

Study on the Fragility of the Banking System

-- Application of Entropy Method

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Abstract. In this paper, the principle of entropy method is studied, and the entropy method is adjusted. Based on the adjusted entropy weighting method, this paper explores the fragility of the banking system of China from the end of first quarter of 2011 to the end of the third quarter of 2016. The article found that in the end of the third quarter of 2016, the banking system had the highest degree of vulnerability during the study period, and in the end of the fourth quarter of 2012 the banking system had the lowest ones. The study also found that the NPL ratio had the greatest impact on the vulnerability of the banking system.

1. Introduction

There are definitions of both broad sense and narrow sense for the fragility of banking system. The narrow sense of the banking system fragility refers to the nature of the banking industry, which is characterized by a high level of liability. The broad sense of the banking system fragility is a kind of financial condition which tends to be high risk, which refers to the accumulation of risks in all financing fields including credit financing and financial market financing. It is the broad sense of banking system fragility that we study.

Historically, the financial crisis occurred frequently such as the Holland tulip bubble which happened in 1637, recorded the first financial bubble in the history. The Asian financial turmoil in 1997 and the global financial crisis in 2008 which is known as the financial tsunami, both are huge and destructive. In order to avoid China's banking crisis, the study of China banking system vulnerability is very necessary. In this paper, we use the entropy method to evaluate the vulnerability of China banking system.

Entropy method is a method of comprehensive evaluation with objective weight. Entropy comes from information theory, and it is a measure for uncertainty. The greater degree of dispersion, the greater the entropy is, as well as the weaker the degree of dispersion, the smaller the entropy is. According to the characteristics of entropy, entropy can be used to determine the degree of dispersion of a certain index. The greater the degree of dispersion of the index, the greater the impact on the comprehensive evaluation the index has. Entropy method is effective in weighting.

For example, Huang G. et al. (2012) applied the entropy weighting method in the evaluation of air combat capability. In the method of evaluating the vulnerability of the banking system, Xiao Z. (2008) pioneered the establishment of a comprehensive index method with entropy method to evaluate the vulnerability of China banking system. Chen Q. et al (2011) improved traditional entropy method, and the calculation precision was improved. Yang Q. et al (2008) used entropy method to evaluate the competitiveness of cities. Wang X. et al (2005) evaluated the operational efficiency of commercial banks using entropy method. Zhu X. (2015) discussed the superiority of the improved entropy method, and selected the best ones.

2. The Introduction of Relevant Knowledge

In entropy theory, the greater the degree of dispersion of the index, the greater the entropy and the greater the impact on the system are. It is the index which has a great influence on the total system that will be given a relatively large weight. The following is the evaluation process of entropy method:

(i) Make the index to be dimensionless and positive. The formula for the data which has the larger value and better quality is:

$$x'_{ij} = \frac{x_{ij} - \min x_{ij}}{\max x_{ij} - \min x_{ij}} \quad (1)$$

The formula for the data which has the smaller value and better quality is:

$$x'_{ij} = \frac{\max x_{ij} - x_{ij}}{\max x_{ij} - \min x_{ij}} \quad (2)$$

(ii) Calculated the data probability value by the formula:

$$p_{ij} = \frac{x'_{ij}}{\sum_{i=1}^n x'_{ij}} \quad (3)$$

(iii) Calculate the entropy of the index by the original formula:

$$e_j = -k \sum_{i=1}^n p_{ij} \ln p_{ij} \quad (4)$$

After the step (i), the values of x'_{ij} would have one or more 0 values which will directly lead corresponding probability to have a value of 0. Because the original method of calculating entropy needs the probability a positive integer, there will be some probability values that do not meet the requirements. It is necessary to adjust the original formula of calculating the entropy. The adjusted formula is:

$$e_j = k \sum_{i=1}^n p_{ij} e^{p_{ij}} \quad (5)$$

The feasibility of model modification: When the original data is relatively large, the data after logarithm is still relatively large, so does the power series data.

For x_{ki} with a specific i, if all x_{ki} are equal, then the probability value is:

$$p_{ij} = \frac{x_{ki}}{\sum_{k=1}^n x_{ki}} = \frac{1}{n} \quad (6)$$

At this point, the index has the smallest amount of information, and gets the smallest entropy. Set the entropy to 1, and we can calculate the k value:

$$k = \frac{1}{e^n} \quad (7)$$

(iv) Calculate the index weight:

$$w_j = \frac{e_j}{\sum_{j=1}^m e_j} \quad (8)$$

(v) Calculate the comprehensive vulnerability index:

$$f_i = \sum_{j=1}^m w_j p_{ij} \quad (9)$$

3. Establishment and Analysis of the Model

3.1. Selection Index

The risk of commercial banks involves credit risk, market risk, liquidity risk, and operational risk. Since the operational risk is always related to operating environment and human factors, which are measuring up difficult, the paper does not consider the operational risk. According to the experience of other scholars' research and the availability of data, this paper selects 23 quarters' data which is from the first quarter of 2011 to the third quarter of 2016. The data are non-performing loan ratio, the ratio of accumulative open foreign exchange positions, the provision coverage ratio, liquidity ratio, the capital profit rate, capital adequacy ratio which are represented by x(1), x(2), x(3), x(4), x(5) and x(6) successively. All of the data is from CBRC. See Appendix 1 for the raw data.

3.2. Build Model

(i) Make the index to be dimensionless and positive:

The rate of non-performing loans is the data which has the bigger value and the higher fragility. Accumulative open foreign exchange needs to be in a safe range, which is neither too big nor too small. In order to facilitate the processing, the paper assumes that the accumulative open foreign exchange is a kind of data which has the bigger value and the higher fragility. The last four are the data which has the small value and the higher fragility. For the direction of the index data is different, it is necessary to make the index to be of no dimension and the same direction. The data which has the larger value and the higher fragility using the formula,

$x_{ij}' = \frac{x_{ij} - \min x_j}{\max x_j - \min x_j} (0 \leq x_{ij}' \leq 1)$, The data which has the smaller value and the higher fragility

using the formula, $x_{ij}' = \frac{\max x_j - x_{ij}}{\max x_j - \min x_j} (0 \leq x_{ij}' \leq 1)$. The results of the procession are shown in Appendix 3.

(ii) Calculation of the probability: Use the formula: $p_{ij} = \frac{x_{ij}'}{\sum_{i=1}^n x_{ij}'}$. The results of the calculation of the probability values are shown in Appendix 4.

(iii) Calculation of the entropy value: Calculate the entropy value of each index with the calculated probability values using the modified formula, $e_j = k \sum_{i=1}^n p_{ij} e^{p_{ij}}$, for $k = \frac{1}{\ln n}$, $n=23$ into the formula and we can get that: $k = \frac{1}{e^{23}}$, The results of calculating entropy are shown in table 1.

Table 1 Index entropy

e_1(1)	e_1(2)	e_1(3)	e_1(4)	e_1(5)	e_1(6)
1.046011	1.024447	1.035812	1.021953	1.021731	1.02921

From table 1, we can see the rate of non-performing loans' entropy has the maximum value which indicates that the maximum amplitude fluctuation of the rate of non-performing loans. The provision coverage, the capital adequacy ratio, the ratio of accumulative open foreign exchange positions, the liquidity ratio, and capital profit follows successively. It can be seen that from the first quarter of 2011 to the third quarter of 2016, the rate of non-performing loans in the banking system is the highest, which indicates that the NPL ratio has the greatest impact on the vulnerability of the banking system.

(iv) Calculate the weight of the index: Calculate the weight of the index probability calculated forward using the formula: $w_j = \frac{e_j}{\sum_{j=1}^m e_j}$. The results are shown in table 2.

Table 2 Index weight

w(1)	w(2)	w(3)	w(4)	w(5)	w(6)
0.16928	0.165791	0.16763	0.165387	0.165351	0.166561

From the table 2, we can see that the weight values from large to small are, w(1), w(6), w(3), w(4), w(2), w(5) successively. It can be seen that the rate of non-performing loans' weight is the maximum one. The provision coverage, the capital adequacy ratio, the ratio of accumulative open foreign exchange positions, the liquidity ratio, and capital profit follows successively.

(v) Calculate the final vulnerability index. Finally, the comprehensive vulnerability is evaluated with the weight and the corresponding probability value using the formula: $f_i = \sum_{j=1}^m w_j p_{ij}$. The results are shown in table 3, and the line graph is shown in figure 1. In this paper, the calculation process of entropy method is all realized by MATLAB, and the MATLAB codes are given in Appendix2.

Table 3 Vulnerability index score

Time	Score	Time	Score	Time	Score
2011_1	0.064376	2013_1	0.027758	2015_1	0.040604
2011_2	0.053897	2013_2	0.034794	2015_2	0.050901
2011_3	0.041934	2013_3	0.036497	2015_3	0.057949
2011_4	0.039748	2013_4	0.037617	2015_4	0.059195
2012_1	0.023825	2014_1	0.025878	2016_1	0.075973
2012_2	0.025934	2014_2	0.030277	2016_2	0.07525
2012_3	0.027001	2014_3	0.02896	2016_3	0.079494
2012_4	0.02198	2014_4	0.040159		

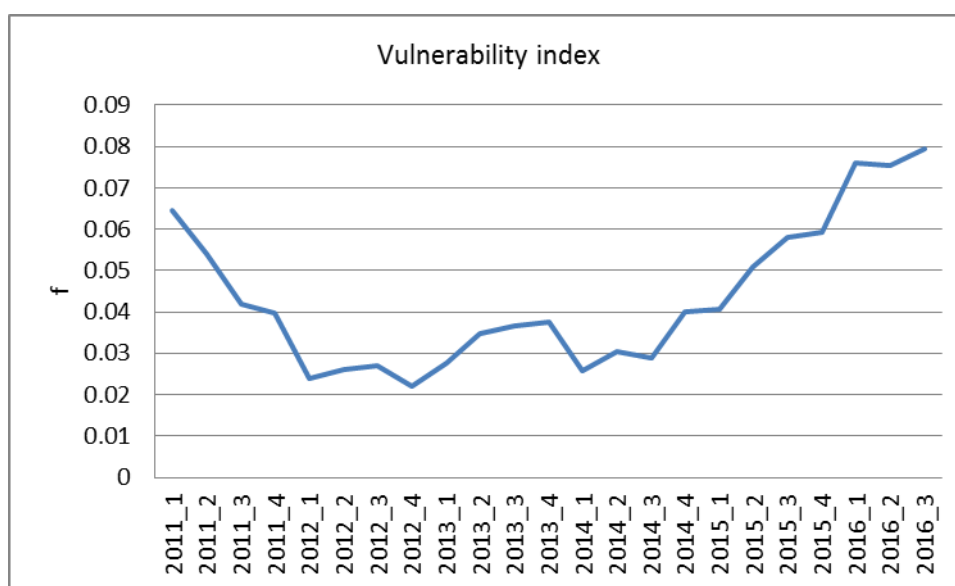


Figure 1 Entropy method comprehensive vulnerability index

3.3. Analysis Results

For the index is made to be dimensionless and positive, that is, the index becomes the data which has the bigger value and the higher fragility. When the numerical index is larger, the vulnerability is larger too. According to Figure 3-1, it can be seen that during the study period, banking fragility can be roughly divided into three stages. In the first stage, the slope of the vulnerability index curve is negative from the end of the first quarter of 2011 to the end of the first quarter of 2012, and the overall vulnerability has a decline state. In the second stage the vulnerability index is basically the same, since the second quarter of 2012 to the third quarter of 2014. Although there were small fluctuations, it was too small to be considered. In the third phase, the fragility of the banking system was on a rise from the fourth quarter of 2014 to the third quarter of 2016. During the studying period, the banking system had the lowest vulnerability index on the end of the fourth quarter of 2012 and the highest vulnerability index at the end of the third quarter of 2016.

According to the results of the analysis, we can find that the fragility of the banking system had been declining since the first quarter of 2011 to the first quarter of 2014. Since the beginning of 2014, which mainly was due to the bad loans, the vulnerability of the banking system had been rising up. The high level of non-performing loan ratio will affect the banking system's capacity of collections. If there are too many loans that cannot be recovered, the banks will face the risk of

collapse, just like the financial crisis of 2008. Therefore, the banking system must control the ratio of non-performing loans to avoid bank system crisis.

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APPENDIX

Appendix1 Raw data

	X(1)	X(2)	X(3)	X(4)	X(5)	X(6)
2011_1	1.1	5.8	230.2	41.3	11.8	22.4
2011_2	1	5.8	248.9	42	12.2	22.6
2011_3	0.9	5.1	270.7	42.8	12.3	22.1
2011_4	1	4.6	278.1	43.2	12.7	20.4
2012_1	0.94	4.25	287.4	45.66	12.74	22.34
2012_2	0.94	5.18	290.18	46.69	12.91	22.29
2012_3	0.95	4.65	289.97	45.23	13.03	21.54
2012_4	0.95	3.92	295.51	45.83	13.25	19.85
2013_1	0.96	3.77	291.95	45.36	12.28	21
2013_2	0.96	4.24	292.5	43.68	12.24	21.19
2013_3	0.97	3.77	287.03	42.8	12.18	20.67
2013_4	1	3.68	282.7	44.03	12.19	19.17
2014_1	1.04	4.04	273.66	46.29	13.13	20.8
2014_2	1.08	3.87	262.88	47.52	12.4	20.66
2014_3	1.16	3.71	247.15	48.53	12.93	19.78
2014_4	1.25	3.5	232.06	46.44	13.18	17.59
2015_1	1.39	2.98	211.98	47.46	13.13	17.76
2015_2	1.5	2.97	198.39	46.18	12.95	17.26
2015_3	1.59	3.55	190.79	46.16	13.15	16.68
2015_4	1.67	3.67	181.18	48.01	13.45	14.98
2016_1	1.75	3.71	175.03	48.08	11.38	15.93
2016_2	1.75	3.06	175.96	48.14	11.1	15.16
2016_3	1.76	3.24	175.52	46.93	11.3	14.58

Appendix2 MATLAB Codes

Begin

```
>> x_max=zeros(1,6);x_min=zeros(1,6);
>> x_max=max(x);x_min=min(x);
>> x_1=zeros(23,6);
>> for i=1:2
    for k=1:23
        x_1(k,i)=(x(k,i)-x_min(1,i))/(x_max(1,i)-min(1,i));
    end
end
>> for i=3:6
    for k=1:23
        x_1(k,i)=(x_max(1,i)-x(k,i))/(x_max(1,i)-x_min(1,i));
    end
end
>> p=zeros(23,6);
>> for i=1:6
    for k=1:23
        p(k,i)=x_1(k,i)/sum(x_1(:,i));
    end
end

>> e=zeros(1,6);
>> for i=1:6
    for k=1:23
        e(1,i)=e(1,i)+p(k,i)*exp(p(k,i));
    end
end
>> e_1=(1/exp(1/23))*e;
>> a=e_1/sum(e_1);
>> f=zeros(23,1);
>> for k=1:23
    for i=1:6
        f(k,1)=f(k,1)+a(1,i)*p(k,i);
    end
end
t=1:1:23;

>> plot(t,f,'*');
```

End

Appendix3 Positive index and dimensionless result

	X(1)_1	X(2)_1	X(3)_1	X(4)_1	X(5)_1	X(6)_1
2011_1	0.263158	0.589583	0.542082	1	0.702128	0.024938
2011_2	0.131579	0.589583	0.386869	0.903181	0.531915	0
2011_3	0	0.44375	0.205926	0.792531	0.489362	0.062344
2011_4	0.131579	0.339583	0.144505	0.737206	0.319149	0.274314
2012_1	0.052632	0.266667	0.067314	0.396957	0.302128	0.032419
2012_2	0.052632	0.460417	0.04424	0.254495	0.229787	0.038653
2012_3	0.065789	0.35	0.045983	0.456432	0.178723	0.13217
2012_4	0.065789	0.197917	0	0.373444	0.085106	0.342893
2013_1	0.078947	0.166667	0.029548	0.438451	0.497872	0.199501
2013_2	0.078947	0.264583	0.024983	0.670816	0.514894	0.17581
2013_3	0.092105	0.166667	0.070385	0.792531	0.540426	0.240648
2013_4	0.131579	0.147917	0.106325	0.622407	0.53617	0.427681
2014_1	0.184211	0.222917	0.181358	0.30982	0.13617	0.224439
2014_2	0.236842	0.1875	0.270833	0.139696	0.446809	0.241895
2014_3	0.342105	0.154167	0.401394	0	0.221277	0.351621
2014_4	0.460526	0.110417	0.526643	0.289073	0.114894	0.624688
2015_1	0.644737	0.002083	0.69331	0.147994	0.13617	0.603491
2015_2	0.789474	0	0.806109	0.325035	0.212766	0.665835
2015_3	0.907895	0.120833	0.86919	0.327801	0.12766	0.738155
2015_4	1.013158	0.145833	0.948954	0.071923	0	0.950125
2016_1	1.118421	0.154167	1	0.062241	0.880851	0.831671
2016_2	1.118421	0.01875	0.992281	0.053942	1	0.927681
2016_3	1.131579	0.05625	0.995933	0.2213	0.914894	1

Appendix4 Probability values

p	p1	p2	p3	p4	p5	p6
2011_1	0.028944	0.114343	0.057951	0.106527	0.076995	0.002737
2011_2	0.014472	0.114343	0.041358	0.096213	0.058329	0
2011_3	0	0.086061	0.022014	0.084426	0.053663	0.006843
2011_4	0.014472	0.065859	0.015448	0.078532	0.034998	0.030108
2012_1	0.005789	0.051717	0.007196	0.042287	0.033131	0.003558
2012_2	0.005789	0.089293	0.004729	0.027111	0.025198	0.004243
2012_3	0.007236	0.067879	0.004916	0.048622	0.019599	0.014507
2012_4	0.007236	0.038384	0	0.039782	0.009333	0.037635
2013_1	0.008683	0.032323	0.003159	0.046707	0.054596	0.021897
2013_2	0.008683	0.051313	0.002671	0.07146	0.056463	0.019297
2013_3	0.01013	0.032323	0.007524	0.084426	0.059263	0.026413
2013_4	0.014472	0.028687	0.011367	0.066303	0.058796	0.046941
2014_1	0.02026	0.043232	0.019388	0.033004	0.014932	0.024634
2014_2	0.026049	0.036364	0.028953	0.014881	0.048997	0.02655
2014_3	0.037627	0.029899	0.042911	0	0.024265	0.038593
2014_4	0.050651	0.021414	0.0563	0.030794	0.012599	0.068564
2015_1	0.070912	0.000404	0.074118	0.015765	0.014932	0.066238
2015_2	0.086831	0	0.086176	0.034625	0.023332	0.073081
2015_3	0.099855	0.023434	0.09292	0.03492	0.013999	0.081018
2015_4	0.111433	0.028283	0.101447	0.007662	0	0.104284
2016_1	0.12301	0.029899	0.106904	0.00663	0.096594	0.091282
2016_2	0.12301	0.003636	0.106079	0.005746	0.109659	0.10182
2016_3	0.124457	0.010909	0.106469	0.023574	0.100327	0.109758