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Evaluating financial fragility: a case study of Chinese banking and finance systems

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Global financial systems are inherently fragile due to their complexities. Thus, it is of great interest to devise various methods to assess the dynamics of financial fragility. As such, this study builds a financial fragility evaluation index system. The study finds three major fluctuations in the trend of financial fragility due to the great recession in 2008, the huge financial volatility in 2015, and the COVID-19 pandemic in 2019. It also tests the index system on the Chinese finance market from 2007 to 2022. Observations of capital adequacy, non-performing loans, and liquidity ratios, in addition to the average return on total assets, are used to assess banking fragility. The results attained show that amongst the tested banks, the Bank of Ningbo has the lowest vulnerability score, mainly due to its higher average return on total assets, capital adequacy ratios, and lower non-performing loan ratio. On the other end of the spectrum, China Minsheng Bank has the highest vulnerability score due to its lower capital adequacy and higher non-performing loan ratios. These findings provide valuable insights into the banking sector in China for policy formulation.

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Introduction

Banks form integral parts of the global financial system, and their stability is key to stabilizing the overall system. Financial fragility in the banking system threatens the survival and development of the banking industry. It can also hinder sustainable economic development and lead to financial crises. The banking system's vulnerability is an important manifestation of financial vulnerability. Additionally, banks' non-performing loans, average return on total assets, liquidity ratio, and capital adequacy ratio collectively stabilize the banking system and ensure the smooth operation of the economy. Reducing the non-performing loan ratio, curbing financial risks, and maintaining the sound operation of banks through the three major frameworks of pre-credit assessment, loan review, and post-loan management are conducive to ensuring the stability of China's banking system. Consequently, there is abundant research on bank fragility. For example, Yu et al. (2015) studied rural commercial banks through a Probit model-based empirical analysis and found that the increment in loan interest rates increases the probability of farmers defaulting on their loans, leading to an increased risk for banks. Djebali and Zaghdoudi (2020) suggested that banks' liquidity risk will increase their non-performing loans, reduce their profitability, and threaten their stability. Hajar and Habib (2020) proposed that when assessing bank risks, capital adequacy ratio, financial asset quality, and prevalence cannot be ignored. Smaoui et al. (2020) showed that banks with low liquidity risk might take more radical measures to attract the clients of competitors who could not secure sufficient funding. Therefore, banks with lower liquidity risk are more vulnerable. Using monthly data from 147 developing countries from 1980 to 2016, Haan et al. (2020) found that most banks with high potential risks have the following characteristics: low levels of current assets and domestic financial liabilities, high levels of foreign liabilities, and high financial leverage. Halili et al. (2021) hypothesized that increasing credit derivatives holdings would also increase banks' risk. In addition, as an important factor affecting bank risk, many scholars have studied and analyzed non-performing loans. Serrano (2021) confirmed that the stock of non-performing loans has a negative impact on the bank's lending activities and is not conducive to the operational stability of the banks, resulting in a financial crisis. The study also established that profitability and capital adequacy ratios also have an impact on the fragility of banks. Kanga et al. (2020) demonstrated through experiments that bank capital and profitability have positive effects on banks. They argue that the more plentiful the bank's capital and profitability, the lower its fragility.

Fragility indices of financial systems are also important because they are strongly correlated with a nation's economy and the formulation of economic policies by stakeholders. When financial vulnerability accumulates to a certain extent or reaches a certain critical state, a financial crisis becomes inevitable if it is not controlled and eliminated at the appropriate time. Once there is a financial crisis, it will be extremely harmful and destructive to the economy. The power of human intervention will be insignificant, necessitating much attention to be given to financial vulnerability, which is related to the lifeblood of the entire economy and the formulation of economic policies. Therefore, it is necessary to consider an alternative indicator for measuring China's financial vulnerability. There are many fragility indicators, including but not limited to GDP growth rate, real interest rate, inflation rate, M2 growth rate, cash savings rate, credit growth rate, return on assets, and foreign investment scale. Laura et al. (2015) found that when the financial market concentration is low, interest rates are low, inflation is high, and there is a decline in GDP, financial risks will be triggered and eventually lead to high financial vulnerabilities. Kim et al. (2020a, 2020b) implied that the diversification of the banking business might also increase financial instability and lead to the collapse of the financial system. Sushanta and

Ricardo (2013) suggested that tight monetary policy is a cause of financial fragility and can affect output. In terms of financial fragility, not only general economic indicators can lead to financial risks, but also other factors, such as macroeconomics, wealth distribution, regulatory authority's policy, and foreign trade, can and will affect the stability of the financial system. For example, Fabio and Claudio (2014) observed that the fluctuations in the financial fragility index could be attributed to certain (global and domestic) macroeconomic, financial, and other factors. Mitkov (2019) suggested that the distribution of wealth affects the degree of financial fragility and that unequal distribution of wealth can also cause financial panic. Danilo (2020) mentioned that in terms of financial vulnerabilities, the government and central bank policies aimed at enhancing market liquidity play a key role. Georgiadis and Zhu (2021) determined from research on the relationship between financial foreign exchange risk and financial fragility that foreign exchange risk may endanger financial stability when the exchange rate depreciates and further hinder macroeconomic stability. Based on these foundations, this paper proposes and builds a new evaluation index to measure fragility in the financial system based on Chinese banks.

Banking system vulnerability as discussed is an important manifestation of financial vulnerability, and this paper makes meaningful contributions to the study of financial vulnerability in two main ways. First, based on the cross-sectional data of the vulnerability indicators of 15 banks in China, the indicators of return on average total assets, liquidity ratio, capital adequacy ratio, and non-performing loan ratio are studied. The study observed that banks with lower vulnerability scored better on the liquidity ratio and non-performing loan ratio indicators. Second, through the organization of the indicators of China's financial system from 2007 to 2022 data, the total score of China's financial system vulnerability was calculated based on the vulnerability scores of each subsystem. It was found that a good economic environment is the main guarantee for the smooth operation of the financial system. The rest of this paper is structured as follows. Section "Methodology and evaluation index" describes the methodology and proposed evaluation index. Section "Experiments and data" presents the data and experiments using the evaluation index. Section "Results and discussion" gives the results and makes an analysis. Section "Conclusion, suggestions, and limitations" summarizes the main findings of this study and provides policy suggestions.

Methodology and evaluation index

Factor analysis. Factor analysis was first developed by Charles Spearman, a British psychologist, who put forward in 1904 that the basic idea of factor analysis is to group the original variables. These variables must be grouped according to the correlation size so that the correlation between variables in the same group is higher, while the correlation between variables in different groups is lower. Each group of variables represents a basic structure, and an unobservable comprehensive variable called a common factor. For a specific problem studied, the original variable can be divided into two parts; a few unmeasurable linear functions or common factors, and special factors unrelated to public factors (Qin and Lin, 2021; Kim et al., 2020a, 2020b).

Suppose there are n samples, each sample observes p indicators, and there is a strong correlation between the p indicators. To facilitate research, the sample observation data is standardized, the standardized variable X_i ($i = 1, 2, …, p$) is used as the evaluation index, and F_j ($j = 1, 2, …, m$) is used as the common factor. ε_k ($k = 1, 2, …, p$) represents a special factor, and

Table 1 Fragility indicators and boundaries.

Economic and environmental fragility indicators and boundaries

Degree of fragility (DOF)	Safe	Normal	High	Dangerous
A1 GDP growth rate	6.5–9.5	5–6.5 or 9.5–11	3.5–5 or 11–12.5	<3.5 or >12.5
A2 Fixed asset investment growth rate	13–19	10–13 or 19–22	7–10 or 22–25	<7 or >25
A3 M2 growth rate	5–15	15–20	20–25 or 0–5	>25 or <0
A4 CPI	<4	4–7	7–10 or −2 to 0	>10 or <−2
FA Index composite index range	0~12	12~15	15–20	>20
Financial market early warning fragility indicators and boundaries				
B1 P/E ratio	<40	40–60	60–80	>80
B2 Total stock market value /GDP	<30	30–60	60–90	>90
B3 Securities index volatility	<40	40–60	60–80	>80
B4 Debt dependence	<10	10–20	20–30	>30
FB Index composite index range	0~35	35–50	50–70	>70
Financial monitoring fragility indicators and boundaries				
C1 M2/M1	1–2	2–2.5	2.5–3	>3
C2 One-year actual deposit interest rate	0–4	4–7 or −4–0	7–10 or −8 to −4	>10 or <−8
C3 Growth rate of various loans of financial institutions	5–15	15–20	20–25 or 0–5	>25 or <0
C4 financial deficit /GDP	<1	1–3	3–9	>9
FC Index composite index range	0~6	6–10	10–15	>15
Financial outward-oriented fragility indicators and boundaries				
D1 debt ratio	0–15	15–30	30–45	>45
D2 Foreign trade dependence	0–10	10–25	25–35	>35
D3 Current account balance /GDP	0–3	3–4.5	4.5–5	>5 or <0
D4 Debt service ratio	0–10	10–20	20–30	>30
D5 Support import time	>6	4–6	3–4	<3
FD Index composite index range	0–10	10–20	20–25	>25
Financial Fragility Composite Index Boundaries				
FFII Financial Fragility Composite Index Range	0–17	17–25	25–35	>35

the specific model of the factor analysis is as follows:

$$\begin{cases} X_1 = a_{11}F_1 + a_{12}F_2 + \ldots + a_{1m}F_m + \varepsilon_1 \\ X_2 = a_{21}F_1 + a_{22}F_2 + \ldots + a_{2m}F_m + \varepsilon_2 \\ \ldots\ldots \\ X_p = a_{p1}F_1 + a_{p2}F_2 + \ldots + a_{pm}F_m + \varepsilon_p \end{cases} \quad (1)$$

Where the common factor F_j ($j = 1, 2, \ldots, m$) is mutually independent and unmeasurable. It is a factor that appears in the expression of the original variable. The special factors and the common factors are also independent of each other. a_{ij} is the factor loading. The greater its absolute value, the greater the degree of dependence between X_i and F_j.

Fragility indicators of the banking system. The key to accurately and comprehensively evaluating the fragility of the banking system lies in selecting evaluation indicators. A study by Gobert et al. (2002) on the issue of financial fragility looked at the indicator of the liquidity ratio of the banking system. In addition, they also argued that liquidity constraint was an important factor that triggered the crisis of financial institutions and led to financial fragility. Karadima and Louri (2020) pointed out that a high non-performing loan rate has aggravated the fragility of banks and has a strong negative impact on economic development. The capital adequacy ratio has become an important indicator of banks' risk management and avoidance capabilities. Many countries are facing the threat of financial fragility to varying degrees while opening their financial markets. Therefore, from the perspective of safe operation, whether capital is sufficient has become a core issue of increasing concern to the banking industry. As Asteriou and Spanos (2018) mentioned, higher capital adequacy performance maintains the stability of the financial system. While banks are improving security and liquidity, profitability cannot be ignored. It can be represented by an indicator of return on average total assets. Therefore, this article adopts the average return on total

assets, capital adequacy ratio, liquidity ratio, and non-performing loan ratio to measure the fragility of the banking system.

Fragility indicators of the financial system. Discussions on the fragility of the financial system have always received great attention from the theoretical community. Subdividing the financial system and monitoring financial risks from different subsystems is the core issue. Aikman et al. (2017) examine financial fragility from the stock, real estate, and bond market subsystems and highlight that there are many different views on the selection of specific evaluation indicators. Hamdaoui and Maktouf (2020) refer to the research of other scholars and use indicators such as international capital flow, inflation, real exchange rate, the ratio of money supply M2, and supervisory diffusion to measure financial fragility. Kaminsky (2006) mainly selected the main indicators, such as the proportion of fiscal deficit to GDP, the actual excess of M1, the proportion of M2 and foreign exchange reserves, and the ratio of foreign debt to imports. Additionally, Kaminsky subdivided the two subsystems of the stock market and bank credit among the model, making the model more comprehensive. According to the theory of the above scholars, combined with the characteristics of China's financial system, this paper focuses on establishing the fragility evaluation model of the financial system from four subsystems: economic environment, financial market early warning, financial monitoring, and financial export-oriented. Among them, determining the boundary of some evaluation indexes and the weight setting of subsystems refers to the common international standards and foreign experts (Graciela L Kaminsky, 2006). Other indicators are based on historical data to get the average value and then determine the index range according to the degree of deviation from the average value. Table 1 provides specific information.

Table 2 Bank statistics.

Bank	Return on average total assets	Liquidity ratio	Capital adequacy ratio	Non-performing loan ratio
Agricultural Bank of China	0.93	55.17	15.12	1.59
China Construction Bank	1.13	47.69	17.19	1.46
Bank of Nanjing	0.93	51.62	12.99	0.89
China Everbright Bank	0.8	64.26	13.01	1.59
China Merchants Bank	1.24	44.94	15.68	1.36
China Minsheng Bank	0.85	51.64	11.75	1.76
Bank of Ningbo	1.04	57.43	14.86	0.78
Ping'An Bank	0.74	60.86	11.5	1.75
Bank of Communications	0.8	67.28	14.37	1.49
Hua Xia Bank	0.81	51.23	13.19	1.85
Shanghai Pudong Development Bank	0.91	56.05	13.67	1.92
Industrial Bank	0.93	66.52	12.2	1.57
China Citic Bank	0.77	50.8	12.47	1.77
China Bohai Bank	0.7	55.39	11.77	1.84
Postal Savings Bank of China	0.57	61.17	13.76	0.86

Note: The unit is %.

Experiments and data

Bank fragility analysis. The fragility index system of the banking system in this study references Kaminsky (2006), Gobert et al. (2002), and Karadima and Louri (2020). This paper studies cross-sectional data from 15 Chinese banks in 2018 (see Table 2). It can be observed that the average return on total assets of China's major banks is mainly concentrated around 1%, and the Postal Savings Bank of China is less than 0.6%; the liquidity ratio of China's banks is not good, mostly concentrated in 50%~60%. The capital adequacy ratio meets the 8% or more stipulated in the Basel Agreement; the non-performing loan ratio is also concentrated at around 1%. To observe the fragility of the banking system more comprehensively, a factor analysis method is adopted to calculate the total score of each bank's fragility factor.

Due to the homogeneity requirement of the sample data, and the frailty examination requiring that a smaller index score is better, the indicator conversions are taken for return on average total assets, liquidity ratio, and capital adequacy as follows: $y_i = \max(x_i) - x_i$. The factor rotation adopts the Varimax method, and the contribution of the three principal components extracted reaches 92.88%. The specific scores are listed in Table 3. It can be seen that the Bank of Ningbo has the smallest fragility score, mainly because its average return on total assets and capital adequacy ratio are better, and its non-performing loan ratio is lower. It is followed by the Bank of Communications, China Construction Bank, and the Industrial Bank. China Minsheng Bank has the highest fragility score due to its low capital adequacy ratio and high non-performing loan ratio.

Financial system fragility analysis. The degree of fragility of the financial system can be calculated from the related indicators of the financial system's fragility. This article takes the method of adding up the indicators of each financial system subsystem and averaging to calculate the fragility score of each. Subsequently, the fragility scores of each subsystem are weighted and averaged. The specific method is as follows:

$$F_i = \sum F_{ij}/j \qquad (2)$$

$$FFII = \sum f_i F_i \qquad (3)$$

where i = A, B, C, D; F_{ij} represents the numerical value of the j-th index of the i-th subsystem, f_i represents the number of indicators of the subsystem, and F_i represents the weight of the comprehensive index of the indicators of the subsystem. Early warning and monitoring of the financial market are central to the

Table 3 Table of fragility factor scores for Chinese banks.

Bank	F1	F2	F3	F
Bank of Ningbo	−0.77	−0.23	−1.74	−0.89
Bank of Communications	−0.55	−1.92	0.09	−0.76
China Construction Bank	−1.99	0.66	0.09	−0.65
Industrial Bank	−0.11	−1.45	0.44	−0.34
Agricultural Bank of China	−0.83	−0.17	0.31	−0.32
China Merchants Bank	−1.57	1.40	−0.11	−0.31
Postal Savings Bank of China	1.12	−0.58	−2.05	−0.25
China Everbright Bank	0.09	−1.22	0.30	−0.23
Bank of Nanjing	0.58	1.03	−1.70	0.07
Shanghai Pudong Development Bank	−0.38	−0.15	1.20	0.13
Ping'An Bank	0.99	−0.44	0.59	0.47
Hua Xia Bank	0.41	0.75	0.79	0.62
China Citic Bank	0.91	0.99	0.51	0.82
China Bohai Bank	1.21	0.36	0.69	0.82
China Minsheng Bank	0.90	0.97	0.59	0.83

Note: F1, F2, and F3 are the three principal component scores, and F is the total fragility score.

evaluation model of financial fragility. This gives the provision that the important position that these two subsystems occupy, the weights of these two subsystems are set to 2, and the weights of the remaining two are set to 1. Based on data collected from the China Statistical Yearbook, China Financial Yearbook, China Macro Statistics Database, National Bureau of Statistics, and other statistical departments, the study calculated and sorted out the index values and comprehensive index intervals of each subsystem in China from 2007 to 2022 (see Table 4).

Results and discussion

Based on experimental results, the degree of fragility for each studied bank is given in Fig. 1. It can be seen that the Bank of Ningbo has the smallest degree of fragility, and the F-value is in the innermost circle of the radar chart. Meanwhile, China Minsheng Bank's degree of fragility is the highest, and the F-value is on the outermost side of the radar chart. The degree of fragility of China's banking system increases in the clockwise direction.

Regarding the degree of fragility of the financial system, this article also analyzes the overall trend chart (see Fig. 2). From 2007 to 2022, the trend of the degree of vulnerability of China's financial system shows fluctuations. The first round of

Table 4 Index values and comprehensive index intervals of each subsystem.

Index	2007	2008	2009	2010	2011	2012	2013	2014
Comprehensive Index of Economic and Environmental Fragility.								
A1	14.2	9.7	9.4	10.6	9.6	7.9	7.8	7.4
A2	24.84	29.95	29.95	23.83	12	20.29	19.91	14.73
A3	16.7	17.8	28.5	19.7	13.6	13.8	13.6	12.2
A4	4.8	5.9	−0.7	3.3	5.4	2.6	2.6	2
FA	15.14	14.81	16.79	14.36	10.15	11.15	10.78	9.08
DOF	H	N	N	N	S	S	S	S
A1	7	6.8	6.9	6.7	6.10	2.30	8.10	3.00
A2	9.76	7.91	5.73	0.69	5.40	2.90	4.90	5.10
A3	13.3	11.3	8.1	8.1	8.75	10.08	8.97	11.81
A4	1.4	2	1.6	2.1	2.90	2.50	0.90	2.00
FA	7.87	7	5.58	4.4	5.79	4.45	5.72	5.48
DOF	S	S	S	S	S	S	S	S
Financial Early Warning Fragility Composite Index								
B11	59.2	14.9	28.7	21.6	13.4	12.3	11	16.9
B12	69.7	16.7	46	44.7	23.1	22	27.8	41.9
B2	121.12	38.02	69.99	64.40	44.01	42.77	40.32	57.89
B31	133.90	73.32	89.74	30.12	33.24	24.05	26.23	59.78
B32	185.22	78.24	123.42	43.49	37.76	34.08	32.96	47.23
B4	46.48	13.67	23.50	22.01	15.65	12.83	14.43	14.33
FB	102.60	39.14	63.56	37.72	27.86	24.67	25.45	39.67
DOF	D	N	H	N	S	S	S	N
B11	17.6	15.9	16.3	12.5	14.55	16.76	18.02	12.78
B12	52.8	41.2	36.2	20	26.15	34.51	33.03	23.44
B2	77.15	68.02	68.16	47.31	60.10	78.65	80.16	72.60
B31	71.95	25.44	13.98	34.40	34.00	27.15	12.06	18.91
B32	123.52	29.73	15.26	39.70	278.41	160.47	21.02	32.67
B4	33.78	48.51	41.12	35.44	35.05	29.23	27.89	37.19
FB	62.80	38.13	31.84	31.56	74.71	57.80	32.03	32.93
DOF	H	N	S	S	D	H	N	N
Comprehensive Index of Financial Surveillance Fragility								
C1	2.64	2.86	2.76	2.72	2.94	3.16	3.28	3.53
C2	2.36	3.29	3.80	2.25	2.33	3.29	3.23	3.00
C3	16.16	15.94	31.74	19.89	14.35	14.96	14.14	13.60
C4	−0.57	0.40	2.23	1.64	1.10	1.62	1.86	1.77
FC	5.15	5.62	10.13	6.63	5.18	5.76	5.63	5.48
DOF	S	S	H	N	S	S	S	S
C1	3.47	3.19	3.11	3.31	3.45	3.49	3.68	3.96
C2	2.96	2.06	1.50	1.50	1.5	1.5	1.5	1.5
C3	15.03	13.46	12.69	13.46	12.34	12.83	11.54	11.05
C4	3.43	3.77	3.66	4.08	4.92	6.19	3.81	4.70
FC	6.22	5.62	5.24	5.59	5.55	6.00	5.13	5.31
DOF	N	S	S	S	S	S	S	S
Financial Export-oriented Vulnerability Composite Index								
D1	11	8.5	8.4	9	9.2	8.6	9	17
D2	61.80	56.36	43.23	48.95	48.45	45.33	43.54	41.06
D3	9.94	9.16	4.77	3.91	1.80	2.52	1.55	2.25
D4	2	1.8	2.9	1.6	1.7	1.6	1.6	2.6
D5	19.18	20.62	28.62	24.47	21.90	21.85	23.52	23.54
FD	20.78	19.29	17.58	17.59	16.61	15.98	15.84	17.29
DOF	H	N	N	N	N	N	N	N
D1	12.5	12.6	14.3	14.3	14.3	16.3	15.5	13.6
D2	35.64	32.61	33.42	33.18	31.97	31.73	34.02	34.76
D3	2.75	1.80	1.58	0.18	0.72	1.69	1.78	2.23
D4	5	6.1	5.5	5.5	6.7	6.5	5.9	10.5
D5	23.79	22.75	20.44	17.26	18.00	18.80	14.58	13.71
FD	15.94	15.17	15.05	14.09	14.34	15.00	14.36	14.96
DOF	N	N	N	N	N	N	N	N
Comprehensive Index of Financial Externality Fragility								
FA	15.14	14.81	16.79	14.36	10.15	11.15	10.78	9.08
FB	102.60	39.14	63.56	37.72	27.86	24.67	25.45	39.67
FC	5.15	5.62	10.13	6.63	5.18	5.76	5.63	5.48
FD	20.78	19.29	17.58	17.59	16.61	15.98	15.84	17.29
FFII	41.90	20.60	30.29	20.11	15.47	14.66	14.80	19.44
DOF	D	N	H	N	S	S	S	N
FA	7.87	7.00	5.58	4.40	5.79	4.45	5.72	5.48

Table 4 (continued)

Index	2007	2008	2009	2010	2011	2012	2013	2014
FB	62.80	38.13	31.84	31.56	74.71	57.80	32.03	32.93
FC	6.22	5.62	5.24	5.59	5.55	6.00	5.13	5.31
FD	15.94	15.17	15.05	14.09	14.34	15.00	14.36	14.96
FFII	26.97	18.28	15.80	15.46	30.11	24.51	15.73	16.15
DOF	H	N	S	S	H	N	S	S

Note: H represents high; N represents Normal; S represents Safe; D represents dangerous. B11 is the price-earnings ratio of the Shanghai Stock Exchange; B12 is the price-earnings ratio of the Shenzhen Stock Exchange; B31 is the volatility of the Shanghai Stock Exchange index; B32 is the volatility of the Shenzhen Stock Exchange index. According to the set weight, FFII = (FA + 2FB + 2FC + FD)/6.
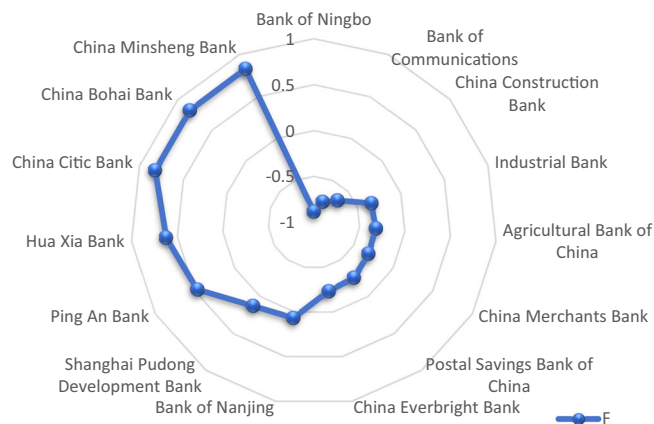
Fig. 1 Fragility levels of major banks in China. The vertices correspond to the individual texts and the names are written above the vertices. Figure shows the level of commercial bank fragility of 15 banks in China in 2018, labeled in blue.
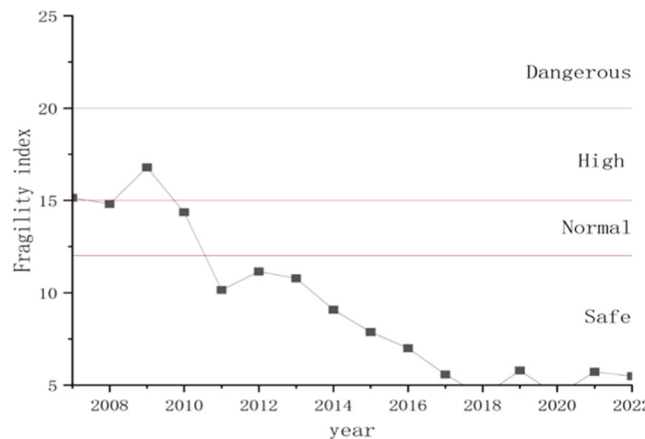
Fig. 3 Trends in the fragility of the economic environment. The fragility of the economic environment has been categorized into four categories: dangerous, high, normal and safe. The basic trend of China's economic environmental fragility was mostly at the normal level before 2011 and below the safety line after 2011.
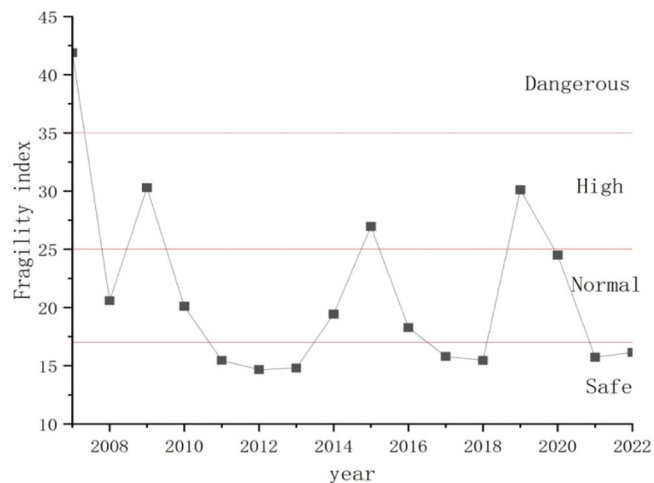
Fig. 2 The general trend of financial fragility in China. From 2007 to 2022, the fragility of China's financial system shows a fluctuating trend, and the fragility of the financial system is categorized into four categories: dangerous, high, normal and safe.

fluctuations is mainly due to the subprime crisis that swept the world in 2007–2009; improper financial regulation led to the fragility of the financial system, the country's economic situation became grim, and the financial system was in turmoil. As such, the degree of the vulnerability index was in danger. According to the state of the financial system, the country took control by gradually leveling off its economy, stabilizing the degree of vulnerability from fluctuations. The second round of fluctuations was mainly due to the huge financial fluctuations in 2015, limiting

the tension of economic growth. However, the return of policies to the rational zone, the shift of exports to a normalized level, and the rational release of financial risks also ensured the long-term stability of the economic development of the situation to a large extent. The third round of volatility was mainly due to the panic in the financial market caused by the COVID-19 pandemic in 2019. This caused the systemic financial risk to gradually decline as domestic COVID-19 was being controlled.

Figure 3 reflects the trend of the fragility of China's economic environment from 2007 to 2022. It can be seen that the fragility of China's economic environment is generally relatively low, mostly at a general level in the first few years and basically below the safety line in the next few years. Specifically, China's GDP, fixed asset investment, M2, and currency growth rates are in a downward trend year by year. Therefore, the fragility of China's economic environment has also been declining. Moreover, the fragility index of the economic environment shows that the current economic environment has been relatively healthy and relatively stable in recent years.

The financial market is often an indicator of a country's financial security. The government judges the degree of financial fragility based on the signals transmitted by the financial market and then establishes a corresponding risk early warning mechanism. Figure 4 reflects the continuous fluctuation of the fragility of China's financial market early warning system from 2007 to 2022. It can be seen that China's financial market was at a dangerous level when the subprime mortgage crisis occurred in 2007. The financial market's early warning levels in 2009 and 2015 were also relatively high. The overall financial market was in a state of volatility. 2019 was affected by the COVID-19 pandemic, and the financial markets expected indicators to be at a dangerous level. Notwithstanding, China's average price-to-earnings ratio is
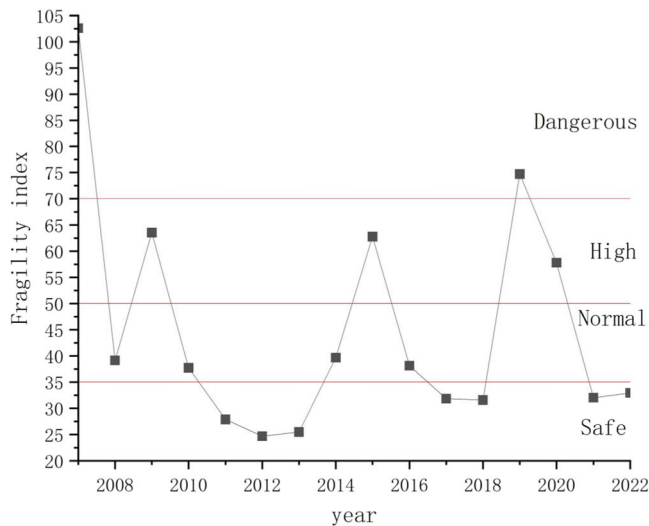
Fig. 4 Time series of the financial market early warning Fragility Composite Index. The figure shows the fluctuation status of the trend of early warning fragility of China's financial market from 2007 to 2022, and the early warning fragility of the financial market is categorized into four categories, namely, dangerous, high, normal and safe.
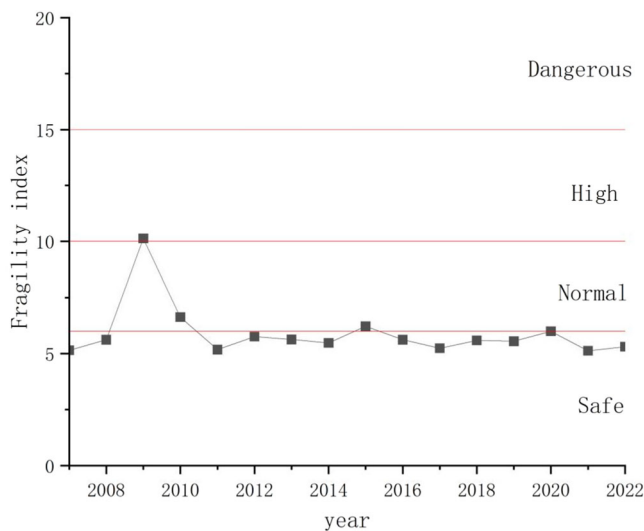

Fig. 6 Trends in extroverted financial vulnerabilities. The trend of China's financial outward fragility shows a decreasing trend from 2007 to 2022, and is basically at an normal level. The financial outward fragility is categorized into four categories: dangerous, high, normal and safe.

financial monitoring system, the government's financial monitoring has also been adjusted accordingly. Implementing a prudent fiscal and monetary policy is consistent with the trend of the fragility of the financial monitoring system.

As shown in Fig. 6, regarding financial outward-looking fragility, a downward trend from 2007 to 2022 can be observed, though it remains within the normal range. This suggests that China can handle the impact of opening the market on the financial system, which corresponds to China's adherence to an independent policy in the process of opening to the outside world. The specific manifestation is the year-on-year decline in foreign trade dependence, debt, and debt service ratios. It has risen in recent years, but they are all at a safe level, while the time to support imports is at a dangerous level due to China's excessive foreign exchange reserves.

Conclusion, suggestions, and limitations

Conclusion and suggestions. The analysis of financial fragility in this article takes the banking system and the financial system as an entry point. On the one hand, it mainly analyzes the cross-sectional data of 15 bank fragility indicators in China in 2018 and conducts bank fragility in the banking system. The scoring arrangement of vulnerability in the banking system makes each indicator comparable and persuasive. The results of the analysis show that the liquidity ratio and non-performing loan ratio are the key factors that affect the fragility scores of internal members of the banking system. Banks with lower vulnerabilities score better on the liquidity ratio and non-performing loan ratio indicators. On the other hand, the analysis of the fragility of the financial system focuses on establishing evaluation models from four subsystems: economic environment, financial market early warning, financial monitoring, and financial export-oriented. By sorting out the data of various indicators of China's financial system from 2007 to 2022, the comprehensive fragility index of the subsystem was calculated, and the corresponding fragility score was determined according to the comprehensive index interval. Finally, the fragility score of each subsystem was calculated. China's financial system fragility scored FFII with an analyzed overall trend. It can be seen that a good economic environment is the main guarantee for the stable operation of the financial system. The continuous improvement of the financial market's early warning system reduces financial risks, and the financial regulatory authorities' regulation of appropriate control of strength and appropriate fiscal currency has improved the security of the financial system.

Fig. 5 Trends in financial surveillance fragility. Financial surveillance fragility is categorized as dangerous, high, normal, and safe. China's financial surveillance fragility has been at a low level from 2007 to 2012, basically in the safe range.

at a safe level, and the fragility of the total stock market value/GDP and debt dependence is at a high level. This is also the main reason for the high level of warning in the financial market and the volatility of the securities index's gradually stabilized status.

Compared with the fragility of the financial monitoring system, the financial market's fragility is relatively satisfactory. As shown in Fig. 5, China's financial monitoring fragility has been at a relatively low level from 2007 to 2022, basically within the range of security levels. The good trend of financial monitoring vulnerabilities also shows that the current financial regulatory authorities have improved the level of financial system monitoring. Active and stable fiscal and monetary policies play an important role in reducing the vulnerabilities of the financial monitoring system. With the changes in the fragility of the
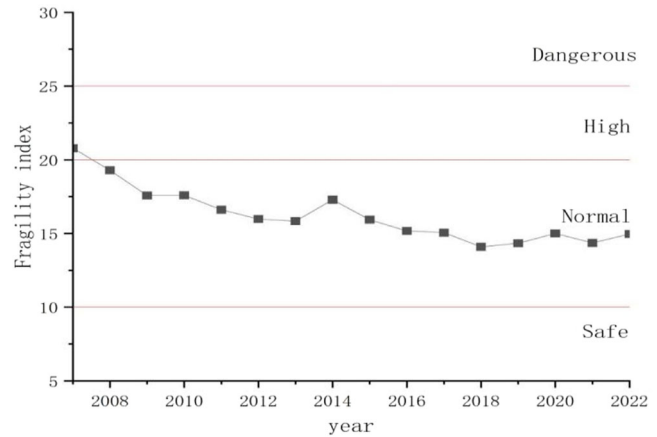
Meanwhile, the rapid development of an export-oriented economy has increased the degree of financial fragility to a certain extent. As such, the financial fragility model established from the four systems (economic environment, financial market early warning, financial monitoring, and financial export-oriented) has certain practical significance for comprehensively grasping the problem of financial fragility in China.

Based on these insightful findings, the following suggestions are proposed to the government and banks. On policy suggestions for government agencies, the study proposes that first, market information should be thoroughly investigated to predict as much as possible the benefits and risks that changing existing policies or issuing new policies will bring to different industries. Consequently, reasonable economic policies should be formulated and released. Secondly, government agencies must make reasonable use of economic means and functions. Also, before issuing various policies, they must consider their stability and consistency in advance to avoid the deepening of information asymmetry caused by frequent policy changes. At the same time, after the policy is issued, regulatory authorities at all levels should strengthen their supervision of the banking industry and the economic and financial markets. They must also ensure that policies are transparently and effectively implemented to prevent situations of hasty or excessive implementation. Thirdly, after the formulation and issue of economic policies, multimedia platforms should be used to promote and guide the new policies, and precise interpretation should be carried out. Again, communication and exchange with market entities such as residents and enterprises should be emphasized to strengthen the ability of each market entity to grasp the policy direction, understand the policy objectives, and avoid making wrong investment and financing decisions due to information asymmetry. On policy suggestions to the various banks, it is suggested that when developing non-interest income businesses, banks should carefully identify various risks that may arise and carry out non-interest income business in an orderly and reasonable manner within the national regulatory red line for non-interest income businesses based on their business situation. This will minimize the increase in their vulnerability level due to the development of non-interest income businesses and thus achieve the stable development of the bank.

Limitations. This paper is based on analyzing the financial vulnerability of the banking and financial systems, which is of great significance to the study of China's financial vulnerability and the prevention of major risks. However, this paper still has some limitations. First, the construction of the stability framework of China's banking system in the paper is not deep enough, so the proposed stability framework still has some defects. Second, due to data unavailability, there may also be defects in the construction of the indicator system. Third, since this paper focuses on financial vulnerability, the banking data of 2018 before the pandemic was chosen as a representative. In that regard, future research may consider the following aspects. Financial stability is not only a matter for the central government to consider, but local governments should prevent regional financial risks to ensure that the economy is running well, and the society is functioning well. Also, the study of financial market stability is an extremely important topic because the study of financial markets is of great significance to financial vulnerability.

Data availability

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Competing interests

The authors declare no competing interests.

Ethical approval

Ethical approval was not required as the study did not involve human participants.

Informed consent

This article does not contain any studies with human participants performed by any of the authors.

Additional information

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