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A Construction and Empirical Test for Financial Risk Assessment

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Abstract

The financial liberalization and opening-up of China contributes to the uncertainty of financial market, which means it is urgent to establish the financial risk assessment. A financial risk assessment model is designed through modified Grey Relating TOPSIS. The financial risk index system synthetically takes into account three aspects including Domestic Real Economy, Domestic Financial System and Balance of Payments. In view of the time lag, the date of each indices has been adjusted by AR (p). Then the weights of indices are determined by combination assigning method. In addition, to eliminate multicollinearity, PCA is adopted to reduce indices' dimensions. Grey Relating TOPSIS is employed to measure financial risk. The evidence from Chinese financial history can support the model appropriately.

Keywords: financial risk assessment, AR (p), PCA, grey relating TOPSIS

1. Introduction

As the "nerve center" of national economy, finance has been the core of national economic system (J. S. Zhang, 2012). Nevertheless, financial crises occurred frequently in recent years, causing serious losses to the economy. With a series of economic indicators, Chinese financial risk rating system is established to guard against financial risk.

In recent years, with the development of the mathematical economic, the financial risk assessment model uses its achievements as reference. Frankel and Rose (1996) set up probit model/logit through financial crisis samples of 100 developing countries from 1971 to 1992. Kaminsky, Lizondo and Reinhart (1998) put forward KLR signal analysis which can react to financial crisis via market pressure index. Kumar, Moorthy and Perraudin (2002) proposed Simple Logit Model based on the hysteretic macroeconomic and financial data.

An increasing number of theoretical and empirical research about financial risk assessment has been done at home and abroad, but there are not ever effective models and methods to identify systemic financial risk. At present, the existing risk rating model gives priority to currency crises or banking crises, causing evaluation indicators incomplete, which obtains flawed results (J. Zhang, 2012).

In August of 2000, IMF put forward relatively macro financial prudence index system, namely the financial sound index system, to evaluate the national security. In recent years, some scholars have discussed the indices of the financial risk assessment. By taking the pressure index in financial crisis as the explained variable, and lagging macroeconomic variables, credit variables, asset price variables and relevant macroeconomic variables as explanatory variables, Lv and Lai (2010) established the index system of financial risk prediction.

In this paper, the index system of the financial risk assessment is established based on variables of Domestic Real Economy, Domestic Financial System and Balance of Payments. A modified Grey Relating TOPSIS is applied to evaluate Chinese financial market risk, which contributes to preventing Chinese financial risk as a reference.

2. Financial Risk Assessment Model

Since 1980s, the Financial Liberalization has destabilized the financial system, causing banks and financial markets to encounter a more complicated and changeable macroeconomic environment, which calls for the research on financial risk. In this paper, the hysteresis of indices is built through AR (P) model and weighted the indices, then the decision matrix is built by combination weighting approach and PCA (Principal Component Analysis). Finally, Grey Relating TOPSIS is adopted to evaluate financial risk.

2.1 Hysteresis Examine: AR (p)

To examine the lagging indices, we use Autoregressive Model, a linear stationary time series model, to determine the lag phase of each indices (Wei & Shuai, 2014). This model which needs not to consider the sequence of white noise. AR(p) is suitable for simulation analysis to the datum with the features of stability, normality and zero-mean (Lv & Juan, 2011). The AR(p) model is expressed as follows:

$$u_t = c + \phi_1 u_{t-1} + \phi_2 u_{t-2} + \cdots + \phi_p u_{t-p} + \varepsilon_t, t = 1, 2, \cdots, T \tag{1}$$

Where the parameter c represents a constant; ϕ_p represents the pth parameter in the autoregressive model; ε_t represents the white noise sequence whose mean value is zero and the variance is . Yule-Walker equation is utilized to obtain the estimate value $\hat{\phi}_p$ from the regression coefficient φ_p :

$$\begin{bmatrix} \hat{k}_0 & \hat{k}_1 & \cdots & \hat{k}_{p-1} \\ \hat{k}_1 & \hat{k}_0 & \cdots & \hat{k}_{p-2} \\ \vdots & \vdots & & \vdots \\ \hat{k}_{p-1} & \hat{k}_{p-2} & \cdots & \hat{k}_0 \end{bmatrix} \begin{bmatrix} \hat{\phi}_1 \\ \hat{\phi}_2 \\ \vdots \\ \hat{\phi}_p \end{bmatrix} = \begin{bmatrix} \hat{k}_1 \\ \hat{k}_2 \\ \vdots \\ \hat{k}_p \end{bmatrix} \tag{2}$$

According to $\hat{\gamma}_t = \dfrac{\hat{k}_t}{\hat{k}_0}$, both sides of the equation are divided by , then substitute the values of $\hat{\gamma}_1, \hat{\gamma}_2, \cdots, \hat{\gamma}_p$ into the equation. As a result, we can get the AR (p) model equation:

$$u_t = c + \hat{\phi}_1 u_{t-1} + \hat{\phi}_2 u_{t-2} + \cdots + \hat{\phi}_p u_{t-p} \tag{3}$$

The lag period of each indices can be obtained. Finally, the indices whose lags are 0 are considered as comparison base period. We adjust the data based on the equation AR(p) to eliminate lag effects of indices. Synchrony indices can be more effective in reflecting the internal factors of evolutional features of the financial crisis (Wei & Shuai, 2014).

2.2 Construction of Decision Matrix: Combination Assigning Method & PCA

In order to avoid the effect of subjective weights, objective weighting method is used in this paper. Considering the different dimensions and directions among indices, we firstly handled them through normalization and uniformization. Then the weight of each indices is computed through Correlation Coefficient Method and Variation Coefficient Method:

$$w_1, w_2, \cdots, w_n$$

Firstly, Correlation Coefficient Method confirms weights based on the correlation between the indices, which means the smaller correlation of an index with others. The stronger its independence is, the larger its weight is. Secondly, Variation Coefficient Method utilizes information content. If an index is more different among evaluated objects, it contains more information and its weight would be larger (Wei, 2013).

To avoid the deviation results from the repeating contents of indices, PCA is employed to extract independent primary components through index dimension reduction. Primary components, whose eigenvalues is more than 1, would be extracted and shape the decision matrix.

2.3 Financial Risk Assessment: Grey Relating TOPSIS

Traditional TOPSIS adopts Euclidean Distance to calculate the linear difference between alternative object and ideal index, but fails to reflect non-linear relationship between sequences. However, Grey Relating TOPSIS can

reflect the non-linear relationship among sequences properly, compensating TOPSIS's disadvantage. The grey relating modulus are as follows:

$$\xi_{ij} = \frac{\min\limits_{i}\min\limits_{j}\left\{\Delta_{ij}^{+}\right\} + \rho\max\limits_{i}\max\limits_{j}\left\{\Delta_{ij}^{+}\right\}}{\Delta_{ij}^{+} + \rho\max\limits_{i}\max\limits_{j}\left\{\Delta_{ij}^{+}\right\}} \tag{4}$$

Where, ξ_{ij} is grey relating modulus; Δ_{ij}^{+} is the optimal distance between the *j*th index value of the *i*th object and the optimum value of its index. And ρ is differentiated coefficient, which can control variation range of grey relating modulus and ranges from 0 to 1.so ρ is valued 0.5 like usual.

According to the modulus matrix, we can calculate the distance of each objects to ideal solution can be computed. Then relative closeness of each object to ideal solution is regarded as :

$$C_i^{+} = \frac{d_i^{-}}{d_i^{+} + d_i^{-}}, i = 1, 2, \cdots n \tag{5}$$

Where, C_i^{+} is comprehensive score of the *i*th object. d_i^{+} is the distance between the *i*th object and positive ideal solution, and d_i^{-} is the distance between the *i*th object and negative ideal project.

The closeness ranges from 0 to 1. If the closeness approaches to 1, the evaluation object is closer to risk-free status of the financial market. And vice versa, the risk of this object is higher.

2.4 Risk Rating Based on Single Index and Comprehensive Score

In order to monitor the financial system comprehensively, so many critical values has been set to get financial risk's source, which would help control risk. Considering that different index has different influence on the financial environment, the datum need been normalized. The risk rating is determined based on the distance between values of each indices and its mean, which is in terms of each standard deviation. The reference standard is shown in Table1.

Table 1. Reference standard for financial risk rating

Range	<0.75*std*	0.75*std*-1.5*std*	1.5*std*-2*std*	>2*std*
State	Safe	Low Risk	Semi-high Risk	High Risk
Rating	0	1	2	3

3. The Empirical Assessment of Financial Risk in China

Nowadays, financial crises occur frequently and cause serious losses to the economy of the stricken countries and the whole world. A common problem faced by different countries is how to guard against the financial crisis effectively and how to minimize the negative impacts produced by financial crises. Based on three aspects including the Domestic Real Economy, Domestic Financial System and Balance of Payments, an index system of financial risk assessment is established and used to grade and rank Chinese financial environment by the economic datum from 2004 to 2013.

3.1 The Financial Risk Index System

Due to the fact that economic fluctuation and accumulation of financial risks are transmitted and spread by a series of financial activities, the fluctuation of any single economic variable cannot represent the overall economy's volatility. Since accession to WTO in 2001, China has accelerated the opening-up of economy and finance to foreign countries. Especially since December, 2006, the stability of financial market in China could be influenced by both home and oversea circumstances due to the full opening-up of financial industry. Ya-Jing Sun and Wei MA demonstrated the necessity and feasibility of the index system of the financial warning. Based on three aspects including the domestic real economy, the domestic financial system and balance of payments, a seasonal financial risk index system, including 20 indices, is employed to evaluate the financial environment of China. Table 2 demonstrates specific indices:

Table 2. The index system of financial crisis risk

Category	Index
Domestic Real Economy (R)	Deficit/GDP (R1), National Finance Income/GDP (R2), Fixed Asset Investment/GDP (R3), Fluctuation of Agricultural Production Price Index (R4), National Debt/GDP (R5), Investment Price in Fixed Assets(R6), Volatility of GDP (R7)
Domestic Financial System (F)	Volatility of Shenzhen Composite Index (F1), Volatility of Shanghai Composite Index (F2), Volatility Index of 30-day Interest Rate (F3), Deposit-to-Loan Ratio (F4), M2 / Foreign Exchange (F5), Asset-Liability Ratio (F6) Volatility of Loan (F7), Volatility of M2 (F8), Price of Stock Market /GDP (F9)
Balance of Payments (B)	Net Exports/GDP (B1), Volatility of Exchange Rate to US Dollar (B2), Volatility of Gross Export Values (B3), Volatility of Foreign Exchange Reserves (B4)

The datum can be obtained from the People's Bank of China, the National Bureau of Statistics of China, China Banking Regulatory Commission (CBRC) and IFB. In consideration of the large number of indices, indices are represented by the identifiers.

3.2 The Hysteresis Examine for Indices

Table3 shows the result of the time-lag calculation of financial risk indices by AR (p). There is one index with 5 lag period in Domestic Real Economy, four indices in Domestic Financial System and three indices in Balance of Payments. These statistics indicate that domestic economic sector, with shorter effect of the time-lag, is rather sensitive when reacting to the change of the market, which also eases it foresee the risk.

Table 3. The result for hysteresis examination

Index	Lagging Period	Index	Lagging Period
R7	5	F6	5
R6	2	F5	5
R5	0	F4	5
R4	2	F3	3
R3	0	F2	3
R2	1	F1	1
R1	4	B4	5
F9	0	B3	5
F8	4	B2	5
F7	5	B1	4

To process the hysteresis quality, these datum are weighted according to the lag period of each indices, which diminishes the data volume, leaving only the indices from 2005 to 2013. This analysis improves the reliability of risk evaluation, and can reflect the internal factors of the features when financial crisis evolves.

In order to eliminate the influence of periodicity and seasonality, we will process the growth rate index into the chain relative index and other indices into the corresponding seasonal indices. In addition, in order to eliminate different dimensions, the indices are inverted to the maximum indices through normalization and unification.

3.3 The Determination of Decision Matrix

In order to avoid the subjective influence on assessment, a combination assigning method, including Correlation Coefficient Method and Variation Coefficient Method, is adopted to confirm the weight of each indices. The weights of financial risk indices are shown in Table4.

In Table 4, Domestic Real Economy, Domestic Financial System and Balance of Payments weighs 32.08%, 42.68% and 25.24%. In table 3, indices of the five biggest weights are as high as 35.01%, including Volatility of Exchange Rate to US Dollar, Asset-Liability Ratio, Volatility of Exports, Fiscal Deficit/GDP and Deposit-to-Loan Ratio. Balance of payments and Domestic Financial System have two indices respectively, while Domestic Real Economy has one index there. All the weights range from 4% to 9%, and most of them weigh 4% to 5%, where Volatility of Exchange Rate to US Dollar and banks' Asset-Liability Ratio weigh over 8%.

Obviously, the financial indices reflect the domestic financial environment. As a result, the domestic financial

sectors have a greater influence on the economy. The global economic crises would spread to the whole world through the national departments in charge of Balance of Payments, affecting national financial environment. In addition, national policies would, to some extent, affect Chinese financial environment.

Table 4. Weights of financial risk indices

Index	Correlation Coefficient Method	Variation Coefficient Method	Average
R1	0.0643	0.0481	0.0562
R2	0.0442	0.0445	0.0443
R4	0.0494	0.0451	0.0473
R5	0.0419	0.0365	0.0392
R6	0.0445	0.0463	0.0454
R6	0.0465	0.0395	0.0430
R7	0.0419	0.0487	0.0453
F1	0.0560	0.0215	0.0388
F2	0.0527	0.0256	0.0391
F3	0.0583	0.0271	0.0427
F4	0.0529	0.0546	0.0538
F5	0.0530	0.0404	0.0467
F6	0.0473	0.1187	0.0830
F7	0.0514	0.0349	0.0431
F8	0.0491	0.0343	0.0417
F9	0.0428	0.0328	0.0378
B1	0.0502	0.0484	0.0493
B2	0.0561	0.1266	0.0913
B3	0.0528	0.0788	0.0658
B4	0.0445	0.0475	0.0460

Considering the multicollinearity among indices, which would affect the result of the assessment, PCA is adopted to reduce dimensions and make indices independent from each other. The total variance of the financial index system is shown in Table 5. Indices whose eigenvalues are greater than 1 are extracted as the primary components.

Table 5. The total variance of the financial index system

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	5.976	29.879	29.879	5.976	29.879	29.879
2	4.072	20.361	50.240	4.072	20.361	50.240
3	3.304	16.521	66.760	3.304	16.521	66.760
4	1.367	6.833	73.593	1.367	6.833	73.593
5	1.299	6.496	80.090	1.299	6.496	80.090
6	0.930	4.650	84.740			
7	0.850	4.250	88.990			
…	…	…	…			
15	0.068	0.342	99.406			
16	0.048	0.240	99.646			
17	0.034	0.170	99.815			
18	0.025	0.126	99.941			
19	0.011	0.054	99.995			
20	0.001	0.005	100.000			

From Table 5, 5 primary components are extracted and their variances are 29.879%, 20.361%, 29.879%, 6.833% and 6.496%. The cumulative contribution reaches 80.09%. According to the contribution, the decision matrix is formed after weighing this five primary components.

3.4 Financial Risk Rating

Using Grey Relational TOPSIS to deal with decision matrix, the scores of financial risk are computed, which indicates the closeness to positive ideal solution. The greater the value of the closeness the safer the financial environment is, and vice versa. Meanwhile, we evaluate the seasonal risk of financial environment from 0 to 3 by relative distance. The higher the rating is, the greater the risk of the financial environment is. Table 6 shows the risk rating of financial environment from 2005 to 2013. Figure1 shows scores' quarterly trend of the financial risk.

Table 6. The quarterly financial risk rating in 2005-2013

Time	Composite Score	Risk Rating	Time	Composite Score	Risk Rating
2005.02	0.573336	0	2009.04	0.576083	0
2005.03	0.584196	0	2010.01	0.551089	2
2005.04	0.568059	0	2010.02	0.569012	0
2006.01	0.567311	0	2010.03	0.562596	0
2006.02	0.562613	0	2010.04	0.544413	2
2006.03	0.56269	0	2011.01	0.557517	1
2006.04	0.57167	0	2011.02	0.554111	1
2007.01	0.563811	0	2011.03	0.5664	0
2007.02	0.550711	2	2011.04	0.567943	0
2007.03	0.553136	2	2012.01	0.587452	0
2007.04	0.540529	3	2012.02	0.58245	0
2008.01	0.558328	1	2012.03	0.596824	0
2008.02	0.550815	2	2012.04	0.582355	0
2008.03	0.536953	3	2013.01	0.612608	0
2008.04	0.557119	1	2013.02	0.641912	0
2009.01	0.595928	0	2013.03	0.638937	0
2009.02	0.591032	0	2013.04	0.6197	0
2009.03	0.600483	0			

Note. 0, 1, 2 and 3 represent safe condition, low risk condition, semi-high risk condition and high risk condition respectively. In Table 6, high risk condition occurs twice and semi-high risk condition occurs five times while low risk condition occurs four times.

From 2005 to 2006, China's financial environment is in a favorable condition, and the development of financial market is continuously stable. From the second quarter in 2007 to the fourth quarter in 2008, China's financial environment has been in great risk. The outbreak of subprime housing crisis in US during 2007 to 2008 caused the financial crisis to spread to the whole world and greatly affected China's financial market. On the other hand, catastrophes like the snowstorm and earthquake in Sichuan and events like the Beijing Olympics in 2008 have also made the financial market unstable.

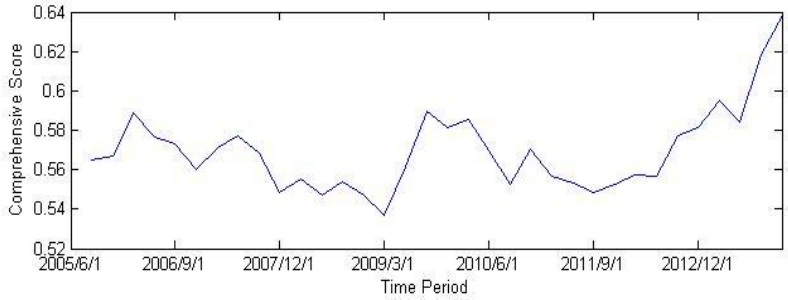

Figure 1. The trend of the financial risk

The semi-high risk condition has been lasted during the first quarter of 2010, followed by the lower risk condition from the fourth quarter of 2010 to the second quarter of 2011, which is probably from the lag effect in

2009 when the government invested 4 trillion RMB to stimulate the economy.

From 2012 to 2013, China's financial risk assessment model does not issue any warning signal, which indicates that the current condition of the financial market is favorable.

3.5 Single Index Analysis for Financial Risk

In order to further analyze the causes of the various financial risks, the level of risk of each indice is determined by comparing the various indices' boundary value, which is beneficial for the analysis of financial conditions and provides some reference for subsequent policies.

Ratings of financial risk indices from 2005 to 2011 are shown in Table 7. Only a part of the indices are demonstrated because of the constant safe condition of China's financial environment in 2011. The risk grade of each single indices ranges from 0 to 3. 0 indicates that the signal level index is in a safe state. The higher number indicates the greater the degree of deviation from the normal, which means that the content of its index is in dangerous condition.

In 2005 the volatilities of M2/ foreign exchange and foreign exchange reserves always deviate from the normal state, which is related to the reform of financial market and the RMB exchange rate in 2005. But due to the micro effect, the signal of financial market risk does not occur.

In 2007, the fluctuations of Shanghai Composite Index was abnormal and prices index rose sharply，leading to the occurrence of the high risk signal in 2007. In 2008, the high fluctuation of exchange rate to US dollar demonstrated that the American subprime crisis had spread to China, impacting China's financial market seriously. The risk signals in China's financial market occurred steadily.

Table 7. Part of the rating of financial risk indices from 2005 to 2011

Time	R1	R2	R3	R4	R5	F1	F2	F3	F4	F5	F6	F7	B1	B2	B3	B4
2005.02	0	0	0	0	0	0	0	0	0	3	0	1	0	0	0	3
2005.03	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	2
2005.04	1	0	0	0	0	0	0	0	0	2	0	1	0	0	0	0
2006.01	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
2006.02	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
2006.03	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
2006.04	2	0	0	0	0	0	2	0	0	1	0	0	0	0	0	0
2007.01	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	1
2007.02	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	1
2007.03	0	0	0	2	0	0	3	0	0	0	0	0	0	0	0	2
2007.04	1	0	0	2	0	0	1	0	0	0	0	0	0	0	0	1
2008.01	0	0	0	3	0	0	0	0	1	0	0	0	0	3	0	1
2008.02	0	0	0	2	0	0	0	0	1	0	0	0	0	3	0	0
2008.03	0	0	0	0	0	0	0	0	2	0	0	0	0	3	0	0
2008.04	2	0	0	0	0	0	1	1	2	0	0	0	0	0	0	0
2009.01	0	0	0	0	0	0	0	1	0	0	0	2	0	0	3	0
2009.02	0	0	0	0	0	0	0	1	0	0	0	3	0	0	3	0
2009.03	0	0	0	0	0	0	0	1	0	0	0	3	0	1	3	0
2009.04	2	0	0	0	0	2	0	0	0	0	0	3	0	0	0	0
2010.01	0	0	0	0	0	3	0	0	0	0	0	0	1	0	0	0
2010.02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
2010.03	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
2010.04	2	0	0	1	0	0	0	3	0	0	0	0	0	0	0	0
2011.01	0	0	1	1	0	1	0	1	1	0	1	0	2	0	0	0
2011.02	0	1	0	1	0	1	0	2	1	0	1	0	0	0	0	0
2011.03	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0
2011.04	2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0

The loan in 2009 fluctuated hugely, which was a reaction to the 4-trillion Economic Stimulus Practice, resulted in a higher risk condition.

After 2010, the datum of each indices tended to be normal and never drastically deviated from the normal value in a long-term. Compared to the actual situation, China's financial market is stable and favorable after 2010.

After analyzing the indices of each periods and comparing to the financial environment at that time, it is found that the rating results of single index risk match with the current situation, which can be used to analyze the causes of the signal of the financial crisis.

4. Conclusion

This paper utilizes a financial market risk index system to analyze the financial environment. Grey Relating TOPSIS is employed to evaluate the financial environment of China from 2005 to 2013, based on the financial risk index system including 20 indices from three departments: Domestic Real Economy, Financial System and Balance of Payments.

Considering the lagging of indices, AR (p) is adopted to test the hysteresis. Then the combination assigning method, including Correlation Coefficient Method and Variation Coefficient Method, is utilized to determine the weight of each index. To avoid the duplication of indices, PCA is employed to reduce the dimensions so that independent primary components indices are generated. Finally, due to the non-linear relationship between the index sequences, Grey Relating TOPSIS is engaged to rate for each period of the financial environment. Meanwhile, by using the standard deviation, the risks of single index and composite score can be graded, so that we can analyze the source of financial risk. The government can intervene the financial market properly when under high risk status. Because of obvious seasonality of most of the indices ,the methods of seasonal index number and link relative ratio are adopted to eliminate the seasonalities in the process of data preprocessing.

The empirical results, to some extent, match the situation in reality and has a guiding significance to cope with China's financial market risk. Recently, however, the indices on National Debt/GDP and Price of Stock Market /GDP are still in risk status. As a result, this paper suggests that individual investors be cautious to enter the market.

According to the circumstances of the different periods, the model can automatically choose better indices to achieve the synchronization between risk assessment and reality. In addition, in order to adapt financial transformation to current situation, we may further explore how to determine dynamic weights.

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