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An Empirical Study of China's Financial Risk Early Warning Based on PSO-AHP Method

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Abstract

As economic globalization proceeds, China plays a more important role in the world's financial markets. In order to guard against financial risks effectively, we propose a financial risk early warning method based on PSO-AHP. First, we select early warning indicators of financial risk in our country, and build a hierarchy model which is composed by target layer, criterion layer and sub-criteria layer, then we use the financial risk early warning method based on PSO-AHP to calculate the weight of each criterion and sub-criterion layer, by using the financial data from 2006 to 2013 in China .The result shows that the overall financial risk in China has been in a very stable state, but external shock risk is still in high levels.

Keywords*: PSO, AHP, Financial risk, Early-warning index system*

1. Introduction

Financial risk exits in economic operation which mainly refer to final results deviate from the main body of financial activities in the economic activity expected results, therefore making income may lose, As recently part of national economic fluctuations caused by crude oil price fluctuations, etc. Financial risk exists in the financial system, in some ways it reflects the instability and vulnerability of today's global economy [1]. At the same time, financial risk also has concealment, potentiality and uncertainty, etc which can reflects the economic operation risk of a country or region. Since 1825, when British broken out the global financial crisis in the first time, the financial crisis has show a growing trend, the global economy run with a huge impacts. At the end of the 20th century as the economic globalization speed up the process, the frequency and influence scope of the financial crisis are on the rise, the harm is bigger than before. In the view of the great harm of the financial risks, in order to prevent financial risks effectively, many economists of the world have launched a research, and have obtained many achievements [2-4]. Sindy proposed the concept of financial early warning in 1979, economists began to study on financial risk from both theoretical and empirical sides, in the process, the focus of the study also towards to the direction of the combination of theoretical and empirical. In recent years, the subprime crisis and European debt crisis burst out which is a alarm to the global economy, under the background of economic globalization, any country is hard to possess[5-7]. China as an important part of the global financial markets which has

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beyond Japan as the world's second-largest economy in 2010. As an emerging market country, China has been rapidly into the global financial system since the reform and opening up to world. At the same time, the global financial system increasingly close with international trade to China not only brought great opportunities, but also leads to various financial risk and influence stability and development of China's financial. Due to China's special historical, there still exists in the lack of financial supervision, the backward relative laws and regulations, atmosphere of social speculation in economic development, which makes the possibility of potential financial risks further increase. China's economy will be greatly influenced by world economic development trend, and its own development will also affect the world's financial markets. Therefore, to establish a stable financial market, effectively guard against financial risk, set up a reasonable and effectively financial risks warning mechanism is a very important task in financial research.

Many scholars have carried out the research on the financial risk early warning. Li [8] puts forward the financial risks warning method based on PSO of optimizing the BP neural network, by improving the PSO optimization algorithm to optimize the threshold and weight of BP neural network, so as to improve the shortcomings of BP neural network effectively, such as it turns out slowly convergence and so on. Nan and Meng[9, 10] analysis of annual data through multiple countries, setting 13 warning variables and using PHM (proportional hazard model) to build the financial crisis warning model and verify its effectiveness. As well as other scholars also used BP neural network in the financial crisis warning, and use Southeast Asia financial crisis as the research object, to build a set of crisis early warning system [11, 12]. Huang [13] presents the RST-FNN model which combined with a rough set theory and fuzzy neural network, this model what he put forward through the way of extract the optimal rules, denoising and preventing redundancy away of the sample data, you can eliminate some shortcomings of fuzzy neural network effectively, finally the model is simulated by Matlab, the results show that the model has higher accuracy and faster convergence rate.

In a word, existing studies due to limited selection of indicators, which has affected the forecast effect. At the same time, most studies are based on banking crisis or currency crisis as research objects and also tended to choose the relevant indicators of these two subjects, thus unable to cover the whole risk within the financial system. PSO and AHP-based financial risk early warning model is proposed in this paper, selecting financial risk early warning indicators of China, building a financial risk early warning indicators hierarchy model which is composed with target layer, criterion layer and sub-criterion layer of our country, and PSO algorithm is used to calculate the weight of each criterion for target layers. Combined with 2006-2013 financial data validation, the early warning method is tested.

2. Selection of Early Warning Indicators

AHP method was proposed by Saadi in the early 1970's which is a combination of qualitative and quantitative within multiple-objective decision analysis. Its basic idea is to according to the nature of the problem to achieve general goal, and then according to the complexity of the problem decomposed into multiple factors, based on the subordinate relationship of each factor to build a multi-level structure model, finally the relative merits and weights of each factor are determined by multiple comparison. Because of the combination of qualitative and quantitative processing various decision-making factors, and its advantages of flexible, simple, and system, which has been widely attention and applied in social and economic fields, such as urban planning, energy system analysis, scientific research evaluation, economic management and so on.

Around our country finance risk overall situation, a hierarchical structure model of financial risk early warning indicators is built, which is composed with target layer,

criterion layer and sub-criteria layer[14]. Target layer is the core problem of this experiment, namely the early warning index system of financial risk in China; criterion layer including four main aspects of it, namely macroeconomic risk, banking system risk, external shock risk and other financial risk[14]; the sub-criteria layer is the representative index of the financial risk. As shown in Figure 1.

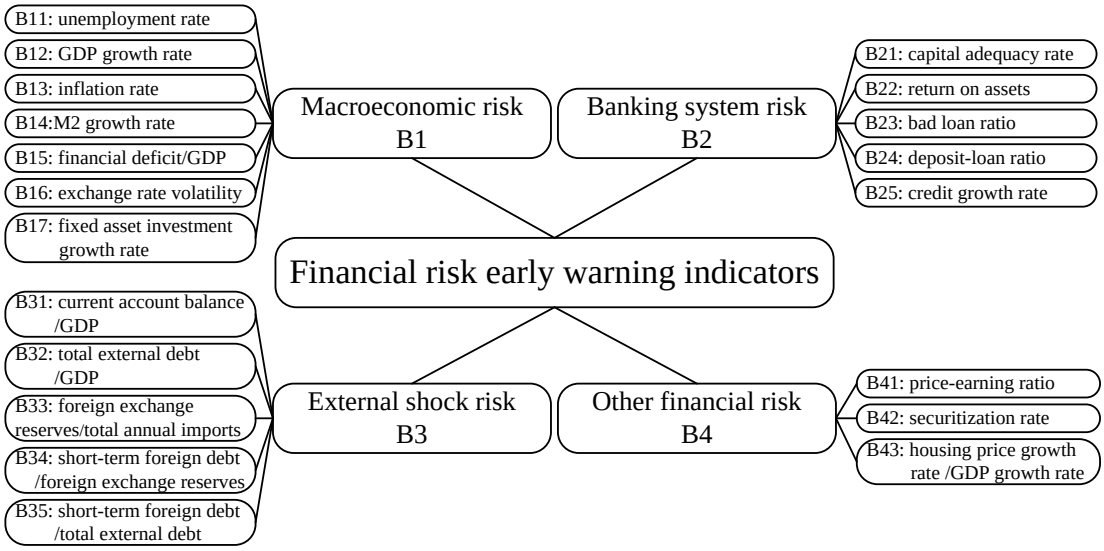

Figure 1. Financial Risk Early Warning Index System

3. Weight Calculation of Early Warning Indicators Based on PSO-AHP

3.1. AHP Model Construction

Using AHP[15] method for decision making, it is divided into the following four steps:

(1) Analyzing the relationship in each factor of system, set up a system of class hierarchy;

(2) Multiple comparison of the importance of a certain criterion in the upper level for each factor in same level, and building multiple comparison judgment matrixes;

(3) Relative weights of elements were calculated by the judgment matrix for criterion layer;

(4) Calculating and sorting the synthesis weights of all levels elements for system target.

AHP method is applied to the index system of financial risk to weight calculation, which need to make indicators are consistent. Generally, according to its value if less than 0.1, the results are acceptable, or have to adjust the judgment matrix. Constrained optimization problem, it can be converted to use computing intelligence method, more accurate than the traditional method.

According to the following method to calculate the weight of each factor[16]:

In the judgment matrix B=$\{ b_{jk} \}_{n\times n}$, k =1, 2,⋯, n. Where n is the number of elements of the hierarchy, b_{jk} is the first k line of the first j column elements. ω_j is the weights of the first j element, ω_k is the weights of the first k elements, then b_{jk} =ω_j/ω_k. If b_{jk}=0, then judgment matrix is completely consistent, so it defined as:

$$\sum_{j=1}^{n} \left| \sum_{k=1}^{n} (b_{jk}\omega_k - n\omega_j) \right| = 0 \quad (1)$$

Due to many influence factors in the index system of financial risk, it is difficult to

judge whether matrix is completely consistent, but the above equation can be transformed into constrained optimization problems. F_{CI} is defined as:

$$F_{CI} = \min \sum_{j=1}^{n} \left| \sum_{k=1}^{n} (b_{jk}\omega_k - n\omega_j) \right| / n \tag{2}$$

$$\omega_k > 0 \tag{3}$$

Then the final weight ω_j^A is calculated as:

$$\omega_j^A = \sum_{k=1}^{n} \omega_k \omega_j^k \tag{4}$$

where ω_j^A is lower j element for the total weights of top target A, ω_j^k is lower j element for the weights of k element. The correspondence index $F_{CI}^A(\omega_j^A)$ is defined as:

$$F_{CI}^A(\omega_j^A) = \sum_{k=1}^{n} \omega_k F_{CI}^k(\omega_j^k) \tag{5}$$

To construct judgment matrix, assignment of different levels is needed as shown in Table 1.

Table 1. Judgment Matrix Elements Assignment

ω_j / ω_k	9	7	5	3	1	2, 4, 6, 8
b_{jk}	A	B	C	D	E	Intermediate value of adjacent scale

*Notes:*A-*most important,* B-*very important,* C-*obvious important,* D-*slightly important,* E-*equally important*

3.2. Particle Swarm Optimization Algorithm

Particle Swarm Optimization (PSO)[17] algorithm is put forward which based on the study of birds swarm behavior, it can improve the speed of solving effectively, as for incomplete consistent problem of judgment matrix, the method combined with PSO and AHP can effectively improve the solution speedy. Due to traditional PSO algorithm in solving is still not perfect, so genetic idea is introduced to PSO algorithm in this paper. Its specific steps are as follows[18]:

(1) Random initialization population particle's position and speed;

(2) Solution of each particle's fitness, the position and speed are stored in their respective optimal particles value p_{best}, and the optimal particle's position and fitness value of all the p_{best} are stored in the global optimal value g_{best};

(3) Updating speed and position of each particle; (even) as for each particles, compared the adaptive value with the better adaptive value of their own experiences, if better, as the best current position;

(4) Comparing with the current all values of g_{best} and p_{best} , updating g_{best};

(5) Sorting the whole particle swarm according to fitness value, replace worse particles with better particles;

(6) If meet the search criteria to stop, otherwise go to the step (3).

(7) As the objective function, type (2) as the corresponding constraints, type (3) can be

obtained weight of each element, and the weight calculation of financial risk actually is a constrained optimization problem. In this paper, penalty function is used to convert it to the unconstrained optimization problem, and F is defined as:

$$F = V \sum_{i=1}^{n} e^{E \cdot |H_i|} \quad (2)$$

where V and E are weight vectors, n is the number of optimization variables, H_i is the constraint of inequality, $|H_i|$ is the Degree of deviation constraints. Using penalty function to adjust and optimize the process by changing the weight of each constraint.

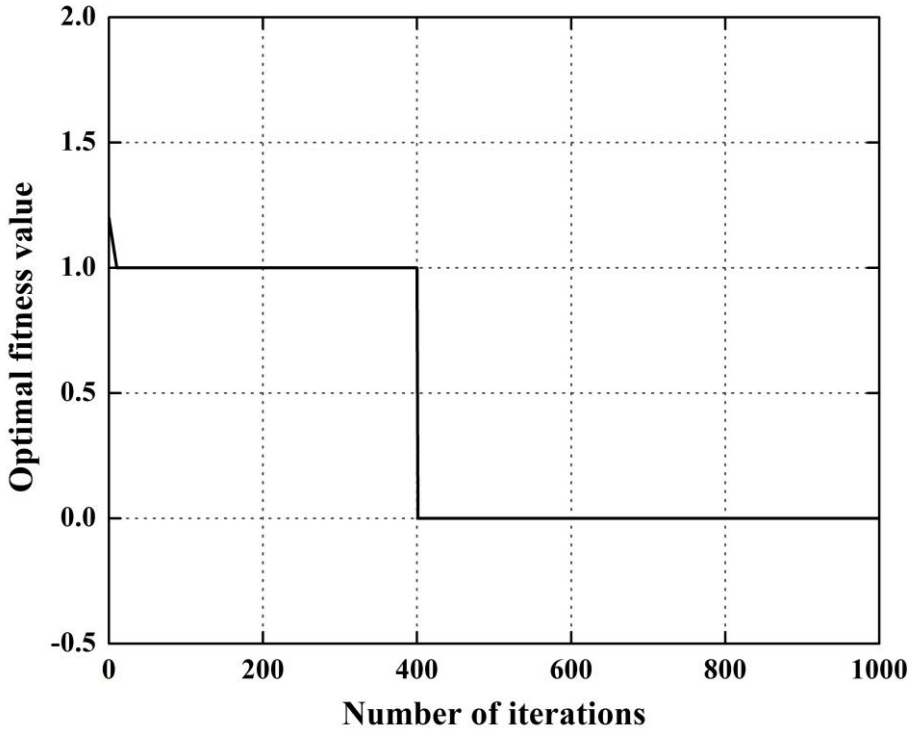

Figure 2. Calculation Process of Improved PSO-AHP Model

Using Matlab programming and the penalty function is applied to the solution which is not satisfy with constraints. Before 300 iterations, the solution does not meet the constraints, so even if H_i is small, the penalty function value is more than 1. After 300 iterations, the solution has meet constraints, and thus penalty function value is zero, which fitness value is equal to the original objective function, and stable convergence. Figure 2 is the calculation process of improved PSO-AHP algorithm.

4. Empirical Analysis

Analysis of the financial data from 2006 to 2013 involved in the index system. In the selection of early warning index system, sorting the impact of the indicators for the ultimate target. Therefore, on the basis of referring to the existing literature and research achievements, building judgment matrix of criterion layer (*i.e.*, macroeconomic risk, banking system risk, external shock risk and other financial risk), as follows:

$$B = \begin{pmatrix} 1 & 2 & 2 & 3 \\ 1/2 & 1 & 2 & 1 \\ 1/2 & 1/2 & 1 & 1/2 \\ 1/3 & 1 & 2 & 1 \end{pmatrix}$$

The weight of macroeconomic risk, the banking system risk, external shock risk and other financial institutions risk are respectively 0.4231, 0.2273, 0.2273 and 0.1221.

After determine the weights of sub-criteria layer, it is necessary to determine the weight of each criterion layer for the target, and therefore need to establish the judgment matrix. The judgment matrix of macroeconomic risk B1, banking system risk B2, external shock risk B3 and other financial risk B4 respectively as follows:

$$B1 = \begin{pmatrix} 1 & 3 & 5 & 1 & 2 & 5 & 2 \\ 1/3 & 1 & 2 & 1/3 & 1/2 & 2 & 1/2 \\ 1/5 & 1/2 & 1 & 1/3 & 1/3 & 1 & 1/3 \\ 1 & 3 & 5 & 1 & 2 & 5 & 2 \\ 1/2 & 2 & 3 & 1/2 & 1 & 3 & 1 \\ 1/5 & 1/2 & 1 & 1/5 & 1/3 & 1 & 1/3 \\ 1/2 & 2 & 3 & 1/2 & 1 & 3 & 1 \end{pmatrix},$$

$$B2 = \begin{pmatrix} 1 & 1 & 3 & 3 & 2 \\ 1 & 1 & 3 & 3 & 2 \\ 1/3 & 1/3 & 1 & 1 & 1/2 \\ 1/3 & 1/3 & 1 & 1 & 1/2 \\ 1/2 & 1/2 & 2 & 2 & 1 \end{pmatrix},$$

$$B3 = \begin{pmatrix} 1 & 1/3 & 1 & 1/2 & 1/5 \\ 3 & 1 & 3 & 2 & 1/2 \\ 1 & 1/3 & 1 & 1/2 & 1/5 \\ 2 & 1/2 & 2 & 1 & 1/2 \\ 5 & 2 & 5 & 2 & 1 \end{pmatrix},$$

$$B4 = \begin{pmatrix} 1 & 3 & 1/2 \\ 1/2 & 1 & 1/5 \\ 2 & 5 & 1 \end{pmatrix}$$

By testing, the above judgment matrixes are in line with the consistency check, if less than 0.1. The judgment matrix is solved using PSO-AHP method, getting criterion layer weight respectively to 0.4231, 0.2274, 0.2273 and 0.1221, the computed weights of sub-criteria layer as shown in Table 2.

Table 2. Computed Weights of Sub-criteria Layer

Macroeconomic risk B1	B11: unemployment rate	0.0361
	B12: GDP growth rate	0.1116
	B13: inflation rate	0.0206
	B14: M2 growth rate	0.1116
	B15: financial deficit/GDP	0.0613
	B16: exchange rate volatility	0.0613
	B17: fixed asset investment growth rate	0.0206
Banking system risk B2	B21: capital adequacy ratio	0.0713
	B22: return on assets	0.0224
	B23: ratio of non-performing loan	0.0713
	B24: deposit-loan ratio	0.0224
	B25: credit growth rate	0.0339
External shock risk B3	B31: current account balance/GDP	0.0189
	B32: total external debt/GDP	0.0189
	B33: foreign debt reserves/total annual imports	0.0581
	B34: short-term foreign debt/foreign exchange reserves	0.0374
	B35: short-term foreign debt/total foreign exchange	0.0940
Other financial risk B4	B41: price-earning ratio	0.0377
	B42: securitization rate	0.0134
	B43: housing price growth rate/GDP growth rate	0.0710

In the index system, the risk threshold of different indicators has different warning boundaries. For the domestic financial risk early warning, the selection of the early warning value is related to correctly judging the extent to which the country's financial crisis. Taking the external shock risk as an example to illustrate. There are five sub-criteria layers of the external shock risk, respectively from B31 to B35. In this paper, financial risk can be divided into four levels as shown in Table 3.

Table 3. The Critical Value and Safety Interval of Risk Grades

Sub-criteria layer	Safety	Light	Medium	Serious
B31: current account balance/GDP	[0, 3)	[3, 4.5]	(4.5, 5]	>5
B32: total external debt/GDP	<15	[15, 25]	(25, 40]	>40
B33: foreign exchange reserves/total annual imports	>6	[4, 6]	[3, 4)	<3
B34: short-term foreign debt /foreign exchange reserves	<40	[40, 80]	(80, 130]	>130
B35: short-term foreign debt/total external debt	<25	[25, 50]	(50, 70]	>70

Table 4 reflects the level of external shock risk. With China's accession to WTO, China is also increasingly affected by the international financial, so the external financial crisis will greatly affect China. From Table 4 we can see that global financial crisis on the effects of China is very large in 2008, an important part of economic growth is the export in China, after the outbreak of the global financial crisis seriously affected the export, as well as the United States and the European Union economic downturn affecting China's economy from multiple aspects. The external shock risk can be obtained by computed weights of each sub-criteria layer.

Table 4. External Shock Risk Grade

Year	B31	B32	B33	B34	B35	External shock risk B3
2006	serious	serious	safety	serious	medium	medium
2007	serious	serious	safety	serious	serious	medium
2008	serious	serious	safety	medium	medium	medium
2009	serious	serious	safety	medium	serious	serious
2010	serious	serious	safety	serious	serious	serious
2011	safety	serious	safety	serious	serious	serious
2012	safety	serious	safety	serious	serious	serious
2013	safety	serious	safety	serious	serious	serious

According to each sub-criterion layer, the risk of the criterion layers and target layers can be obtained. According to the data of different years, the financial risk levels can be divided into serious, medium, light and safety with their score range of [0, 20], [20, 50], [50, 80], [80, 100]. The whole comprehensive value of financial risk can be obtained from above. As shown in Figure 3, from 2006 to 2013, overall financial risk has been in a very stable state, but some indicators risks remain in the financial system. Experiencing the global financial crisis in 2008, risk scores in its highest level.

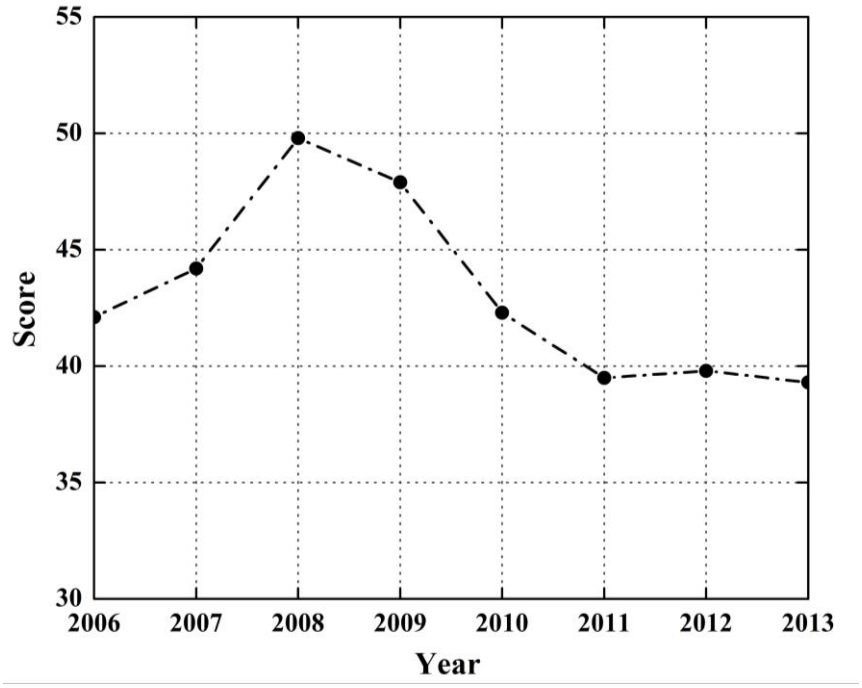

Figure 3. The Change Chart of Financial Risk Synthesis Score

5. Conclusions

In this paper, we propose a financial risk early warning model based on PSO–AHP method, and make the empirical analysis by using financial data from 2006 to 2013; the conclusions of this research are as follows:

(1) Around our country financial risk overall situation, we build a financial risk early warning index hierarchy model combined with the target layer, criterion layer and sub-criterion layer, and the model contains 20 indexes widely coverage of the index system;

(2) By using the approach of AHP and PSO, the improved particle swarm optimization algorithm and penalty function are applied to weights calculation of AHP, which effectively improve the solving efficiency;

(3) Combining the financial data from 2006 to 2013, we analyzed the financial risk, the results show that the overall financial risk was in a very stable state, but some indicators risks remain in the financial system. Through the global financial crisis in 2008, the risk score is highest.

As mentioned above in this paper, the financial risk early warning method based on PSO-AHP is feasible and reasonable; it can provide important reference for financial risks warning, which has a very important practical significance.

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