Macro Risk Measurement Model of Commercial Bank Project Based on Multivariate Copula Function

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Abstract: It is of great significance to measure the project risk of commercial bank investment while the bank is unable to obtain the full information of the project. The macro risk of project is shown through 3 risk factors, namely, government risk, industry risk, and policy risk. A measurement model of project macro risk based on the insufficient information is built in this paper. The innovation and feature of this paper come in two ways. First, the function relationship among the project risk factors is determined through Multivariate Copula Function. The large sample data of project risk factors are generated through Monte Carlo Simulation. Thus, the large sample data of risk factors can be obtained, which makes up for the deficiency of inaccurate weight of small sample. Second, the weight of each risk factor is determined through the mean square error method. Therefore, the macro risk of project can be measured.

Key words: Project macro risk, risk measurement, multivariate copula function, mean square error.

1. Introduction

As the risk measurement of commercial bank project is an important part of risk management in banking, it is urgent to carry out studies on the measurement of project macro risk, especially when the commercial bank is unable to obtain the specific information of project.

Current situation of the risk measurement of commercial bank project has the following two aspects.

1) Qualitative research on project risk. One of the most representative researches, conducted by Robert and Tiong [1], proposed that the risk of project would be affected by the support the bank got from government. Stand & Poor's [2] discussed the main risk factors which would impact the risk of project in report. Deng Chao [3] established an evaluation index system of credit risk.
2) Quantitative research on project risk. Gatti [4] calculated the credit default risk of project through the value at risk. Bu-Qammaz *et al*. [5] built a risk assessment model on the basis of Analytic Network Process. Shan Xiaoli and Dai Dashuang [6] established a project financing model through the use of statistical techniques. Ulucan and Atıcı [7] studied the efficiency of the social risk of World Bank project through Data Envelopment Analysis.

Limitations to the previous researches: the previous studies can only be used to measure the project risk on the basis of the full financial information of project. In other words, the researches on the measurement of project risk are quite limited while the commercial bank is unable to get the full information of project.

In order to solve the above mentioned problem, this paper firstly uses three risk factors to reflect the project macro risk. Secondly, this paper applies multivariate Copula Function to get the large sample data of risk factors. Finally, the macro risk of project is measured by weighted model of risk factors.

This paper consists of six sections including introduction, measurement principle of project risk, analysis and grading of risk factors, sample augment via multivariate copula function, measurement model of project macro risk, establishment of project macro risk measurement model.

2. Measurement Principle of Project Risk

2.1. Research Questions

According to the sources of project risk, project risk can be classified into two types, namely project macro risk and project micro risk. In this paper, the project macro risk refers to government risk, industry risk, and policy risk. Whereas, the project micro risk refers to investment risk and the credit risk.

It is urgent to carry out studies on how to measure project macro risk through observable macro risk indices of project while the commercial bank is unable to get the full information of project.

2.2. Problems in the Measurement of Project Risk

1) Problem One: generate large sample according to the limited small sample of risk factors.
2) Problem Two: determine the quantitative relation among the 3 risk factors which show the macro risk of project, i.e., wi (i=1,2,3).

2.3. Solution to the Problems

1) Solution to Problem One

The macro risk of project can be shown through the Government Risk R1, Industry Risk R_2, and Policy Risk R_3. The function relationship among the risk factors is determined through multivariate Copula Function.

2) Solution to Problem Two

According to the 3 macro risk factors of project, the Project Macro Risk Rp can be expressed as:

$$R_p = f(R_1, R_2, R_3) \tag{1}$$

3. Analysis and Grading of Risk Factors

3.1. Analysis of Risk Factors

1) Government Risk R_1. The Government Risk R1 shows the macro risk of project with much support from government [1], [2].
2) Industry Risk R_2. The Industry Risk R_2 shows the macro risk of project with different industry prosperity indices [1], [2].
3) Policy Risk R_3. Policy Risk R_3 shows the macro risk of project with different policies[1-2].

3.2. Grading of Risk Factors

1) Standard Formula

The standard formula [8] of positive index is:

$$R = \frac{r_i - \min(r_i)}{\max(r_i) - \min(r_i)} \times 0.5 + 1 \tag{2}$$

The standard formula [8] of negative index is:

$$R = \frac{\max(r_i) - r_i}{\max(r_i) - \min(r_i)} \times 0.5 + 1 \quad (3)$$

It should be pointed out that, in order to make sure that the mean-square-error weighting method will work when the index is 0, the normalized interval of index in this paper is [1, 1.5].

2) Grading of Government Risk

The project types are listed in the 1st column of Table 1 and the support the bank gets is listed in the 2nd column of Table 1. The values of Government Risk R_1 obtained by expert scoring method are listed in the 3rd column of Table 1.

Table 1. Government Risk R_1

Serial number	(1) Project type	(2) Support	(3) R_1
1	National key project	Greatest	1.0
…	…	…	…
5	Other projects	Smaller	1.5

3) Grading of Industry Risk R_2

The industry prosperity index adopted in this paper is substituted by the business climate index released by the National Bureau of Statistics of China each quarter (http://www.stats.gov.cn/.2003-2014). The Industry Risk R_2 is measured through the predicated value of time series of business climate index due to the delay in the releasing of business climate index.

Let x_M be the maximum of the time series of the prosperity index of a certain industry, x_A be the mean value, and x_m be the minimum. According to PERT Decision-making Method, the Predicted Value P of the industry prosperity index is [8]:

$$P = (x_M + x_A + x_m)/6 \quad (4)$$

The Predicted Value P of industry prosperity index is worked out by Formula (4) and is listed in the 1st row of Table 2. The Industry Risk R2 listed in the 3rd column of Table 2 is obtained by Formula (3).

Table 2. Industry Risk R_2

Serial number	(1) Industrial classification	(2)P	(3)R_2
1	All industries	129.73	1.236
…	…	…	…
9	Lodging and catering industry	104.64	1.500

4) Grading of Policy Risk R_3

The industry categories are listed in the 1st column of Table 3. The values of the policy risk obtained through the expert scoring method are given in the 2nd column of Table 3.

Table 3. Policy Risk R_3

Serial number	(1) Industry categories	(2) R_3
1	Category One: restrict or eliminate	1.5
2	Category Two: support	1.0
3	Category Three: other industries	1.2

4. Sample Augment via Multivariate Copula Function

4.1. Fitting of Marginal Distribution

Let u_k be the marginal distribution function sequence of Risk Rk(k=1,2,3). Then the calculation formulae of u_k are [9]:

$$u_k(i)=\frac{1}{n}\sum_{j=1}^{n}\Phi\left(\frac{R_{ki}-R_{kj}}{h_k}\right) \tag{5}$$

where n is the sample size, $\Phi(\cdot)$ is the standard normal distribution function, R_{ki} is the values of Sample i of risk R_k, and h_k is smoothing parameters.

The calculation formulae of Smoothing Parameters h_k is [9]:

$$h_k=1.06n^{-0.2}\sqrt{\frac{1}{n-1}\sum_{i=1}^{n}\left(R_{ki}-\overline{R_k}\right)^2} \tag{6}$$

4.2. Multivariate Copula Function Fitting

In order to fit the multivariate joint distribution of risk factors, the multivariate normal Copula Function is used in this paper. The expression of multivariate normal Copula Function is [9]:

$$c=\int_{-\infty}^{\Phi^{-1}(u_1)}\int_{-\infty}^{\Phi^{-1}(u_2)}\int_{-\infty}^{\Phi^{-1}(u_3)}\left|\rho\right|^{-\frac{1}{2}}\exp\left(-\frac{1}{2}\zeta'\left(\rho^{-1}-I\right)\zeta\right)du_1du_2du_3 \tag{7}$$

where ρ is the correlation coefficient matrix of u_1, u_2 and u_3, ζ is the column vector, and I is unit matrix.

4.3. Monte Carlo Simulation

In order to get the large sample date of risk factors, Monte Carlo Simulation is performed by the Copula Function (7). The random sequence of multivariate normal Copula Function is generated through Monte Carlo Simulation and then the large sample data can be obtained.

5. Measurement Model of Project Macro Risk Rp

1) Calculation Formula of Project Macro Risk Rp

The project macro risk is measured through the linear combination of the 3 risk factors. The Project Macro Risk R_p is:

$$R_p=w_1R_1+w_2R_2+w_3R_3 \tag{8}$$

2) Calculation of Weight Coefficients w_1, w_2 and w_3

Let s_k be the sample standard deviation of risk factor k, then w_k (k=1,2,3) is:

$$w_k=s_k\Big/\sum_{k=1}^{3}s_k \tag{9}$$

In Formula (9), the standard weight coefficient of risk factors is obtained through the mean-square-error objective weighting method.

6. Establishment of Project Macro Risk Measurement Model

Since the measurement model of project macro risk is not established, the aim of this section is not an application example, but establishment of project macro risk measurement model.

If we only use the samples collected from such media to measure weight values, weight values will be unstable and inaccurate as change of the sample. To avoid the drawback of small samples, this paper uses multivariate copula function to get a large sample and applies this large sample to measure weight values.

Stability test of weight values shows that when the sample is greater than the number 962, the weight value is stable [10]. Due to the fact that the sample number of this paper is 10,000, the weight value is stable.

6.1. Project Data

In order to reveal the fixed importance of three risk factors, this paper firstly uses project data in Table 4 to measure functional relationship of risk factors. Then this paper uses a large sample obtained from multivariate copula function to measure the fixed importance of three risk factors. The fixed importance shows that no matter sample numbers and sample fluctuations, the important degree of three risk factors is stable.

The 72 loan projects between 2006 and 2014 are listed in the 1st, 2nd, and 3rd columns of Table 4. All the information of these loan projects comes from such media as People's network (http:// www.people.com.cn) and NetEase (http:// www. money.163.com).

According to the information in the 1^{st}, 2^{nd}, and 3^{rd} of Table 4, the values of Government Risk R_1, Industry Risk R_2, and Policy Risk R_3 obtained through Tables 1, 2 and 3 are listed in the 4^{th}, 5^{th}, and 6^{th} columns of Table 4.

Table 4. The Data of Project and Risk Factor

Serial number	(1) Project name	(2) Project type	(3) Industry	(4) R_1	(5) R_2	(6) R_3	(7) u_1	(8) u_2	(9) u_3
1	Huangpu-River-crossing construction project	Provincial key project	Communication and transportation	1.1	1.439	1.2	0.166	0.778	0.491
…	…	…	…	…	…	…	…	…	…
72	Wujiang East Taihu Lake construction project	Key project of county	All industries	1.3	1.427	1.0	0.486	0.183	0.211

6.2. Sample Augmented through Copula Function

1) Fitting of Marginal Distribution

Parameter h_1=0.176, h_2=0.025, h_3=0.137 are obtained by Formula (6) and marginal fitted value u_1, u_2, u_3 are filled in the 7^{th}-9^{th} column of Table 4 by Formula (5).

2) Monte Carlo Simulation

By Formula (7), the data of the 10,000 samples of the 3 risk factors obtained through the Monte Carlo Simulation are listed in the 1^{st}- $10{,}000^{th}$ rows of Table 5.

6.3. Measurement Model of Project Macro Risk Rp

1) Calculation of the Weight w_k of risk factor

The sample standard deviations s_k of the risk factors from Project 1 to Project 10,000 in Table 5 are listed in the $10{,}001^{st}$ row of Table 5. The Weight w_1, w_2 and w_3 of the risk factors is obtained by Formula (9). The results are filled in the $10{,}002^{nd}$ row of Table 5.

Table 5. Large Sample Data and the Weight of Risk Factor

Serial number	(1)Project name	(2)Government Risk R_1	(3)Industry Risk R_2	(4)Policy Risk R_3
1	Project 1	1.500	1.486	1.000
…	…	…	…	…
10 000	Project 10 000	1.500	1.438	1.200
10 001	Standard deviation s_k	0.176	0.069	0.137
10 002	Weight w_k	0.461	0.180	0.359

2) Macro Risk Measurement Model of Project

The Project Macro Risk R_p can be obtained by formula (8). Model of R_p is:

$$R_p = 0.461 \times R_1 + 0.180 \times R_2 + 0.359 \times R_3 \tag{10}$$

7. Conclusion

According to the weight of risk factors calculated through large sample, the importance of the 3 risk factors from high to low is: Government Risk R_1(w_1=0.461), Policy Risk R_3 (w_3=0.359), and Industry Risk R_2 (w_2=0.180).

First, the function relationship among risk factors is determined through Multivariate Copula Function. The large sample data of risk factors are generated through Monte Carlo Simulation. Second, the weight of each risk factor is determined through the mean square error method. So, the macro risk of project can be measured.

The future research trend is to construct a rating model of project macro risk for commercial bank.

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