

# Analysis of Regional Financial Risk Identification and Prediction Under CVM-GM(1, N) Algorithm

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## ABSTRACT

Financial risk is characterized by "bottom-up" and "accumulation followed by the outbreak," and the study of core financial risk factors is important for effective identification and prediction of regional financial risk. In this paper, 16 financial risk-related indicators of Guangdong Province, China, from 2011 to 2020 are selected and classified into macro risk and industry risk levels according to their correlation. Objective weights are assigned through the coefficient of variation method (CVM) method, and the GM(1, N) method is used to forecast the future regional financial risk of Guangdong province using the weighted indicator data. The results show that the above study can provide research implications for regional financial risk forecasting and provide a more comprehensive and scientific analytical framework and metrics for effectively monitoring regional financial risk in practice. It reveals the financial risk situation and the trend of risk changes in the province in the past ten years more realistically and objectively and provides a strong basis for formulating relevant risk prevention measures in the future.

**Keywords:** Regional financial risk; CVM; GM(1,N); Macro risk; Industry risk

## 1. INTRODUCTION

In 2020, with the global outbreak of COVID-19, the global financial markets were thus severely hit. The stock markets of many countries plummeted faster than the 2008 financial crisis, import and export trade was affected, enterprises also borrowed heavily to maintain their operations, and the low-interest rates and quantitative easing policies of central banks increased the instability of international exchange rates and economic recovery. Small and medium-sized enterprises operating difficulties, regional debt risk hidden, the effective identification and prediction of regional financial risk have important theoretical significance and practical necessity. Guangdong Province is the most pioneering region in China's financial development, which has made a significant breakthrough in financial reform and opening up in 2020, with the successful implementation of the reform of the registration system of the Shenzhen Stock Exchange and the official approval of the Guangzhou Futures Exchange, etc. The study of financial risks in Guangdong Province is significant for future research and forecast of the surrounding areas and even the national economy. Moreover, there are few studies in this area.

In terms of systemic financial risk monitoring and early warning, Tan et al. [1] used factor analysis to analyze 22 indicators to identify five types of risk factors that constitute China's systemic financial risk, such as economic growth dynamics risk and economic vulnerability risk. They used vector autoregressive models to analyze the dynamic impact of systemic financial risk and its five types of risk factors on China's economic fluctuations. Guo et al. [2] selected a macro-level indicator system containing four dimensions: macroeconomic, monetary liquidity, external markets, and asset bubbles, and used principal component analysis to construct a sub-level and overall systemic risk index to measure the overall risk level of China's financial system. Zhu et al. [3] used the SCCA model to measure the systemic risk in China's banking sector under the influence of Internet finance and then used stepwise regression to verify the above risk triggering mechanism and forecast the risk level over a certain period. Zhang et al. [4] used a combination of qualitative and quantitative research to construct a risk evaluation index system for Internet finance in five dimensions, including credit moral risk and operational risk, and calculated the weights of indicators at each level and established the importance ranking of each risk indicator based on hierarchical analysis.

In terms of regional financial risk monitoring and early warning research, Li et al. [5] measured and analyzed the debt risk levels of provinces, autonomous regions, and cities in recent years based on entropy TOPSIS method and comprehensive fuzzy evaluation method, and established VAR model to assess the impact of regional financial risk. Luo et al. [6] used three dimensions of regional macroeconomic operation, regional financial institutions, and regional financial, ecological environment as the first-level indicators of the regional financial risk monitoring "three-tier" indicator early warning system. The AHP weighting method, mapping method, and comprehensive index method are used to determine the indicator weights, standardize the indicator values, and calculate the comprehensive. The system uses AHP, mapping, and composite index methods to determine the weight of indicators, standardize the values of indicators and calculate the overall risk degree.

Through the literature, it can be found that most of the past studies on financial risk indicators have favored the use of a combination of subjective and objective methods for selecting indicators and assigning weights, and to a certain extent, making qualitative judgments on the results. This subjective problem leads to establishing indicators and weighting systems and the prediction results still depend on empirical judgment to a certain extent. The coefficient of variation method is an objective weighting method combined with the GM(1, N) method for quantitative prediction, which makes the results more objective. It is reduced the uncertainty caused by subjective analysis and saves the time cost of human judgment compared with previous studies.

## 2. THE IMPORTANCE OF REGIONAL FINANCIAL RISK IDENTIFICATION

Financial risk refers to any risk that may lead to financial losses of an enterprise or institution. Moreover, regional financial risk refers to the consequences of risk of a financial institution in the region, which often exceeds the impact on itself, the specific crisis of a financial institution due to poor operation may pose a threat to the proper operation of the entire region or even the national financial system; once the systemic risk, the financial system failure, will certainly lead to the disruption of the entire social and economic order, and even trigger a serious political crisis. The correct and rapid prediction of regional financial risks is an important part of the modern financial system, and the quantitative forecasting method can meet this requirement well. Quantitative forecasting refers to applying mathematical formulas applied to historical data, predicting future results, and is suitable for situations where there is sufficient historical information. In an era of frequent financial crises, the quantitative forecasting method can obtain sufficient data and

identify and predict financial risks more objectively.

## 3. INTRODUCTION REGIONAL FINANCIAL RISK SYSTEM INDICATORS

The selection of regional financial risk indicators should take into account the universality of financial risk factors and the regional nature of financial development and fully reflect the stage characteristics of financial development in the region. The principles of selecting indicators are that the selected indicators are as concise and representative as possible; secondly, the availability of data is considered. Thirdly, the cost of data collection and the economic practicality of model prediction are balanced with each other. This paper constructs a regional financial risk monitoring indicator system from two dimensions: regional macroeconomic factors and regional financial institutions factors, and sets them as primary indicators while setting secondary and tertiary indicators under each primary indicator, respectively. Considering the comprehensiveness, correlation, significance, and accessibility of the indicators, 5 secondary indicators and 14 tertiary indicators of Guangdong Province are selected in this paper. The data are obtained from Guangdong Provincial Bureau of Statistics, Guangzhou Branch of People's Bank China, and Hutchison Macro Data.

### 3.1. Regional macroeconomic factors

Macroeconomic environmental conditions play an important role in promoting or hindering the stable development of regional finance, and Tan et al. [1] proposed that the risks arise from unhealthy macroeconomics. Financial risk is quite closely related to the health of macroeconomic operation, and the regional macroeconomic operation dimension in this paper is mainly reflected from three aspects: regional macroeconomic condition, regional financial condition, and regional enterprise operation condition. Regarding regional macroeconomic conditions, we select regional GDP growth rate, fixed asset investment growth rate, consumer price index growth rate, and the registered unemployment rate to reflect regional economic growth rate, price increase, and population employment situation. In terms of regional financial situation, we select indicators such as the growth rate of local fiscal expenditure, the ratio of local fiscal revenue to GDP, and the growth rate of local tax revenue to reflect the ability of government departments to regulate and control to resist regional risks. In terms of enterprise operation, indicators such as asset-liability ratio and profit growth rate of industrial enterprises above the scale are selected to reflect the asset structure and profitability of the industry.

### 3.2. Regional financial institution factors

Tan et al. [1] proposed that severe capital deficiency, deterioration of profitability, dramatic fluctuations in financial markets, and even loss of market functions of regional financial institutions may directly lead to the occurrence of regional financial risks. The risk dimension of regional financial institutions is divided into two aspects according to the nature of the financial institutions' industry: the banking industry's operating condition and the insurance industry's operating condition. In this paper, we select indicators based on the availability of data, the liquidity, and profitability of financial institutions and draw on the positive and

negative indicators proposed by Luo et al. [6] to measure the risk status of financial institutions. In the operating condition of the banking industry, we select the deposit-lending ratio, the non-performing loan ratio, and the loan growth rate to reflect the capital adequacy, leverage, and asset quality of the banking industry and the loan concentration profitability liquidity of the banking industry. In the operating condition of the insurance industry, the premium income growth rate and insurance depth are selected to reflect the development profitability and insurance penetration of the insurance industry.

In summary, the financial risk indicators are organized as shown in Table 1:

**Table 1** Regional Financial Risk Indicators

Primary Indicators	Secondary indicators	Tertiary indicators	Indicator Positive Negative
Regional macro factors	Macroeconomic conditions	GDP growth rate	-
		The growth rate of fixed-asset investment	-
		Consumer price index growth rate	+
		Registered unemployment rate	+
	Regional Financial Status	Fiscal spending growth rate	+
		Tax revenue growth rate	-
		Financial self-sufficiency rate	-
	Regional Business Status	Assets and liabilities ratio of industrial enterprises above the scale	+
		Above-scale industries achieved a profit growth rate	-
Regional Financial Factors	Banking sector operating conditions	Deposit-to-Loan Ratio	-
		Non-Performing Loan Ratio	+
		Loan growth rate	+
	Insurance Operations	Premium income growth rate	-
		Insurance depth	-

## 4. CONSTRCTCTION OF CVM-GM(1,N) METHOD

### 4.1. Construction of CVM

CVM (coefficient of variation method) is a method of calculating the degree of variation of each indicator of a system based on statistical methods, according to which indicators with more significant variation are weighted more, and those with minor variation are weighted less, thus determining their importance based on the statistical laws of the indicators. The coefficient of variation method is a standardized measure of the dispersion of a probability distribution or frequency distribution, and it is also commonly used in fields such as engineering or

physics to indicate the accuracy and repeatability of analysis. Economists and investors use the CVM in economic models, which is usually expressed as a percentage. Its greatest advantage is that as a more objective method, it can objectively reflect information about the changes in indicator data and derive the weights of each indicator. The process is shown as follows.

Step 1 Raw data collection and collation

$$X = \begin{pmatrix} x_{11} & \cdots & x_{1p} \\ \vdots & \ddots & \vdots \\ x_{n1} & \cdots & x_{np} \end{pmatrix} \quad (1)$$

The above figure assumes that there are n samples

with  $p$  indicators, forming the original indicator data matrix, where  $X_{ij}$  denotes the  $j$ -th indicator of the  $i$ -th sample

Step 2 Calculate the mean and standard deviation of the  $j$ -th index

$$\bar{X}_j = \frac{1}{n} \sum_{i=1}^n X_{ij} \quad (2)$$

Step 3 Calculate the coefficient of variation of the  $j$ -th index

$$S_j = \sqrt{\frac{\sum_{i=1}^n (X_{ij} - \bar{X}_j)^2}{n-1}} \quad (3)$$

$$v_j = \frac{S_j}{\bar{X}_j} \quad (4)$$

Step 4 Normalize the coefficients of variation to obtain the weights of each index

$$W_j = \frac{v_j}{\sum_{j=1}^p v_j} \quad (5)$$

$$W = \{w_1, w_2, \dots, w_p\} \quad (6)$$

#### 4.2. Construction of GM(1,N) Gray System Theory Model

The GM model is a part of gray system theory, a control theory about systems with incomplete or uncertain information, and a technical system with system analysis, evaluation, modeling, prediction, decision making, control, and optimization as the main body. Wu et al. [7] used the gray system correlation analysis theory to construct an optimized multidimensional gray GM(1, N) model to simulate and forecast the development of China's GDP with GDP as the internal characteristic factor and the output value of industry, wholesale and retail trade, and finance as the main influencing factor variables. GM(1, N) indicates that the forecasting model is of order 1 with  $N$  variables, and its advantages are low computational workload and high prediction accuracy. High forecasting accuracy and does not require a large number of samples. The process is generally as follows.

Step 1 Let the system have a feature data sequence

$$X_1^{(0)} \quad (7)$$

Step 2 Derive the sequence of correlation factors

$$X_2^{(0)} = (X_2^{(0)}(1), \dots, X_2^{(0)}(n))$$

$$\dots \quad (8)$$

$$X_N^{(0)} = (X_N^{(0)}(1), \dots, X_N^{(0)}(n))$$

Step 3 Let the 1-AGO sequence of  $(i=1,2,\dots,N)$  be  $X_i^{(1)}$

Accumulate  $X_N^{(0)}$  in order to weaken the volatility and randomness of the random sequence, and obtain a new sequence as follows

$$X_i^{(1)}(k) = \sum_{k=1}^n X_i^{(0)}(k) \quad (9)$$

Step 4 Generated Immediate Neighborhood Mean Series

Generate the adjacent mean equal weight sequence of  $Z^{(1)}$  here, and then find  $Z_1^{(1)}(k)$

$$Z^{(1)} = (Z^{(1)}(2), Z^{(1)}(3), \dots, Z^{(1)}(k))$$

$$\dots \quad (10)$$

$$Z_1^{(1)}(k) = \frac{1}{2} [X_1^{(1)}(k) + X_1^{(1)}(k-1)]$$

Step 5 Establish the differential equation GM(1, N) according to gray theory

$$X_1^{(0)}(k) + aZ_1^{(1)}(k) = \sum_{i=2}^N b_i X_i^{(1)}(k) \quad (11)$$

Among them,  $X_1^{(0)}(k)$  is called Grey derivative,  $a$  is called development coefficient,  $Z_1^{(1)}(k)$  is called whitening background value,  $a$  is called the development factor, called the driving factor, called the drive term, and  $b$  is called Grey action quantity.

Step 6 , introduced the matrix-vector notation

Accumulate the generated data for mean generation  $B$  and constant term vector  $Y$

$$B = \begin{pmatrix} -Z^{(1)}(2) & X_2^{(1)}(2) & \dots & X_N^{(1)}(2) \\ -Z^{(1)}(3) & X_2^{(1)}(3) & \dots & X_N^{(1)}(3) \\ \vdots & \vdots & \ddots & \vdots \\ -Z^{(1)}(n) & X_2^{(1)}(n) & \dots & X_N^{(1)}(n) \end{pmatrix}, Y = \begin{pmatrix} X^{(0)}(2) \\ X^{(0)}(3) \\ \vdots \\ X^{(0)}(n) \end{pmatrix} \quad (12)$$

Step 7 Using the least-squares method, we can find:

$$u = \begin{pmatrix} a \\ b \end{pmatrix} = (B^T B)^{-1} B^T Y \quad (13)$$

Step 8 When  $(i=1,2,\dots,N)$  is varied by a small amount, we get:

$$\bar{X}_1^{(1)}(k+1) = [x_1^{(0)}(1) - \frac{1}{a} \sum_{i=2}^N b_i x_i^{(1)}(k+1)] \quad (14)$$

Step 9 Solve for the reduced value:

$$\bar{X}_1^{(0)}(k+1) = \bar{X}_1^{(1)}(k+1) - \bar{X}_1^{(1)}(k) \quad (15)$$

## 5. ANALYSIS OF REGIONAL FINANCIAL RISK IDENTIFICATION AND PREDICTION UNDER CVM-GM(1,N)

### 5.1. Subjects (study area) and data collection

This paper selects the data from Guangdong Provincial Bureau of Statistics, Guangzhou Branch of People's Bank of China, and Hutchison Macro Data for

analysis. The data of GDP growth rate, fixed asset investment growth rate, consumer price index growth rate, registered unemployment rate, fiscal expenditure growth rate, tax revenue growth rate, fiscal self-sufficiency rate, the asset-liability ratio of industrial enterprises above the scale, bank deposit-lending ratio, bank non-performing loan ratio, bank loan growth rate, premium income growth rate, insurance depth and other 14 indicators from 2011 to 2020, i.e., the last ten years, are collected respectively for the analysis.

### 5.2. CVM-based risk index construction

Based on the CVM formula described in 4.1, the importance of each indicator under CVM is obtained by substituting the financial risk-related data of Guangdong Province from 2011 to 2020. The specific results are shown in Table 2

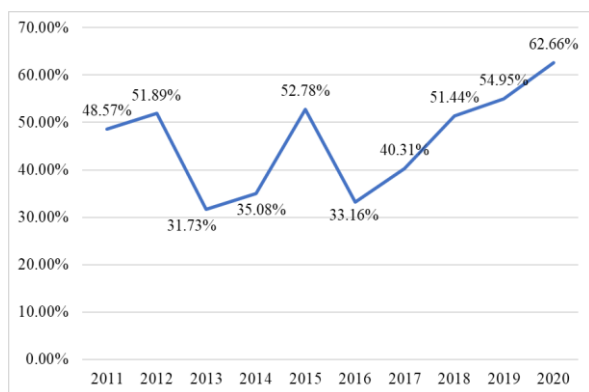
**Table 2** Coefficient of variation method weighting table

Serial number	Indicators	Weights
1	GDP growth rate	5.97%
2	The growth rate of fixed-asset investment	7.20%
3	Consumer price index growth rate	8.88%
4	Registered unemployment rate	0.65%
5	Fiscal spending growth rate	19.02%
6	Tax revenue growth rate	11.95%
7	Fiscal self-sufficiency rate (fiscal revenue/fiscal expenditure)	1.58%
8	Assets and liabilities ratio of industrial enterprises above the scale	0.45%
9	The profit growth rate of industries above the scale	17.35%
10	Bank deposit to loan ratio	1.28%
11	Bank Non-Performing Loan Ratio	3.60%
12	Bank loan growth rate	2.45%
13	Premium income growth rate	14.93%
14	Insurance depth	4.70%

From the above table, we can learn that the growth rate of fiscal expenditure, the growth rate of industrial profit above the scale, the growth rate of premium income, and the growth rate of tax revenue these four indicators have the most considerable weight, 19.02%, 17.35%, 14.93%, and 11.95% respectively. Together, the four indicators have accounted for more than 60% of the weight. From the characteristics of the coefficient of variation method, we can see that the annualized fluctuations of these four indicators are more extensive than other indicators, which have a more significant impact on The annualized fluctuations of these four indicators are greater than those of other indicators, which have a more significant impact on risk. The two indicators of the minimum risk coefficient, the registered unemployment rate and the asset-liability ratio of

industrial enterprises above the scale, are less volatile, with a weight of 0.65% and 0.45%, respectively, and the gap between the maximum and minimum is relatively wide.

Based on the CVM weights calculated above, the risk coefficients of the Guangdong Province region from 2011 to 2020 can be obtained by weighting, as shown in Fig.1

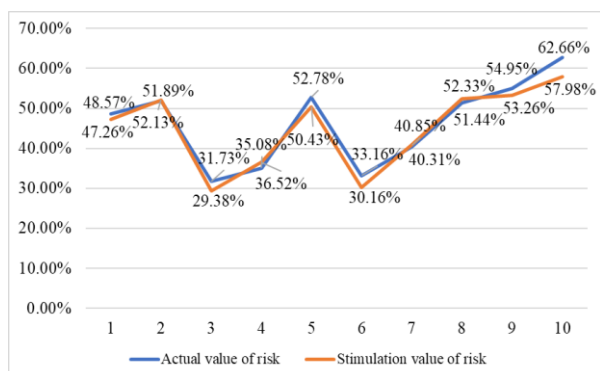


**Figure1** 10 years risk factor chart

In the risk factor chart, it can be seen that there are high-risk factors in 2011~2012, 48.57% and 51.89% respectively, which are consistent with the three consecutive years of downturn in the Chinese stock market from 2010 to 2012. Moreover, after government regulation, the risk factor fell back to lower levels in 2013~2014, at 31.73% and 35.08%, respectively. In 2015, another crisis in the Chinese stock market, and the risk factor reached its highest level in recent years at 52.78%. Then, it fell again to a low of 33.16% in 2016. However, it is continued to rise in the subsequent three years from 2017~2019, at 40.31%, 51.44%, and 54.95%. In the case of an outbreak in 2020, the risk factor reaches a ten-year high of 62.66%. It can be seen that higher as dramatic fluctuations occur every few years, while lower risk factors tend to occur after years with high-risk factors, reflecting the positive impact of the adjustments made by the government to reduce risk after high-risk years.

### 5.3. Risk-fitting prediction based on GM(1, N)

The risk coefficient data and the weighted risk indicator data were substituted into the gray modeling software for the GM(1, N) gray system fitting prediction, and the predicted fitting results were as follows.



**Figure2** Comparison chart between actual risk factor and stimulation risk factor

From Figure 2, it can be concluded that the fitting accuracy error of the prediction results is only 2.95%, so the model can accurately predict the risk and can provide a reference for the subsequent formulation of risk warning policies.

### 5.4. Policy Opinion and Analysis

Even though the government can use quantitative easing and other bailout measures when a crisis occurs, and the Chinese stock market has regulations such as a stop-limit board to limit risk, it is ultimately the regulator's power to regulate the market, which in the long run will lead investors to rely on government regulation and thus take risk lightly. The government should focus more on preventive measures beforehand than on bailout policies after the fact. The first point is to prevent regional financial risks by stabilizing economic growth, effectively reducing corporate leverage, improving corporate profitability, and further enhancing local tax and fiscal revenues. The second point is to study the establishment of essential systems and long-term mechanisms in line with provincial conditions and adapt to market laws to avoid regional economic growth being too sensitive to changes in the real estate investment market.

In the current situation, where the world epidemic has led to the economic crisis, the local and regional financial instability in China has come to the fore. It is vital to identify and forecast the risks and their elements affecting regional financial stability objectively and accurately, and to provide an effective diagnostic basis for decision makers to grasp and control regional financial risks to maintain financial stability and sustainable economic development in China. Moreover, the present prediction has high accuracy and provides a less subjective and more quantitative perspective than previous studies to be an effective financial risk prediction tool.

## 6. CONCLUSION

This paper conducts the identification and prediction study of regional financial risk by combining the CVM objective weighting method with the GM(1, N) gray system theory model for fitting prediction. The financial index of the region is used as data to evaluate to get the CVM weights. The weights are substituted into the original index to get the risk coefficients. Finally, the risk coefficients and the weighted index of the original index are substituted into the GM(1, N) model for fitting prediction to compare the actual value of risk and the predicted value of risk. The conclusions are as follows.

Applying the model to Guangdong Province, 14 indicators such as GDP growth rate, fixed asset investment growth rate, consumer price index growth rate, registered unemployment rate, fiscal expenditure growth rate, tax revenue growth rate, fiscal self-sufficiency rate, the asset-liability ratio of industrial enterprises above the scale, bank deposit-lending ratio, bank non-performing loan rate, bank loan growth rate, premium income growth rate, insurance depth, etc. From 2~2011 years, i.e., the data of the last ten years are

analyzed, etc., and the financial risk identification and prediction are carried out for 2020 the data of 2~2011 years and nearly ten years. The results show that among the selected financial indicators, the growth rate of fiscal expenditure, the growth rate of industrial profit above the scale, the growth rate of premium income, and the growth rate of tax revenue have the most excellent weight, and the fluctuation of financial risk in Guangdong Province between 2011 and 2020 has gone down and then up twice, with a w-shaped trend. The error between the actual value of risk and the predicted risk value is 2.95%.

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