The Calculation of China's Financial Stability Index--Based on Improved Analytic Hierarchy Process and Entropy

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Abstract. This article selects the seven first-class indexes of international financial stability index, macroeconomic stability index and so on. And according to the situation of China, multiple secondary indexes are selected under the first-class indexes. We adopt the improved AHP and entropy to calculate the weight of each second-grade index respectively, which lead to a conclusion that the gap between the results is not big and the agreement is very high. Therefore, the average value of the two methods is chosen as the final weight for the calculation. And the fuzzy evaluation method is used to calculate the financial stability index--take inflation index as an example to construct the relative membership vector and explain its calculation process. This method provides a way for regulators to measure regulation.

Keywords: China's financial stability index, improved AHP, entropy.

1. Literature Review

There are different definitions of financial stability in terms of institutions and scholars. Among them, two types of perspectives are most widely recognized. Among many definitions of financial stability, the financial system has always been based on two elements, although the contents are different. One is that the financial system performs its economic function, and the other is that the financial system can withstand certain external shocks (Xu Guoxiang, Guo Jianna and Chen Fuping, 2017).

The former definition refers to Padoa-Schioppa (2003), which considers financial stability to mean that the financial system is capable of withstanding shocks, the allocation of deposits to investment opportunities and payments in economic activities addresses the disruptive effects of the process of accumulation without shocks. The Federal Reserve Board understands financial instability from the perspective of Finance Instability, the definition of financial stability as non-existence of financial instability suggests that financial instability refers to a situation in which the price of certain important financial assets deviates significantly from the base value and where there are serious distortions in the functioning of financial markets and in the issuance of credit, which hampers economic growth. The latter definition is represented by Houben and Kakes(2004). They believe that financial stability is a state in which the financial system can effectively allocate resources across industries and time, evaluate and manage financial risks and absorb risks. The European Central Bank considers financial stability to mean that financial institutions, financial markets and financial infrastructure are functioning well and can maintain an effective transformation of savings into investment in the face of various shocks. The Peoples Bank of China has also defined financial stability in its 2005 Financial Stability Report, which considers that financial stability means that the financial system is in a stable state capable of effectively carrying out its key functions.

2. Index System Construction

Starting from the connotation of financial stability, this article selects international financial stability, macroeconomic stability index, the index of financial market stability, the banking stability index and stability index for the securities industry, insurance industry stability index and non-financial sector stability index seven first-level indicators, according to China's national conditions under the primary index selecting multiple secondary indexes. As the following table:

Table 1. Indexes table

First level indicators	The secondary indicators	note
International financial stability index	Ted spread	Liquidity pressures in banking markets
	VIX	The stock market as a whole fluctuates in price
Macroeconomic stability index	The GDP growth rate	Economic growth
	Inflation rate	Price stability
	Fiscal deficit /GDP	The fiscal situation
	Current account balance /GDP	The balance of payments
	Foreign exchange reserves/short-term foreign debt	solvency
Financial market stability index	Shanghai stock price/earnings ratio	The securities market
	The rate at which Banks lend to each other for seven days	The money market
	The real effective exchange rate of RMB	The foreign exchange market
	The real estate price index	Real estate market
Banking stability index	Bank broad credit growth	Assets and liabilities (including off-balance sheet financing)
	Inter-bank debt ratio	Assets and liabilities
	The bank's non-performing loan ratio	Asset quality
	Bank capital adequacy ratio	Capital and leverage
	Liquidity coverage	Liquidity
Securities industry stability index	Risk coverage	Risk coverage
	Capital leverage ratio	Capital and leverage
	Liquidity coverage	Liquidity
Insurance stability index	Solvency adequacy ratio	solvency
	Integrated flow rate	Liquidity
Non-financial sector stability indicators	Local government debt /GDP	Local government debt risk
	The asset-liability ratio of industrial enterprises	Non-financial corporate debt
	Household debt /GDP	Household leverage ratio

3. Financial Stability Index Weight Calculation

Through the understanding of literature reading and methods, this paper finally chooses to use objective methods and subjective methods to calculate weights separately. The objective method is the entropy method, which is based on historical data that affect financial stability variables, the weight of each index is calculated, and then the weight of each index to the total index is calculated. Then a comprehensive index to evaluate the financial stability of China is obtained. The subjective method is the improved analytic hierarchy process, the two methods use the expert scoring method, through the matrix transformation, finally get the weight of each index.

Based on the objective data, the quarterly data between 2010 and 2017 are selected. See the appendix for detailed data. Through the above calculation process, the weight of secondary indicators on corresponding primary indicators is obtained as follows:

Table 2 quarterly data between 2010 and 2017

First level indicators	The secondary indicators	Entropy weight	Improved AHP weight	The mean
International financial stability index	Ted spread	0.621012125	0.583333333	0.602173
	VIX	0.378987875	0.416666667	0.397827
Macroeconomic stability index	The GDP growth rate	0.331242107	0.49072818	0.410985
	Inflation rate	0.127657362	0.273527173	0.200592
	Fiscal deficit /GDP	0.148052449	0.033341814	0.090697
	Current account balance /GDP	0.146269605	0.131738025	0.139004
	Foreign exchange reserves/short-term foreign debt	0.246778477	0.070664808	0.158722
Financial market stability index	Shanghai stock price/earnings ratio	0.131365876	0.12267303	0.127019
	The rate at which Banks lend to each other for seven days	0.299559769	0.150835851	0.225198
	The real effective exchange rate of RMB	0.391538109	0.400648439	0.396093
	The real estate price index	0.177536246	0.32584268	0.251689
Banking stability index	Bank broad credit growth	0.341066757	0.351984124	0.346525
	Inter-bank debt ratio	0.208806632	0.204413082	0.20661
	The bank's non-performing loan ratio	0.184730726	0.188450874	0.186591
	Bank capital adequacy ratio	0.100657914	0.137316351	0.118987
	Liquidity coverage	0.164737971	0.117835569	0.141287
Securities industry stability index	Risk coverage	0.280822404	0.381937083	0.33138
	Integrated flow rate	0.298459982	0.213871365	0.256166
	Liquidity coverage	0.420717614	0.404191552	0.412455
Insurance stability index	Solvency adequacy ratio	0.374565034	0.285714286	0.33014
	Integrated flow rate	0.625434966	0.714285714	0.66986
Non-financial sector stability indicators	Local government debt /GDP	0.269289578	0.296296296	0.282793
	The asset-liability ratio of industrial enterprises	0.438773435	0.407407407	0.42309
	Household debt /GDP	0.291936987	0.296296296	0.294117

4. The Financial Stability Index Is Calculated by Fuzzy Evaluation Method

Fuzzy comprehensive evaluation can deal with the subjectivity and the vagueness of people in the process of evaluation. The fuzzy comprehensive evaluation usually follows the following steps:

1. Establish the factor set U of comprehensive evaluation Fuzzy evaluation factor set:

$$u = \{u_1, u_2, u_3, u_4, u_5, u_6, u_7\}$$

$$u_1 = \{u_{11}, u_{12}, u_{13}, u_{14}\} \dots \dots$$

Fig 1. fuzzy evaluation factor set

2. Establish a set of evaluation grade standards $V = \{V_1, V_2, V_3, \dots, V_m\}$, where is $V_j (j=1, 2, \dots, n)$ as the evaluation grade standard, and n is the number of elements, i.e., the number of grades or the number of comment columns. In this article, $n=4$, that is, we have a total of 4 levels of comments, namely stability, potential stability and potential instability, and finally instability. They're assigned 10,35,65,90. This set defines the selection range of evaluation results of an evaluation factor. Evaluation elements can be qualitative or quantitative.

3. Determine the membership matrix

Assuming that the evaluation factor is evaluated by a single factor, a relative fuzzy vector $R_j = (r_{i1}, r_{i2}, \dots, r_{ij}), i = 1, 2, \dots, n; j = 1, 2, 3, 4$ is obtained. r_{ij} Is the u_i 's degree of the factor V_j . If n elements are evaluated comprehensively, the result is a matrix of n rows and 4 columns, which is called membership R. Obviously, each row in this matrix is the evaluation result of each single factor, and the whole matrix contains all the information obtained by evaluating the evaluation factor set U according to the evaluation standard set V . In this paper, the membership degree of qualitative index is determined by expert scoring method, and the membership function is used to calculate the membership degree of quantitative index. According to the requirements of this paper, the membership function of the evaluation system has four evaluation criteria: For the evaluation factors with higher value and greater positive effect on financial stability, the membership degree of these factors is described by the lower half ladder distribution function. The membership functions of 4 levels in each factor corresponding to the comment set are as shown as fig 2.

$$r_1 = \begin{cases} 1, 0 \leq u_i \leq V_1 \\ \frac{V_2 - u_i}{V_2 - V_1}, V_1 \leq u_i \leq V_2 \\ 0, u_i > V_2 \end{cases}$$

$$r_2 = \begin{cases} 0, u_i \leq V_1 \text{ 或 } u_i \geq V_3 \\ \frac{u_i - V_2}{V_2 - V_1}, V_1 \leq u_i \leq V_2 \\ 1, u_i = V_2 \\ \frac{V_3 - u_i}{V_3 - V_2}, V_2 \leq u_i \leq V_3 \end{cases}$$

$$r_3 = \begin{cases} 0, u_i \leq V_2 \text{ 或 } u_i \geq V_4 \\ \frac{u_i - V_2}{V_3 - V_2}, V_2 \leq u_i \leq V_3 \\ 1, u_i = V_3 \\ \frac{V_3 - u_i}{V_3 - V_2}, V_3 \leq u_i \leq V_4 \end{cases}$$

$$r_4 = \begin{cases} 0, u_i \leq V_3 \\ \frac{u_i - V_2}{V_4 - V_3}, V_3 \leq u_i \leq V_4 \\ 1, u_i > V_4 \end{cases}$$

Fig 2. Membership function

$$r_1 = \begin{cases} 1, u_i > V_1 \\ \frac{V_2 - u_i}{V_1 - V_2}, V_2 \leq u_i \leq V_1 \\ 0, 0 \leq u_i \leq V_2 \end{cases}$$

$$r_2 = \begin{cases} 0, u_i \leq V_3 \text{ 或 } u_i \geq V_1 \\ \frac{u_i - V_2}{V_1 - V_2}, V_2 \leq u_i \leq V_3 \\ 1, u_i = V_2 \\ \frac{V_3 - u_i}{V_2 - V_3}, V_3 \leq u_i \leq V_2 \end{cases}$$

$$r_3 = \begin{cases} 0, u_i \leq V_4 \text{ 或 } u_i \geq V_2 \\ \frac{V_2 - u_i}{V_2 - V_3}, V_3 \leq u_i \leq V_2 \\ 1, u_i = V_3 \\ \frac{u_i - V_4}{V_3 - V_4}, V_4 \leq u_i \leq V_3 \end{cases}$$

$$r_4 = \begin{cases} 0, u_i < V_3 \\ \frac{V_3 - u_i}{V_3 - V_4}, V_4 \leq u_i \leq V_3 \\ 1, u_i < V_4 \end{cases}$$

Fig 3. 4 levels in each factor corresponding

For the evaluation factors with higher value and greater positive effect on financial stability, the membership degree of these factors is described by the lower half ladder distribution function. The membership functions of 4 levels in each factor corresponding to the comment set are as shown as fig 3.

Take inflation rate as an example to calculate the relative membership vector of inflation rate. Suppose that the actual value of inflation rate is 1.8, and the rating standard of inflation rate is as follows:

Table 3. rating standard of inflation rate

indicators	stable	Potentially stable	Potentially instable	instable
Inflation rate	0	4	7	10

The index is negative, $u = 1.8$ and $V_1 \leq u \leq V_2$, according to the formula, is calculated as follows:

$$r_1 = \frac{V_2 - u}{V_2 - V_1} = 0.55, \quad V_1 \leq u \leq V_2$$

$$r_2 = \frac{u - V_1}{V_2 - V_1}, \quad V_1 \leq u \leq V_2$$

$$r_3 = 0, \quad u < V_3$$

$$r_4 = 0, \quad u < V_4$$

Therefore, the relative membership vector of the inflation index is $(0, 55, 0, 45, 0, 0)$, indicating that China's current inflation rate is zero for stability of 55%. The potential stable membership is 0.45. That is, 55% is stable, 45% is potentially unstable. According to the steps described above, we can calculate the relative membership vector of other indicators and summarize them to obtain the fuzzy comprehensive evaluation matrix. Then multiply left by the row vector of the weight of the first order index to get the final financial stability index (a probability distribution that measures the stability level).

5. Summary

This paper provides a method for regulators to measure financial stability. The improved analytic hierarchy process (AHP) and entropy value method are used to calculate the weights of each secondary indicator to the primary indicator respectively. Different regulators can set different rating standards, for the quality of the fuzzy evaluation method to calculate the financial stability of different regulators may develop different rating standards, the result will be different, so this paper does not give a rating standard, just give an example to illustrate the calculation method, and provide a new way for regulators.

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