Measurement and Forecasting of China's Financial Stress Index in the A-E-G Coupling Perspective

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Abstract. After the outbreak of the global financial crisis in 2008, many scholars began to quantify financial risks and find alternative variables to reflect financial risks better. The financial stress index is a good alternative. In this paper, nine important factors of economic aggregate, economic benefit, and economic structure are selected to construct China's Financial Stress Index (CFSI). Then, the coupling identification of AHP and entropy weight method (A-E) is carried out, and the CFSI and its fluctuation are predicted by the grey dynamic prediction model GM(1, N). The results show that the CFSI constructed by a-E coupling weight can measure the pressure of China's financial system more accurately, and the CFSI is predicted to show A gentle decline trend from 2022 to 2024. Inspired by previous studies by scholars, this paper tries to construct and predict CFSI from the perspective of A-E-G coupling, combining subjective and objective, and hoping to open new ideas on CFSI construction and prediction.

Keywords: GM(1,N) model; Financial stress index; AHP model; EWM model.

1. Introduction

The global market's transmission speed of financial risks has been accelerating with the continuous development of economic globalization, financial innovation, and financial liberalization after the 1980s. The outbreak of the global financial crisis in 2008 reflects that there are still deficiencies in the financial supervision system of all countries in the world. At the 19th National Congress of the Communist Party of China, General Secretary Xi Jinping also made it clear that "the bottom line of financial risks should be firmly guarded." Many scholars also attach great importance to the study of financial risk measurement, hoping to find alternative variables to reflect financial risk. Moreover, the financial stress index is just one of the essential indicators of financial risk early warning. A reasonable financial stress index can accurately reflect the stability of the financial system, effectively identify and prevent systemic financial risks, and maintain financial stability. Therefore, it is necessary to construct a national financial stress index, which can serve as the navigator and vane of China's finance.[14]

In the early stage, the fixed weight method compiled the pressure index. Liu [1] selected nine indicators, such as credit institutions and the stock market, and constructed the Canadian Financial Stress index using factor analysis and equal variance weighting. Hakkiot and Keton[2] constructed the famous Kansas Financial stress index using the principal component method. In recent years, domestic scholars have also studied the financial stress index. Wang [3] used daily data, including market information of banks, stocks, bonds, and foreign exchange, and constructed financial stress indexes of China, the United States, Germany, and Japan using equal variance weight, principal component analysis, and factor analysis, and verified the accuracy and universality of the indexes through event analysis and MS-DR model. Ding Hui et al. [4] measured the pressure faced by China's financial market from four aspects of currency, bonds, stocks, and foreign exchange. Then, based on the dynamic correlation coefficient method and dynamic credit weighting method, they synthesized The Stress index of China's financial market (CFMSI) and established the Markov zone transfer (MS-VAR) model to test its nonlinear effect on the macroeconomy. Zhang [5] analyzed the relationship between the financial stress index and social financing growth rate using the VAR model. According to China's financial market characteristics, Li and Liang Shuang [6] selected 17 representative indicators of the bond market, stock market, money market, and foreign exchange market. They constructed stress indexes of each sub-market using the accumulated experience distribution function method. The time-varying correlation among various sub-markets characterizes the cross-market contagion characteristics of systemic financial risks. The stress index of the financial market is synthesized, and the stress state of the financial market is identified by the transformation model of the Markov zone system.

In the past, invariable parameters, single dimension regression, and other methods were used to determine the weight of financial variables, or the subjective assignment method was used to determine the weight. However, with the diversity and complexity of economic and financial forms, the financial stress index obtained by subjectively assigned weights or static and definite weights is too subjective or can only measure the financial stability and future trend consistently for a long time, and cannot sufficiently adapt to the complex and diverse situation changes.[14]Inspired by previous studies, this paper attempts to construct and predict CFSI from the perspective of A-E-G coupling. A-e coupling identification is carried out first, followed by GM (1, N) prediction. Finally, empirical analysis and data processing is carried out. The combination of subjective and objective is expected to open up new ideas about CFSI construction and prediction. Then it provides some new thinking directions for the index selection and construction of the financial stress index and the research of weight selection. This study is conducive to the construction and prediction of the index selection of financial index and provides a certain basis for selecting a weight, which combines subjective and objective.

2. CFSI definition and index system construction

2.1 China's financial Stress Index

Financial stress refers to the pressure brought to economic institutions by the uncertainty of financial institutions and the market and the constantly adjusted expectations and is an important indicator to measure the risk of the financial system [7].CFSI is a continuous variable, and when it reaches an extreme value, it shows a financial crisis. Its value increases with the increase of uncertainty or risk and financial expected loss. The strength of shock and the contagion ability of shock in the fragile financial system determines the size of financial pressure. The financial stress index is a comprehensive index synthesized by a series of index variables that can map the pressure state of various subsystems of the financial system. If its value exceeds the threshold, it indicates that the systemic financial risk exceeds the threshold; otherwise, it exceeds the threshold. When the index value exceeds a certain critical value, it indicates that the economy has been under pressure needing attention [7].

2.2 CFSI index construction

This paper intends to use grounded theory to process data and construct indicators. Grounded theory is a process of analyzing and sorting out phenomena by the inductive method and developing and verifying theories by summarizing the laws contained in complex economic phenomena [8]. Strauss[9] pointed out that grounded theory emphasizes the construction of theoretical models based on the deduction of case data, and its development comes from the continuous exploration of data collection and analysis.

Data collection and coding. Based on the research needs, this paper collects literature about the financial stress index from THE CNKI database as the research basis and carries out data coding on this basis.

The literature survey found that the existing domestic financial stress research still mainly selects monthly index data in the economic and financial fields to construct financial stress index [3-7]. Therefore, from the three dimensions of economic aggregate, economic benefit, and economic structure, this paper integrates the source indicators reflecting the changes of pressure in China's financial market, namely, domestic and foreign currency deposits, GDP, foreign exchange, fiscal revenue, import and export balance, national housing boom index, macroeconomic boom index, money supply, and CPI. The specific CFSI index is designed as 0-100.0-50 indicates that financial system pressure is at a low level and the financial system is under a small pressure.50-100 indicates that financial pressure is at a high level. The higher CFSI is, the greater pressure the financial system will bear, and the greater the financial risks.

Table 1 Source index of pressure change in the financial market

Level indicators	Leve2 indicators	Index number	Plus or minus the sex	Paraphrase	Reference
Economy	Local and foreign currency deposits	X_1	negative	The total amount of renminbi and foreign currency deposited with financial institutions.	[6][14]
	GDP	X_2	negative	Gross domestic product	[5]
	Foreign currency	X_3	negative	A bond is available to monetary authorities in a balance of payments deficit.	[6][14]
Economic benefits	Fiscal revenue	X_4	negative	The sum of all funds raised by the government to fulfill its functions, implement public policies and provide public goods and services.	[4]
	Import and export balance	X_5	negative	The difference between total exports and total imports	[5]
	National housing index	X_6	negative	National real estate development industry composite prosperity index	[7]
The economic structure	Macroeconomic climate index	X_7	negative	It reflects entrepreneurs' feelings and confidence in the macroeconomic environment and predicts the changing trend of economic development.	[15]
	Money supply	X_8	The middle type	The sum of cash and deposits in circulation at a given point.	[6][14]
	CPI	X_9	The middle type	A macroeconomic indicator reflecting changes in the price level of consumer goods and services generally purchased by households.	[5]

3. The Coupling of Analytic Hierarchy Process and Entropy Weight Method

3.1 Analytic Hierarchy Process

The core idea of this method is to decompose a complex problem into several levels to choose the best decision. AHP has the advantages of flexibility, simplicity, and qualitative and quantitative [10]. Specific steps of AHP are as follows.

STEP1 Build a hierarchical structure model.

STEP2 Compare the importance of two elements according to certain criteria and define the judgment matrix $A=\left(a_{ij}\right)_{n\times n}$ based on the Satty scale method.

STEP3 Using the consistency ratio CR as an index, which is defined as follows:

$$CR=\frac{CI}{RI} \tag{1}$$

CI is the consistency index:

$$CI=\frac{\lambda_{\max}-n}{n-1} \tag{2}$$

Where $\lambda_{\max}$ is the eigenvalue of the maximum of the judgment matrix, and RI is the mean random consistency index. When $CR<0.10$ the judgment matrix is considered valid, it needs to be corrected. Finally, the ranking weights are obtained.

3.2 Entropy Weight Method

The Entropy Weighting Method (EWM) is used to quantify the impact of the relative degree of change of an indicator by calculating its information entropy. The greater the degree of the change, the greater the weight is. The EWM is an objective assignment method that can avoid subjectivity [11].EWM consists of the following three main steps.

STEP1 Standardization of data matrix. The indices are converted into positive indicators, and the normalized matrix is obtained as follows:

Positive type:

$$z_{ij} = \frac{x_{ij} - x_{j\min}}{x_{j\max} - x_{j\min}} (i = 1, 2, \cdots, m; j = 1, 2, \cdots, n) \tag{3}$$

Negative type:

$$z_{ij} = \frac{x_{ij} - x_{j\min}}{x_{j\max} - x_{j\min}} (i = 1, 2, \cdots, m; j = 1, 2, \cdots, n) \tag{4}$$

Intermediate type: the best index value is x_{best}:

$$z_{ij} = 1 - \frac{\left|x_{ij} - x_{best}\right|}{\max\left\{\left|x_{ij} - x_{best}\right|\right\}} (i = 1, 2, \cdots, m; j = 1, 2, \cdots, n) \tag{5}$$

Interval type: the best index value is the interval $[a, b]$:

$$z_{ij} = \begin{cases} 1 - \dfrac{a - x_{ij}}{\max\{a - \min\{x_{ij}\}, \max\{x_{ij}\} - b\}}, x_{ij} < a \\ 1 \qquad , \qquad a \le x_{ij} \le b \\ 1 - \dfrac{x_{ij} - b}{\max\{a - \min\{x_{ij}\}, \max\{x_{ij}\} - b\}}, x_{ij} > b \end{cases} \tag{6}$$

$$(i = 1, 2, \cdots, m; j = 1, 2, \cdots, n)$$

STEP2 Calculate the information entropy, and the information entropy of the jth index is

$$e_j = -\frac{1}{\ln n} \sum_{i=1}^{m} p_{ij} \ln\left(p_{ij}\right) \tag{7}$$

Where p_{ij} is the weight of the jth index of the ith evaluation object:

$$p_{ij} = \frac{r_{ij}}{\sum_{i=1}^{m} r_{ij}} \tag{8}$$

STEP3 Calculate the weight. The weight of the jth index is

$$w_j = \frac{1 - e_j}{m - \sum_{i=1}^{m} e_j} \tag{9}$$

3.3 The Coupling of Analytic Hierarchy Process and Entropy Weight Method

The AHP and EWM are integrated into new weights by the Lagrange multiplier method based on the synthesis of subjective and objective evaluations. The model is as follows:

Let the subjective weights of each index obtained from AHP be

$$w_A = [w_{A1}, w_{A2}, \cdots, w_{An}] \tag{10}$$

And let the objective weights of each index obtained from EWM be

$$w_E = [w_{E1}, w_{E2}, \cdots, w_{En}] \tag{11}$$

Denote the normalized matrix $Z = (z_{ij})_{m*n}$, and the A-E weight coupling model is developed as follows:

$$\min f(w)=\sum_{i=1}^{m}\sum_{j=1}^{n}z_{ij}^{2}[(w_{Aj}-w_{j})^{2}+(w_{Ej}-w_{j})^{2}] \tag{12}$$

$$s.t.\begin{cases}\sum_{j=1}^{n}w_{j}=1\\ w_{j}\geq 0(j=1,2,\cdots n)\end{cases} \tag{13}$$

Where w_A is the corresponding weight for the AHP solution, w_E is the corresponding weight for the EWM solution, and w is the new weight after coupling.

4. Grey Dynamic Forecast Model

4.1 Grey system theory

Grey system theory focuses on "small-sample" and "information-poor" uncertain systems and generates sequences by effectively extracting information to monitor the system. The core is the Grey Dynamic Model, which takes the original data columns with no regularity and processes them into time series to predict the partially unknown data[12].

4.2 Grey Dynamic Model GM(1, N)

The GM(1, N) model is established by transforming the time series into an N-element-first-order continuous function of time for differential equations. It has the advantages of simple principles and calculations, no need to consider distribution laws, and high prediction accuracy. There are five main steps in building the GM(1, N) model[13]. Let the system characteristic data be

$$X_1^{(0)}=\left(x_1^{(0)}\left(1\right),x_1^{(0)}\left(2\right),\ldots,x_1^{(0)}\left(n\right)\right) \tag{14}$$

And let the related factor sequences be

$$X_j^{(0)}=\left(x_j^{(0)}\left(1\right),x_j^{(0)}\left(2\right),\ldots,x_j^{(0)}\left(n\right)\right);j=2,3,\ldots,N \tag{15}$$

STEP1 Generate the first order cumulative generation of the original data sequence. The 1-AGO sequence of $X_i^{(0)}$ is

$$X_i^{(1)}=\left(x_i^{(1)}\left(1\right),x_i^{(1)}\left(2\right),\ldots,x_i^{(1)}\left(n\right)\right) \tag{16}$$

Where $x_i^{(1)}=x_i^{(0)}$, $x_i^{(1)}=\sum_{j=1}^{k}x_i^{(0)}\left(j\right)$, $i=1,2,\ldots,N;k=2,3,\ldots,n$.

STEP 2 Establish the adjacent mean generating sequence $Z_1^{(1)}$:

$$Z_1^{(1)}=\left(z_1^{(1)}\left(2\right),z_1^{(1)}\left(3\right),\ldots,z_1^{(1)}\left(n\right)\right) \tag{17}$$

Where

$$z_1^{(1)}\left(k\right)=0.5x_1^{(1)}\left(k\right)+0.5x_1^{(1)}\left(k-1\right);k=2,3,\ldots,n. \tag{18}$$

The GM(1, N) grey differential equation is obtained as follows:

$$x_1^{(0)}\left(k\right)+az_1^{(1)}\left(k\right)=\sum_{i=2}^{N}b_ix_i^{(1)}\left(k\right) \tag{19}$$

Where a is the development grey number, and b is the endogenous control grey number.

STEP3 Solve parameters $a,b_1,b_2,\ldots,b_n$. The parameter column $\Phi=\left[a,b_1,b_2,\ldots,b_n\right]^T$ can be determined using the least-square method :

$$\Phi=\left[B^TB\right]^{-1}B^TY \tag{20}$$

Where

$$B=\begin{pmatrix} -z_1^{(1)}(2) & x_2^{(1)}(2) & \dots & x_N^{(1)}(2) \\ -z_1^{(1)}(3) & x_2^{(1)}(3) & \dots & x_N^{(1)}(3) \\ \vdots & \vdots & \vdots & \vdots \\ -z_1^{(1)}(n) & x_2^{(1)}(n) & \dots & x_N^{(1)}(n) \end{pmatrix} \tag{21}$$

$$Y=\left(x_1^{(0)}(2) \quad x_1^{(0)}(3) \quad \dots \quad x_1^{(0)}(n)\right)^T \tag{22}$$

STEP4 Build the model and predict. Under the initial conditions $\hat{x}_1^{(1)}(1)=x_1^{(1)}(1)=x_1^{(0)}(1)$, the data series model is generated as follows:

$$\hat{x}_1^{(1)}(k)=\left[x_1^{(0)}(1)-\frac{1}{a}\sum_{i=2}^{N}b_i x_i^{(1)}(k)\right]e^{-a(k-1)}+\frac{1}{a}\sum_{i=2}^{N}b_i x_i^{(1)}(k) \tag{23}$$

The original data series model is

$$\hat{x}_1^{(0)}(k)=\hat{x}_1^{(1)}(k)-\hat{x}_1^{(1)}(k-1) \tag{24}$$

By substituting $k=2,3,\dots,n$, the fitted value of the initial data is obtained. When $k>n$ the predicted value can be obtained.

5. CFSI Measurements and Predictions

5.1 Data collection and processing

This time, annual data for each indicator from 2012 to 2021 were collected and used to construct the annual index. Monthly and quarterly data were converted to annual data. Data on GDP, foreign exchange reserves, fiscal revenue, import/export balance, money supply, and CPI were obtained from Chinas National Bureau of Statistics. Data for domestic and foreign currency deposits, Nat ional Housing Sentiment Index, and Macroeconomic Sentiment Index are obtained from the Eastmoney International Securities Limited database.

It is necessary to normalize and standardize the data to unify the analysis of indicator data and eliminate the influence of indicator magnitudes. In this paper, the Max-Min standardization method is used to standardize the n indicator data of m evaluation objects using Eqs (3-6), and the percentage superimposed bar chart of standardized data is obtained, as shown in Figure 1.

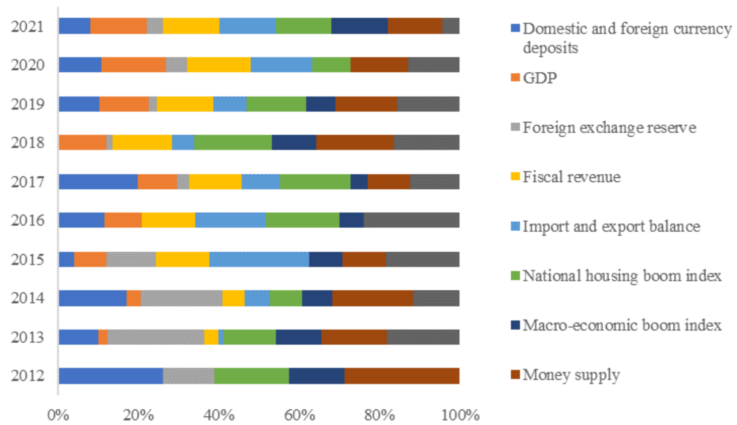

Figure 1 Standardized data percentage stacked bar chart

5.2 Weight identification and CFSI measurement

5.2.1 Weight identification

The idea of both AHP and EWM is to get the indicator weights first, which combines the indicator weights with the original data, and then get the evaluation value of each object. Therefore, this paper uses the Lagrange multiplier method to couple the weights obtained from AHP and EWM.

The experts are used to compare the importance of the first-level indicators two by two to obtain the judgment matrix, and then the experts construct the judgment matrix separately. The judgment matrices of the second-level indicators corresponding to the first-level indicators of economic volume, economic efficiency, and economic structure are B_1, B_2, and B_3, respectively. From Eqs. (1-2), the AHP weights are obtained by calculation; the normalized matrix obtained from 5.1 is noted as R and from Eqs. (7-9), the EWM weights of each index are obtained by calculation. Finally, the coupling weights can be obtained by solving the nonlinear programming model composed of Eqs. (12-13) using the Lagrange multiplier method, the specific results are shown in Fig. 2, and the AHP weights pass the consistency test.

$$A=\begin{pmatrix} 1 & 2 & 1/3 \\ 1/2 & 1 & 1/5 \\ 3 & 5 & 1 \end{pmatrix}, B_1=\begin{pmatrix} 1 & 1/5 & 1/2 \\ 5 & 1 & 5/2 \\ 2 & 2/5 & 1 \end{pmatrix}, B_2=\begin{pmatrix} 1 & 1/3 & 1/2 & 1/4 \\ 3 & 1 & 3/2 & 3/4 \\ 2 & 2/3 & 1 & 1/2 \\ 4 & 4/3 & 2 & 1 \end{pmatrix}, B_3=\begin{pmatrix} 1 & 1/2 \\ 2 & 1 \end{pmatrix}.$$

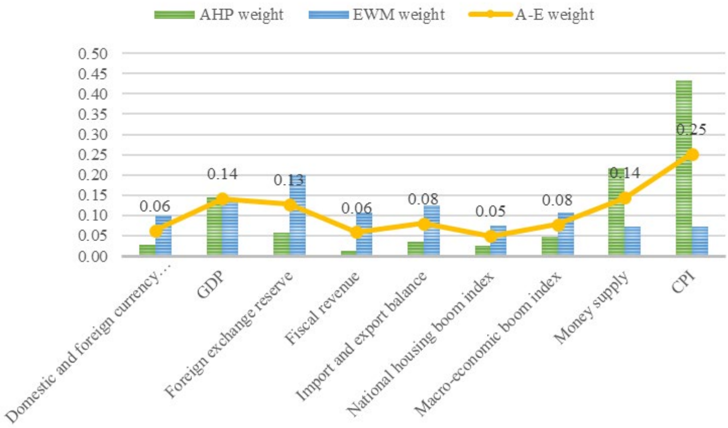

Figure 2 AHP、EWM and A-E weight

As shown in Figure 2, it can be seen that CPI, money supply, and GDP have larger weights of 0.25, 0.15, and 0.14, respectively, while the national housing boom index has a smaller weight of 0.05. CPI is a relative number reflecting the trend and degree of price changes of consumer goods and services purchased by urban and rural residents in a certain period, which reflects peoples livelihood and public sentiment and can reflect Chinas basic economic situation to a larger extent. It is a reflection of the primary economic situation of China. GDP is an essential comprehensive statistical indicator in the accounting system, which reflects the countrys economic strength, market size, and development trend. The National Housing Prosperity Index is only an overall index reflecting the boom status of the national real estate industry development, which has limited impact on Chinas financial pressure. Overall, the weights obtained through A -E coupling are scientific and of great practical significance.

5.2.2 CFSI measurement

The weights of each indicator are obtained from Eqs (1-13), and the weights are combined with the time-series indicator data to calculate the raw index data. The data are normalized to be between 0 and 100, and the CFSI and its fluctuations from 2012 to 2021 are obtained as shown in the figure below. The larger the value of CFSI in a given period, the greater the stress on Chinas financial system in that period.

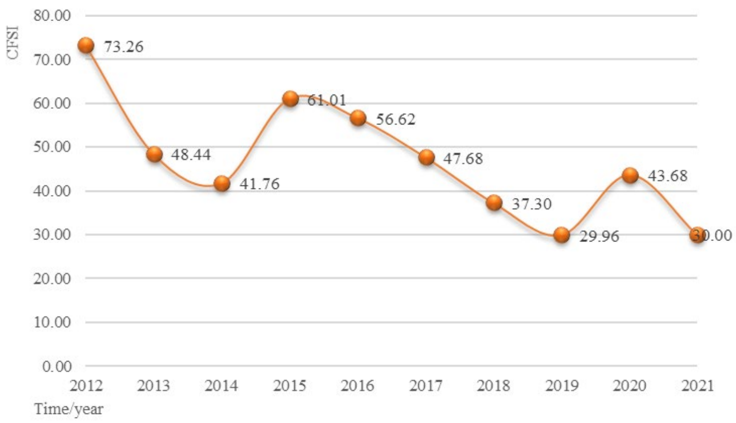

Figure 3 CFSI Fluctuate

As shown in Figure 3, the fluctuation trend of CFSI coincides with the major financial stress events at home and abroad, which can accurately reflect the stress situation of Chinas financial system.CFSI was at a high level in 2012 and showed a decreasing trend from 2012 to 2014.CFSI showed an increasing trend in 2015 and a decreasing trend for four consecutive years from 2016 to 2019. CFSI showed an upward trend again in 2020. During this period, the European debt crisis broke out in the second half of 2011, and the world financial system was in turmoil. China was also greatly affected, and the CFSI was still at a high level in 2012. 2015 saw the most severe stock market crash in the history of A-shares, which caused a considerable impact on Chinas financial system. Finally, the government bailed out the stock market crash, and the CFSI climbed to a higher level. The CFSI continued to decline as the Chinese economy gained momentum over the next four years. 2020 saw the outbreak of the new crown pneumonia epidemic, which put tremendous pressure on the Chinese financial system, and the CFSI climbed. The stress in Chinas financial system tends to be stable, and the abnormal fluctuations of CFSI are closely related to significant financial stress events at home and abroad, and the CFSI constructed in this paper can well reflect the stress in Chinas financial system.

5.3 GM(1, N) prediction

A MATLAB program was written from Equations (14-24) to import the time series data of nine indicators from Excel into MATLAB for parameter estimation and prediction of CFSI for the next three years.

Figure 4 GM(1, N) Simulation and Prediction

Model accuracy analysis:

Table 2 Simulation errors of the GM(1, N) model

Time	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Residuals	0	144.37	-20.15	1.97	-0.94	-1.71	-1.98	-1.40	2.62	-2.61
Relative Error	0%	21.44%	3.11%	0.31%	0.14%	0.26%	0.31%	0.22%	0.42%	0.41%

As shown in Table 2, the average relative error of the GM(1, N) model is 2.96%, reaching a higher accuracy level. The relative error of the simulated values in 2013 is larger, but the average relative error of the remaining simulated values is only 0.57% when the relative error of 2013 is removed, such as the simulation accuracy of the data from 2015 to 2021 are at a higher level. Therefore, this model can predict the development of CFSI in the next three years and can maintain a high level of prediction accuracy.

5.4 Analysis and Discussion

The above paper analyzes the causes and development trend of abnormal fluctuations of CFSI from 2012 to 2021 through the construction of CFSI. Among them, the European debt crisis in 2011 caused fiscal contraction, the continued weakness of the euro, and the relative appreciation of non-European currencies, which directly led to a decline in the price competitiveness of Chinas export trade products to Europe. In addition, with the appreciation of the U.S. dollar, foreign exchange reserves denominated in U.S. dollars have shrunk. Therefore, the European debt crisis has warned China not to rely excessively on export-driven economic growth, which is an economic structure highly vulnerable to external shocks and detrimental to Chinas long -term economic development. China should focus on expanding domestic demand, and consumption is the extended source of economic growth. 2015 A stock market crash led to the climb of CFSI, and the risk of banks and other matching companies rose. In response to this situation, regulators should introduce related policies to encourage value and long-term investment and gradually change the phenomenon of speculative investment in the stock market. 2020 outbreak of the new coronavirus pneumonia epidemic has brought a huge negative impact on Chinas economic development. The government should help restore production by adjusting fiscal and monetary policies and reducing the epidemics pressure on Chinas financial sys tem.

In addition, the forecast results of CFSI for the next three years in Figure 4 show that the overall trend of stress in Chinas financial system is decreasing, but the CFSI in 2022 is slightly higher compared to 2021, and the continued impact of the new crown pneumonia epidemic needs to be guarded.

6. Conclusion

This paper adopts the Lagrange multiplier method for A-E coupling weights. It constructs the CFSI based on nine indicators: GDP, foreign exchange reserves, fiscal revenue, import/export balance, money supply, CPI, domestic and foreign currency deposits, national housing boom index, and macroeconomic boom index. We analyze the rationality and practical significance of the CFSI construction from 2012 to 2021. In addition, the CFSI and its fluctuations from 2012 to 2021 are simulated with high model accuracy by building the GM(1, N) model, and the CFSI and its fluctuations from 2022 to 2024 are predicted. The conclusions are as follows:

(1) The CFSI constructed by A-E coupling weights is a more accurate measure of financial system stress in China, such as the ongoing impact of the European debt crisis from 2011 to 2012, the phenomenon of "1,000 stock suspensions" in A-shares in 2015, and the impact of the new crown pneumonia epidemic in 2020, all of which are more accurately reflected. Overall, A-E-G is a good measure of the stress in Chinas financial system and proposes a more accurate approach to forecasting.

(2) In reality, the stress in Chinas financial system is expected to show a downward trend in the next three years but a slight increase in 2022, and should be alert to the direct impact of the new crown pneumonia epidemic on normal production and life, import and export trade in the future. Attention should also be paid to the possible unemployment caused by the blow to the development of small and medium-sized enterprises in the new crown pneumonia epidemic. Furthermore, it also focuses on regulation to ease the risk pressure on banks and other placement companies.

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