit risk evaluation model of corporate bond, also carries out case study taking the data of ten enterprises for example, accordingly analyzing the credit risk of corporate bond, meanwhile, the multi-hierarchy fuzzy evaluation method built in this paper can be reference for the analysis and evaluation of other multi-factor systems.

References

[1] Liu, Y. F. (2006). An Empirical Analysis on the Basis of VaR Methodfor the Risk of the Opened Fund. *Journal of East China University of Scienceand Technology*, 23 (2) 34-39.

[2] Sun, Q. (2010). Estimation and Management on the Market Risk of Corporate Bond in China. *Journal of Shijiazhuang University of Economics*, 28 (3) 293-297.

[3] Das, S. R. (2011). Credit Risk Derivatives, *Journal of Derivative*, 23 (2) 196-204.

[4] Cornell, B., Gree, K. (2010). The Investment Performance of Low Grade Bonds Fund. *Journal of Finance*, 26 (7) 38-46.

[5] Durand, T. (2009). Strategizing for Innovation: Competence Analysis in Assessing Strategic Change. *Competence-based Strategic Management*, 19 (8) 127-150.

[6] Meyer, Y. (2010). The Product Family and the Dynamics of Core Capability. *The Sloan Management Review*, 17 (3) 29-47.

[7] Kusuoka, S.(2009). A Remark on Default Risk Model, *Advances in Mathematical Economics*, 21 (1) 69-82.

[8] Worel, F. E.(2010). The Global Competitiveness Report. *Journal of Banking & Finance*, 31 (9) 61-83.

[9] Ya, Y. S., Janst S. H. (2008). Fuzzy quality attributes for evaluating Internet marketing system performance. *Total Quality Management*, 10 (12) 931-936.

Author Biographies

Ouyang Jiazhong, is basically an economist, received Bachelor deegree in electromechanical application from Nanchang University in 1996, and MS deegree in Industry economics from Nanchang University in 2003, Now he is working for Ph. D in enterprise management and his interested research field is financial enterprise management.

Li Min, is an associate professor, received Bachelor degree in Chinese Culture from Jiangxi Education University in 1996, received MS deegree in Chinese Culture from Nanchang University in 2004, PhD in enterprise management from Jiangxi University of Finance and Economics in 2010. His interested research field is human resources management and organizational behavior management.