2011 International Conference on Computer Science and Information Technology (ICCSIT 2011)
IPCSIT vol. 51 (2012) © (2012) IACSIT Press, Singapore
DOI: 10.7763/IPCSIT.2012.V51.89

Establishment of Risk Evaluation Model by Analytic Hierarchy Process and Fuzzy Logic Theory

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Abstract. Financial Institutions are one of the keys for a nation's economy, while the operation statues of commercial banks bring the prompt action on the financial stability. So, it is vital to construct an effective risk evaluation system which can monitor the risks timely for commercial banks. Up to now, a great number of statistical methods have been applied to appraise the bank risks, and among these studies, Analytic Hierarchy Process and Fuzzy Logic Theory were very popular in different fields and many fruits were obtained in this aspect. In this paper, we try to establish a risk evaluation model by combining Analytic Hierarchy Process with Fuzzy Logic Theory. First of all, we propose some indexes to response the risks in the macro economy, estate and stock markets, and bank itself. Then, the individual weight for each index will be worked out by Analytic Hierarchy Process Theory. Lastly, Fuzzy Logic Theory is used to appraise the bank risks. Fixing with the above works, we construct a Risk Evaluation Model for commercial banks.

Keywords: bank risks evaluation; weights; index system; Analytic Hierarchy Process; Fuzzy Logic Theory

1. Introduction

Financial institution plays a major role in today's economy, and it has been significant to establish an effective risk evaluation model which can efficiently monitor the risks of commercial banks. Analytic Hierarchy Process is a decision-making principle of multiple standards proposed by Thomas L. Saaty （1971）, which was mainly applied to the uncertain situation with multiple evaluation standards.[1] Fuzzy Logic Theory was published at first by Lotfi Zadeh, an expert at control-theory, in 1965. Using this theory, we can research and deal with the "fuzzy" phenomena by mathematical methods. Analytic Hierarchy Process is an effective tool of making decision in the complicated systems with some obvious advantages including practicability, systematization and concision. However, it ignored the subjective judgment and people's favoritism affected on the decision results. Comparatively, Fuzzy Logic Theory could overcome these shortages and make evaluation results more objective. At present, many scholars combine two methods, and apply them in the diverse research fields. [2- 4] Thus, this paper comes up with a new risk evaluation model applying Analytic Hierarchy Process and Fuzzy Logic Theory (FUZZY-AHP method). About 40 monitor indexes are chosen when we finished analyzing the factors which induce the risks of commercial banks. And then, we present an individual weight for each index by Analytic Hierarchy Process Theory. Finally, the Fuzzy Logic Theory is used to evaluate synthetically the bank risks. Based on these works, a Risk Evaluation Model of commercial banks is finally constructed.

2. Establishment Of The Risk Evaluation Model By Fuzzy-Ahp Methods

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Financial institution plays a major role in today's economy, and it has been significant to establish an effective risk evaluation model which can efficiently monitor the risks of commercial banks. Analytic

2.1. Design the index system

There are various factors leading to the risks in bank operation. Based on the origin and exposure manner of risks, at least three levels of indexes need to be selected which include monitoring macroscopic economy, the real estate and stock markets and the bank itself. These indexes should be objective, relevant, and predictable. We analyze the relationship of various factors and establish the indexes of the hierarchy structure.

- Apex: a monitor index system of bank risks
- Sub-objectives: macroscopic risks; intermediate market risks; microscopic risks;
- Factors: The macro economy may be affected by the overall economy conditions, fiscal and financial conditions, monetary policies, international balance of payments. The factors of intermediate level risks should include the situations of stock and real estate markets, and we may reflect the micro risks from the operation conditions of bank itself.
- Monitor indexes: After analyzing the factors which affect on the three levels risks, we choose some indexes to measure the risks of banks by the domestic and foreign data combining with some of our existed state index systems.

2.2. Present an individual weight for each index by Analytic Hierarchy Process Theory.

2.2.1 Comparing the same hierarchy of the elements in pairs according to the importance in some criteria, construct the comparative judged Matrix.

$$A=[a_{ij}]=\begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ 1/a_{12} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ 1/a_{1n} & 1/a_{2n} & \cdots & 1 \end{bmatrix} \tag{1}$$

2.2.2 Normalizing the matrix according to

$$\overline{a_{ij}}=\sum_{k=1}^{n} a_{ij},\ \text{i,j=1,2,…n;} \tag{2}$$

2.2.3 Calculating the sum of each element of every line in the matrix A:

$$\overline{W_{ij}}=\sum_{j=1}^{n}\overline{a_{ij}}\ ,\ \text{i,j=1,2,…n;} \tag{3}$$

2.2.4 Normalizing:

$$w_i=\sum_{j=1}^{n}\overline{w_i}, i,\ j=1,2.....n\ ; \tag{4}$$

2.2.5 Calculating the Consistency Index:

$$CI=\frac{\frac{\sum_{i=1}^{n} W_i}{n}-n}{n-1} \tag{5}$$

2.2.6.Calculating the Consistency Ratio:

$$CR=CI/RI \tag{6}$$

RI was Random Index. If CR＜0.1, we can judge it with satisfaction that the judged matrix A were consistent with the inspection requirements.

In accordance with the process, we can calculate the weights of all indexes. The index system and the weight of each index are as the following Fig1.

A { B_1 (21.1%) Macroscopic risk
  { B_2 (10.2%) Intermediate market risk
  { B_3 (68.7%) Microscopic risk

B_1
- C_{11} (8.4%) Economy condition
- C_{12} (9.3%) Fiscal condition
- C_{13} (28.9%) Financial condition
- C_{14} (39.9%) Monetary policies
- C_{15} (13.5%) International balance of payments

B_2
- C_{21} (66.7%) Real estate situation
- C_{22} (33.3%) Stock market situation

B_3
- C_{31} (28.5%) Capital risk
- C_{32} (21.7%) Liquidity risk
- C_{33} (16.3%) Asset quality
- C_{34} (12.5%) Benefits
- C_{35} (6%) Market risk sensitivity
- C_{36} (4.3%) Off-balance sheet business risk
- C_{37} (10.7%) Management quality

C_{11}
- D_{111} (33.3%) GDP growth
- D_{112} (66.7%) CPI

C_{12}
- D_{121} (66.5%) Fiscal deficit /GDP
- D_{122} (23.1%) Revenue balance
- D_{123} (10.4%) Treasury bonds/GDP

C_{13}
- D_{131} (9.7%) Loan volume/GDP of last year
- D_{132} (28.4%) The proportion of credit assets which is invested in securities and real estate
- D_{133} (61.9%) Bad assets rate

C_{14}
- D_{141} (23%) Money supply growth
- D_{142} (12.2%) Money supply growth
- D_{143} (64.8%) The exchange rate of foreign currency

C_{15}
- D_{151} (50.3%) Current account deficit/GDP
- D_{152} (24%) Short-term debt/foreign exchange reserves
- D_{153} (16.6%) Foreign exchange reserves/ average monthly imports
- D_{154} (9.1%) (foreign investment + current account deficit)/GDP

C_{21} D_{211} (66.7%) Real estate vacancy ratio

C_{22}
- D_{221} (57.1%) Incomes of treasury bonds/ financial expenditure
- D_{222} (28.6%) Earnings ratio
- D_{223} (14.3%) Market value of stock/GDP

C_{31}
- D_{311} (55.6%) Capital ratio
- D_{312} (32%) Core capital ratio
- D_{313} (12.4%) Capital / total assets

C_{32}
- D_{321} (47.6%) Liquidity ratio
- D_{322} (7.8%) Loan deposit ratio
- D_{323} (24.9%) The proportion of liquid assets
- D_{324} (19.7%) Till money / total savings

C_{33}
- D_{331} (20.1%) Concentrated degree of loans
- D_{332} (79.9%) Quality of assets

C_{34}
- D_{341} (25.9%) Return of Asset
- D_{342} (44%) Return of Earning
- D_{343} (9.6%) (interest income-interest expenditure)/aggregate income
- D_{344} (20.5%) Cost-benefit ratio

C_{35} D_{351} (6%) (interests－sensitivity assets)/(interest－sensitivity debts)

C_{36} D_{361} (4.3%) Off-balance sheet deals / total assets

C_{37} { D_{371} (40%) The effectiveness of the internal control system; D_{372} (30%) Management and administrative ability of leadership D_{373} (9.4%) Plan and the ability to adapt to change D_{374} (17.2%) The Inspire mechanism }

D_{375} (3.4%) The staff training

D_{331} { E_{3311} (87.5%) Loan of first-ten customers ratio E_{3312} (12.5%) Loan of shareholders ratio }

D_{332} { E_{3321} (44.4%) Bad assets ratio E_{3322} (15.8%)（core capital + till money）/ total bad assets E_{3323} (5.8%) Earning rate of loan E_{3324} (34%) Secured and mortgage loan / total loan }

Fig1. The index system and the weight of each index

2.3. Set up the aggregate of fuzzy evaluation standards

The aggregate of fuzzy evaluation standards Z=｛Z1，Z2，Z3，Z4，Z5｝，the meaning of Zi (i=1,2,3,4,5) are as the following table1.

Table.1 The evaluation standards

Z_i	Z_1	Z_2	Z_3	Z_4	Z_5
degree of risk	safety	Basic safety	risks	More risks	Serious risks
values	0－20	20－40	40－60	60－80	80－100

2.4. Assess the membership degree of single index

After fixing the individual evaluation standards of each index according to domestic and international experiences, the corresponding matrixes of membership degrees are made through different membership functions and the membership degree of single index is determined.

2.4.1 The macroscopic and immediate levels indexes

Take the index of GDP growth (D111) as an instance:

Referring to the historical data and the development conditions of our country, we should make 9.5% as the safe point of economy, put the range 8%——9.5% as the safety region of GDP growth, and take every 1.5% increase or decrease as a safety standards.

Table.2 The Standards of GDP growth (D111)

degree of risk	A safety	B Basic safety	C risks	D More risks	E Serious risks
values	8-9.5	6.5-8 or 9.5-11	5-6.5 or 11-12	4-5 or 12-13	< 4 or > 13

Table.3 2005－2009 GDP growth

Year	2005	2006	2007	2008	2009
True values	9.9	10.7	11.4	9	8.7
Degree	B	B	C	A	A

The data from the website： http://www.stats.gov.cn/tjgb/

Comparing the actual values of GDP GROWTH from 2005-2009 years to the evaluation standards, we can calculate the relative membership grade of GDP growth, the result is as the below table4.

Table.4 Degree of risks

Degree of risks	A	B	C	D	E
membership grade	40%	40%	20%	0	0

We can obtain the relative membership grade of the macroscopic and immediate levels indexes according to the above methods.

2.4.2 The microscopic indexes

As for the microscopic indexes, we can mark "P_n" as the actual value of any index, and the membership grade is determined by comparing the actual value to evaluation standards of each index.

If: $P_n < A$ or $P_n > E$, the membership grade is 1, we choose level A or level E.
If: $A < P_n < B$或$A > P_n > B$，
then $B^*=[(P_n - A)/(B-A)]$, $A^*=[(B- P_n)/(B-A)]$, and $A^*+B^*=1$.
the membership grade is A* and B*， we choose level A or level B
If: $B < P_n < C$ or $B > P_n > C$
$C < P_n < D$ or $C > P_n > D$，

We take the index E3321 (bad assets ratio) as an example. The loan category of a certain bank is given as the below table5.

Table.5 The loan category (2009)

category	sum	ratio
Total loans	18 738	
secured loans	8 252	44.04%
mortgage loans	4 771	25.46%
Other loans	2 374	12.67%
Bad loans	3 341	17.83%

- Fixing the evaluation standards of index E3321 according to domestic and international experiences (table6.)

Table.6 The standards of bad assets ratio

Degree of risk	A (safety)	B (basic safety)	C (risk)	D (more risk)	E (serious risk)
values	＜8%	10%-12%	12-14%	14-16%	＞16%

- Bad assets ratio=539.1/1873.8=28.77%;
- Because of Pn (28.77%)＞E(16%), the membership grade is 1, we choose level E as the membership grade of the index E3321. Following this way, we can calculate each membership grade of the level E indexes. The each membership grade of the indexes E3311—E3324 are showed as the below table7.

Table.7 The membership grade

Index	Actual value	The membership grade				
		A	B	C	D	E
E_{3311}	21.56%	0	0	0	0	100%
E_{3312}	0	100%	0	0	0	0
E_{3321}	28.77%	0	0	0	0	100%
E_{3322}	26.1%	0	0	0	0	100%
E_{3323}	35.2%	100%	0	0	0	0
E_{3324}	69.5%	95%	5%	0	0	0

2.4.3 The quantitative indexes

As for the quantitative indexes, such as the management quality of a bank, we use questionnaire method and statistical method of frequency. In accordance with the survey results, we calculate the membership grade as the following table8.

Table.8 The membership grade

INDE	A	B	C	D	E
D_{371}	21.3%	33.%	24.5%	18.2%	3%
D_{372}	27.2%	30.3%	21.2%	15.2%	6%
D_{373}	24.2%	36.4%	18.2%	12.1%	9.1%
D_{374}	24.2%	24.2%	27.3%	12.1%	12.1
D_{375}	21.2%	24.2%	36.5%	12.1%	6%

2.5. Fuzzy comprehensive evaluation

2.5.1 The first level evaluation

$$\begin{aligned} &Bijk \\ &= Aijk \circ Rijk \\ &= \begin{bmatrix} aijk1 & aijk2 & \cdots & aijkm \end{bmatrix} \circ \begin{bmatrix} rijk11 & rijk12 & \cdots & rijk1m \\ rijk21 & rijk22 & \cdots & rijk2m \\ \vdots & \vdots & \vdots & \vdots \\ rijkn1 & rijkn2 & \cdots & rijknm \end{bmatrix} \\ &= \begin{bmatrix} bijk1 & bijk2 & \cdots & bijkm \end{bmatrix} \end{aligned} \tag{7}$$

For example: the membership degrees matrixes of indexes D331 and D332 as the follows:

$$R_{331} = \begin{bmatrix} 0 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 \end{bmatrix} \tag{8}$$

$$R_{332} = \begin{bmatrix} 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 \\ 0.95 & 0.05 & 0 & 0 & 0 \end{bmatrix} \tag{9}$$

index	weight
D_{331}	A_{331}=（87.5%, 12.5%）
D_{332}	A_{332}=（44.4%,15.8%,5.8%,34%）

$B_{ijk}=A_{ijk}$ ○ R_{ijk}

B331= A331 ○ R331=(0, 0,0,0,0.875)

B332= A332 ○ R332=(0.34,0,0,0,0)

Then make the vector B_{ijk} normalize, and the membership grade vector of D331 and D332 will be generated.

B*331=(0,0,0,0,1), B*332=(1,0,0,0,0)

2.5.2 The second level evaluation

We can obtain the matrixes of membership degrees Rij in accordance with the above results.

$$Rij = \begin{bmatrix} Bij1 \\ \vdots \\ Bijn \end{bmatrix} = \begin{bmatrix} bij11 & bij12 & \cdots & bij1m \\ bij21 & bij22 & \cdots & bij2m \\ bijn1 & bijn2 & \cdots & bijnm \end{bmatrix} \tag{10}$$

$B_{ij} = A_{ij}$ ○ $R_{ij,}$ make the vector B_{ij} normalize , and the membership grade vector of the indexes of level D will be acquired.

Following the same method, we can finish the third and forth levels evaluation, and gain the membership grade vector of whole risks.

F. Propose the evaluation model

We use the Weighted Moving Average method to deal with the results and propose the risk evaluation model of a bank.

$$Z=Bi \times Vi=b1\times V1+ b2\times V2+ b3\times V3+ b4\times V4+ b5\times V5$$

“Vi” is the mid-value of “Zi” in the table1.

Table.9 The values of “Vi”

Vi	1	2	3	4	5
value	10	30	50	70	90

3. Conclusions And Suggestions

Factors which lead to the risks are manifold, containing macroeconomic environment and the management quality of a bank itself. As a result, we should make the comprehensive evaluation for different factors. Since the risk evaluation model is based on combining Analytic Hierarchy Process and Fuzzy Logic Theory, we can not only consider the various factors which may lead to the bank risks, but also integrate the qualitative and quantitative analysis. Because of subjective and objective factors, however, the model has several following shortcomings. First, it could lead somewhere subjective, as the indexes were selected from the domestic and foreign data combining with some of our existed state index systems. The imperfect calculation is unavoidable. The second, most of commercial banks would cover their important financial data to survive the fierce competition. In defect of the adequate data, it is quite difficult to test the model effectiveness in a proper way. Thus, the accuracy and sensitivity of these modles are to be evaluated in their future practices.

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